Comparison of the Optimization of the Coagulation-Flocculation and Electrocoagulation Treatment of Slaughterhouse Wastewater Using the Response Surface Method

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Abstracts: In this work, the coagulation-flocculation and electrocoagulation treatments were compared in the removal of pollutants from wastewater from the Conchucos slaughterhouse, Lima. For the coagulation-flocculation treatment, we worked with 4 independent variables with their respective experimental ranges, coagulant dose (600-1000 mg / L), flocculant dose (4-8 mg/L), fast stirring speed (250-350 rpm), slow stirring speed (80-100 rpm), for electrocoagulation the parameters of stirring speed (250-350 rpm) and stirring time (15-30 rpm). The central compound design method (DCC) optimizing by response surface (RSM) was used as an experimental method for the reduction of pollutants as a function of chemical oxygen demand (% COD), a jar test equipment was used for the coagulation-flocculation and a one-liter shaker with aluminum plate electrodes at 30 V. The results show that coagulation/flocculation and electrocoagulation presented statistical models with *F-values* of 5.33, 20.30, significance $p<0.05$, with adjustments of R^2 of 0.6179, and 0.7571 for an optimal arrangement with %COD reduction prediction, respectively. The electrocoagulation treatment presented a reduction of 75.43% similar to the predicted model, of the 2 treatments compared, the electrocoagulation is below the maximum admissible values (VMA) in COD, BOD and Oils and Fats, complying with the necessary parameters for the discharge to the sewerage system.

Keywords: Cation Exchange Membrane, Chronopotentiometry, Limiting Current Density, Transport Number.

1. INTRODUCTION

Wastewater has become the main source of pollution in the environment, which is commonly discharged into surface water bodies with little or no treatment due to the limited availability of treatment facilities in many countries around the world [1]. In Latin America 70% of wastewater goes untreated and is returned completely polluted to surface water bodies [2]. Thus, pollution has adverse ecological consequences that affect all living beings that directly or indirectly use water resources. Therefore, it is urgent to develop effective and economical innovative techniques for wastewater treatment [3].

Global population growth has generated a high demand for consumption of food products such as red meat and its derivatives worldwide consumption of pork, beef, cattle and poultry, suggesting a high demand for derivatives of these products [4], which, when processed and industrialized, demand a large amount of water, which is converted into wastewater [5]. The effluent generated by processing these foods with the blood of animals is often not adequately treated and therefore impacts the receiving bodies in a negative way, which is why the Environmental Protection Agency classifies effluents from slaughterhouses as harmful [6].

Slaughterhouses generate as waste; blood [7]; rumen which is the content of the stomachs of cattle together with blood, which is the waste that produces the most pollution; coarse solids that correspond to remains of meat, skin, bones, hair and visors, which are produced in the cutting are dragged with wastewater and wastewater that are characterized by a high content of nitrogen, phosphorus, salts, volatile fatty acids and amines mainly [8]. In that sense, the high concentrations of organic matter, suspended solids, oils and fats, nitrogen and phosphorus in the water require adequate treatment to be discharged into the sewage system or surface bodies.

The Conchucos slaughterhouse in Lima, Peru, is one of the animal slaughterhouses with the highest daily production and generates a large amount of wastewater from the slaughter of animals and cleaning of the facilities. The Conchucos slaughterhouse is currently treating its wastewater with conventional chemical treatments, which generates high treatment costs and generates a large amount of waste; alternative technologies could reduce its potential impact.

Currently, farms use technologies such as chemical dosing, reverse osmosis, anaerobic digestion, dissolved air flotation and membrane bioreactors to treat their wastewater [9]. In recent years, a number of studies have investigated the potential of incorporating the electrocoagulation process alongside or in place of more conventional treatment technologies to treat these wastewater effluents [10].

Electrocoagulation treatment compared to the conventional coagulation-flocculation process can obtain advantages and may be the most suitable to promote the treatment of wastewater from animal houses [11] generating clean water that also complies with current regulations and reducing economic costs. This research aims to compare the optimization of the coagulation-flocculation and electrocoagulation treatment of wastewater from a slaughterhouse using the response surface method (RSM).

2. MATERIEL AND METHODS

2.1. Characterization Of Soil Contaminated With Lead

The initial characterization of the slaughterhouse water was carried out during the operating hours of the slaughterhouse from July to November 2021. The parameters analyzed were Biochemical Oxygen Demand (mg BOD_5/L), Chemical Oxygen Demand (mgO_2/L), Conductivity (mS/cm), pH (pH unit), Total Phosphorus (mg/L), Oils and Fats (mg/L), Turbidity (NTU).

2.2. Experimental procedure

2.2.1. Coagulation-flocculation

For coagulation-flocculation treatment, factors such as: (F_1) coagulant dose (600 to 1000 mg/L), (F_2) flocculant dose (4 to 10 mg/L), (F_3) flocculation rate (250 to 350 mg/L) and (F_4) coagulation rate (80 to 100 mg/L) were studied as shown in Figure **1a**.

The coagulation-flocculation tests were carried out in 1 L beakers through a jar test rig (Figure **1b**), in a 6-vessel jar test rig with a speed regulator. As an important point about the stirring speed (RPM), the proposed range for this research is between 100 rpm to 250 rpm according to the best efficiencies obtained in the research of Bayar [12]. As a response variable for the optimization, the Chemical Oxygen Demand COD removal (%) was evaluated (Figure **1c**).

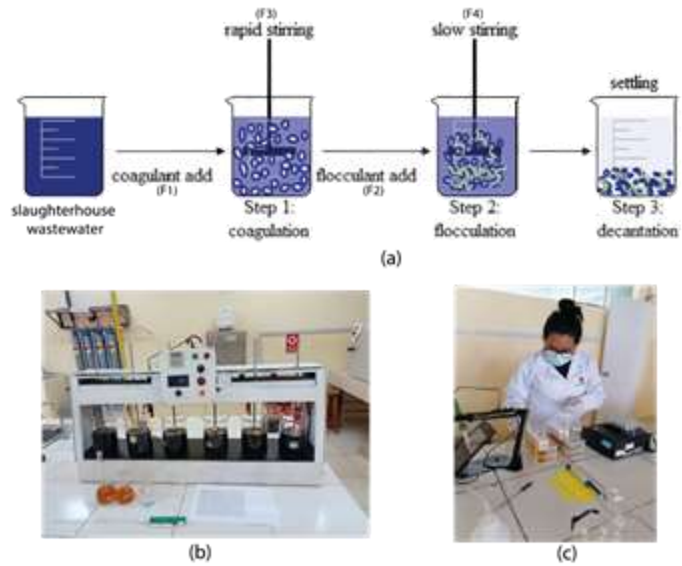

Figure 1: Flocculation-coagulation treatment of slaughterhouse wastewater

2.2.2. Electrocoagulation treatment

For the experiments in an electrocoagulation system, a configuration as shown in Figure **2** was used, the aluminum plates were placed vertically according to Figure **2b**. Six aluminum plates were conditioned in the electrochemical reactor. They were connected to DC power supply terminals at 30 V constant format.

To obtain the optimum values for each factor, a Composite Central Design (CCD) arrangement was used. The parameters studied were: agitation speed (250 and 350 rpm) and agitation time (15 and 30 min) with 4 central points, 4 axial points and 3 replicates in the COD results. For this treatment, optimization was evaluated based on the highest COD removal.

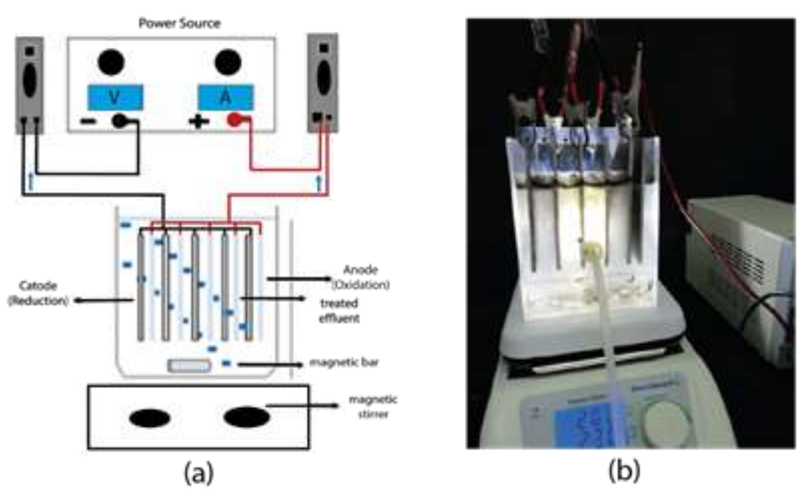

Figure 2: Schematic diagram of the electrocoagulation system

2.2.3. Experimental Design

A For the data analysis, the response surface method has been applied with a Composite Central Design (CCD) which is a Response Surface Design based on the factorial design that allowed optimizing the response of the

%COD removal for both treatments; in addition, to having axial and central points allowing estimating the curvatures to then be able to optimize. Equation 1 shows the second order regression model used.

$$y = b_0 + \sum_{i=1}^{n} b_i X_i + \sum_{1 \le i \le j}^{n} b_{ij} X_i X_j + \sum_{1 \le i \le j}^{n} b_i X_i^2 X_j^2 \qquad (1)$$

Where:

X is an answer

X1 and X2 are manipulated factors

b0, βi, βij are unknown parameters

Xi, Xij, are the study factors.

Comparison of factor effects and obtaining significant statistical differences occurs with factorial design and ANOVA is used for data analysis and interpretation [13]. For the validation of the model the acceptability analysis was performed where the result is in function of the *F-value* and *p-value* and the model fit in function of the R^2, R^2-adjusted and R^2-predictive.

3. RESULTS

3.1. Characterization of wastewater

Table **1** presents the characteristics of the wastewater from the Conchucos slaughterhouse. It shows high values of organic matter, oils and fats that exceed the AMVs. In addition, the water is characterized by no acidity, but high turbidity. The total phosphorus values are high; this parameter is of importance due to the affinity to iron elements for an improvement in treatments.

Table 1: Physico-chemical characteristics of the effluents from the Slaughterhouse Wastewater

Parameters	Unit	Results	VMA
Oils and Fats	mg/L	25	100
Conductivity	mS/cm	2.12	
Biochemical Oxygen Demand	mg BOD_5 /L	759	500
Chemical Oxygen Demand	mg COD_2/L	4005.4	1000-
pH	pH unit	6.88	-
Turbidity	NTU	485	
Total Phosphorus	mg/L	244.5	

3.2. Coagulation - flocculation treatment

Table **2** shows the four-factor composite central design (CCD) studied: Coagulant dosage, Flocculant dosage, Coagulation rate, 2-level flocculation rate for each factor with observed and predicted values for the experimental COD percent removal and COD predicted by the multiple regression model.

Table 2: Reduced %COD in the coagulation-flocculation treatment system by central composite design (CDD)

N°	Coagulant dosage	Flocculant dosage	Coagulation rate	Flocculation rate	COD (mg/L)	COD (%) experimental
	mg/L	mg/L	RPM	RPM		%
1	800	6	300	70	1500	62.55
2	600	4	250	100	2630	34.34
3	1200	6	300	90	2235	44.2
4	600	8	350	80	1700	57.56
5	800	6	300	90	2660	33.59
6	600	8	350	100	2635	34.21
7	1000	8	250	100	1705	57.43
8	600	4	250	80	1830	54.31
9	800	6	200	90	1730	56.81
10	800	6	300	90	2465	38.46
11	1000	8	350	100	2545	36.46
12	400	6	300	90	2590	35.34
13	800	2	300	90	2505	37.46
14	800	6	300	110	2220	44.57
15	1000	4	350	100	2330	41.83
16	1000	4	350	80	1535	61.68
17	600	8	250	80	2030	49.32
18	800	6	300	90	2430	39.33
19	600	4	350	80	1800	55.06
20	1000	8	250	80	1395	65.17
21	1000	4	250	100	2410	39.83
22	1000	4	250	80	1355	66.17
23	800	10	300	90	2590	35.34
24	600	4	350	100	2900	27.6
25	800	6	400	90	1720	57.06
26	1000	8	350	80	1595	60.18
27	600	8	250	100	3025	24.48

The significance of each parameter of the model for %COD removal presented in Table **6** was evaluated using the F-value test and p-values for each variable, including linear, quadratic interaction and *p-values* less than 0.05 identify the model coefficients as significant.

Table **3** shows that for a %COD removed the accuracy of the statistical model developed was confirmed by F-values of 5.33 and p-values of 0.0031 ($p<0.05$). Specifically, the coagulant dose concentration (A), slow agitation speed (D) showed a significant effect on the model, while interactions and quadratics are not significant.

Table 3: Four-factor ANOVA on the coagulation-flocculation treatment system

Source	Sum of squares	df	Mean square	F-value	p-value
Model	3396.11	14	242.58	5.33	0.0031
A-Dosage of coagulant (mg/L)	500.53	1	500.53	11	0.0062
B-Flocculant dosage (mg/L)	0.0026	1	0.0026	0.0001	0.9941
C-Fast speed (rpm)	10.64	1	10.64	0.2337	0.6375
D-Slow speed (rpm)	1823.83	1	1823.83	40.07	< 0.0001
AB	14.98	1	14.98	0.329	0.5768
AC	102.24	1	102.24	2.25	0.1598
AD	20.2	1	20.2	0.4437	0.518
BC	0.0156	1	0.0156	0.0003	0.9855
BD	12.22	1	12.22	0.2684	0.6138
CD	14.98	1	14.98	0.329	0.5768
A^2	15.71	1	15.71	0.3452	0.5677
B^2	0.0052	1	0.0052	0.0001	0.9917
C^2	565.66	1	565.66	12.43	0.0042
D^2	395.68	1	395.68	8.69	0.0122
Residual	546.22	12	45.52		
Lack of error	527.07	10	52.71	5.51	0.1634
Total error	19.15	2	9.57		
Total	3942.33	26			

Figure **3** shows the significant effects of coagulant dosage and flocculation speed on the % COD removed. According to Figure **3a, 3b** the % COD removal have slightly increase as the coagulant dosage increases, contrary to the slow speed the slower the agitation there is an increase in % COD removal.

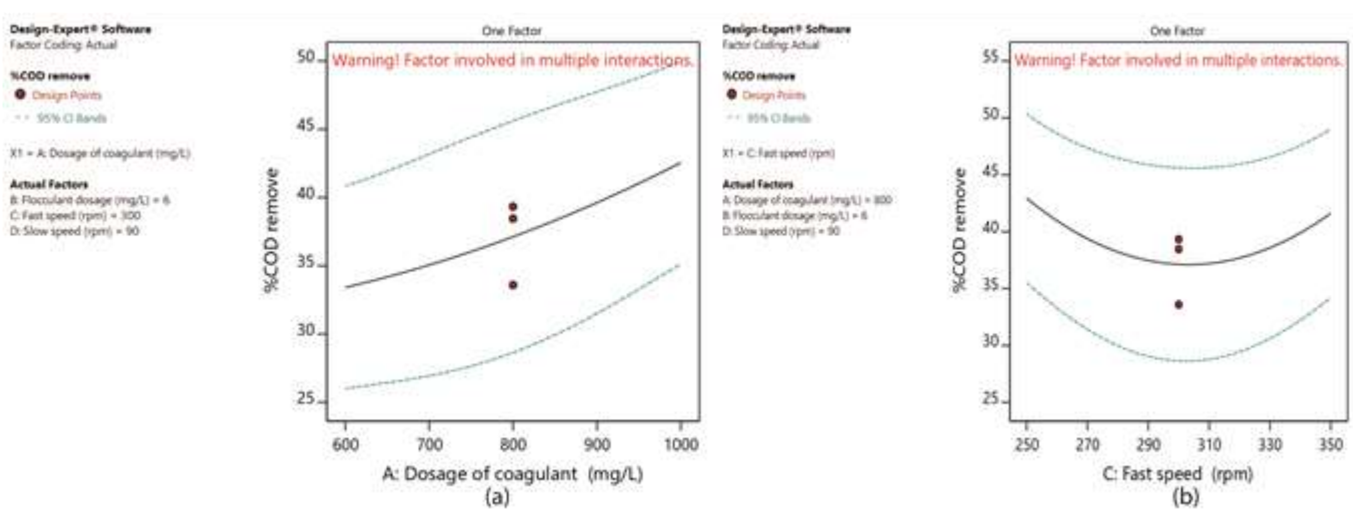

Figure 3: Significant effects of coagulant dosage factors and slow agitation speed

On the experimental test, the central composite response surface model provides a predictive model (Equation 2) of %COD removal for the coagulation/flocculation treatment. Validation of the model allows treatment optimization.

$$\%DQO = +37{,}13 + 4{,}57A - 0{,}01B - 0{,}67C - 8{,}72D + 0{,}97AB - 2{,}53AC + 1{,}12AD + 0{,}0312BC + 0{,}87BD + 0{,}97CD + 0{,}86A^2 + 0{,}02B^2 + 5{,}15C^2 + 4{,}31D^2 \quad (2)$$

Table **4** shows that for both the coagulation treatment the R^2 and R^2- adjusted are significant parameters in the model, showing an adequate variation of the quadratic model to the experimental data. The R^2 values for %COD reduction was 0.8614 and R^2- adjusted was 0.6998 for the coagulation-flocculation treatment. The difference of the predicted R^2 and R^2- adjusted for the coagulation-flocculation treatment was 0.48.

Adequate precision (AP) illustrates the range of the predicted data (at the design points) up to the average prediction error. AP measures the signal-to-noise ratio and its values greater than four are desirable. Therefore, the quadratic model can be applied to navigate the optimization design. The AP values are at 8.02 for %COD removal. The %CV represents the error between experimental and predicted data. It cannot be more than ten for an adequate model. In the investigation, the CV values were at 14.57 for %COD removal, for the coagulation and flocculation treatment.

The response surface method proposed in this research allows determining the optimal experimental conditions to obtain the maximum COD removal percentage.

Table 4: Response surface model fits of COD removal response surface in coagulation-flocculation treatment system

Descriptive	Coagulation-Flocculation
Standard Deviation	6.75
Media	46.31
Coefficient of Variance (CV%)	14.57
R^2	0.8614
R^2 adjusted	0.6998
R^2 predictive	0.219
Adequate accuracy (AP)	8.02

The coagulation-flocculation treatment was conditioned with a maximum coagulant dosage and a minimum in the factors of flocculant dosage, coagulation speed and flocculation speed.

Figure **4** shows that the desirability value for the coagulation-flocculation treatment was found to be 0.97 to achieve maximum removals of 61.79 for % COD removal.

3.3. Electrocoagulation Treatment

The electrocoagulation treatment of the slaughterhouse water resulted in 75.99% COD removal as shown in Table **5**, with a maximum removal rate of 77.30%. The Table **5** shows the two-factor composite central design (CCD) (agitation speed and electrocoagulation time with 2 levels for each factor) with observed and predicted COD removal percentage values.

Table 5: %COD reduced in the electrocoagulation treatment system by means of the two-factor Central Composite Design.

Corrida	Coded value		COD (mg/L)			COD (mg/L)	COD experimental	COD predictive
	A: Speed	B: Time	R1*	R2	R3	Averag	%	%

	rpm	Min				e		
1	350	15	986	960	986	977.3	75.5996	75.84
2	300	22.5	966	960	981	969	75.8077	75.61
3	300	10	979	986	987	984	75.4332	75.32
4	350	30	930	918	911	919.7	77.0393	77.28
5	384	22.5	902	914	910	908.7	77.314	77.18
6	250	30	983	980	986	983	75.4581	75.72
7	250	30	979	979	988	982	75.4831	75.72
8	350	15	958	966	969	964.3	75.9242	75.84
9	250	15	995	984	993	990.7	75.2667	75.28
10	300	35	904	917	913	911.3	77.2474	76.91
11	216	22.5	972	973	973	972.7	75.7161	75.4
12	300	22.5	959	980	959	966	75.8826	75.61
13	300	22.5	975	983	984	980.7	75.5164	75.61
14	250	15	100 0	998	100 8	1002	74.9838	75.28
15	350	30	920	914	908	914	77.1808	77.28

Note: * R- means replica

The significance of each parameter of the %COD removal model presented in Table **6** was evaluated using the *F-value* test and p-values for each variable, including linear and quadratic interaction. As shown in Table **6**, *p-values* less than 0.05 identified the model coefficients as significant.

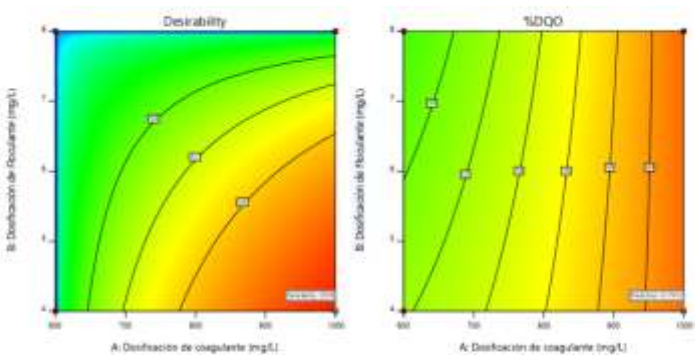

Figure 4: 2D desirability plots for the optimization of %COD in the coagulation-flocculation treatment system.

Table 6: Two-factor ANOVA on the electrocoagulation treatment system

Source	Sum of squares	df	Mean square	F-value	p-value
Model	8.03	5	1.61	20.3	0.0001
A-Stirring speed	3.84	1	3.84	48.53	< 0.0001
B-Electrocoagulation time	3.04	1	3.04	38.38	0.0002
AB	0.5028	1	0.5028	6.36	0.0327
A^2	0.5666	1	0.5666	7.16	0.0253
B^2	0.3121	1	0.3121	3.95	0.0782
Residual	0.7117	9	0.0791		
Lack of error	0.5338	3	0.1779	6	0.0308
Total error	0.1779	6	0.0296		
Residual	8.74	14			

Specifically, the agitation speed (A), slow agitation time (B) and interaction (AB) showed a significant effect on the model (less than 0.001), while the experimental error is low. It is also shown that the percentage (%) COD removed has a high precision according to the statistical model developed which is confirmed by *F-values* of 20.30 and p value of 0.0001 ($p<0.05$).

Figure **5a** illustrates the effect of agitation speed and electrocoagulation time of the influent on the reduction of % COD. It can be seen that the agitation speed and electrocoagulation time are directly proportional to the COD percentage removals (% COD). This slight effect refers to electrokinetic reactions as a non-limiting factor of % COD removal; therefore, % COD removal is due to reduction and oxidation reactions only.

Figure **5b** of cross-factor interactions between independent variables were plotted on 3D surface plots. The cross-factor interaction effect between agitation speed and influent agitation time (AB) is highly significant in the model. From this plot it can be inferred that, at higher agitation time and agitation speed, it is possible to achieve maximum % COD removal.

On the experimental test, the central composite response surface model provides a predictive model (Equation 3) of the % COD removal for the electrocoagulation treatment; the validation of the model allows optimizing the treatment.

$$\%COD = +75.61 + 0.5301A + 0.4714B + 0.2507\,AB + 0.2396A^2 + 0.1779B^2 \quad (3)$$

Table **7** shows that for both the electrocoagulation treatment the R2 and adjusted R2 are significant parameters in the model, showing an adequate variation of the quadratic model to the experimental data. The R^2 value for % COD reduction was 0.9186 and R^2*-adjusted* was 0.8733 for the electrocoagulation treatment. In this research, the difference of the R^2*-predicted* and R^2*-adjusted* was 0.17, having a representative predictive model.

Adequate precision (AP) illustrates the range of predicted data (at design points) to the average prediction error. AP measures the signal-to-noise ratio and its values greater than four are desirable. Therefore, the quadratic model can be applied to navigate the optimization design. The AP values were at 11.26 for %COD removal. The %CV represents the error between experimental and predicted data. It cannot be more than ten for an adequate model. In the investigation, the CV values are at 0.37 for %COD removal, for the electrocoagulation treatment.

For the electrocoagulation treatment, it was conditioned to a minimum energy expenditure in the agitation speed while maintaining a maximum time. Fig. **6** shows that the desirability value for the electrocoagulation treatment was found to be 0.56 to achieve the maximum removals of 75.71 for %COD removal.

Table 7: Adjustments to the response surface model of %COD removal in the electrocoagulation treatment system

Descriptive	Electrocoagulation
Standard Deviation	0.2812
Media	75.99
Coefficient of Variance (CV%)	0.3701
R2	0.9186
R2 adjusted	0.8733
Predictive R2	0.7081
Adequate accuracy (AP)	11.26

Table 8: Comparison of results with predictive models

Parameters	Unit	Treatments			
		Coagulation-Flocculation		Electrocoagulation	
		Predictive	Experimental	Predictive	Experimental
Chemical Oxygen Demand (COD)	%.	61.79	68.09	75.71	75.43

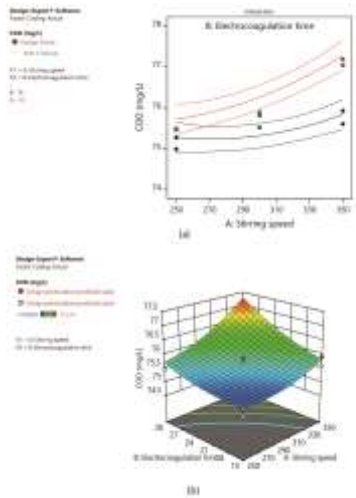

Figure 5: 2D interaction graphs (a) and 3D graphs of the indicators with the greatest effect (b).

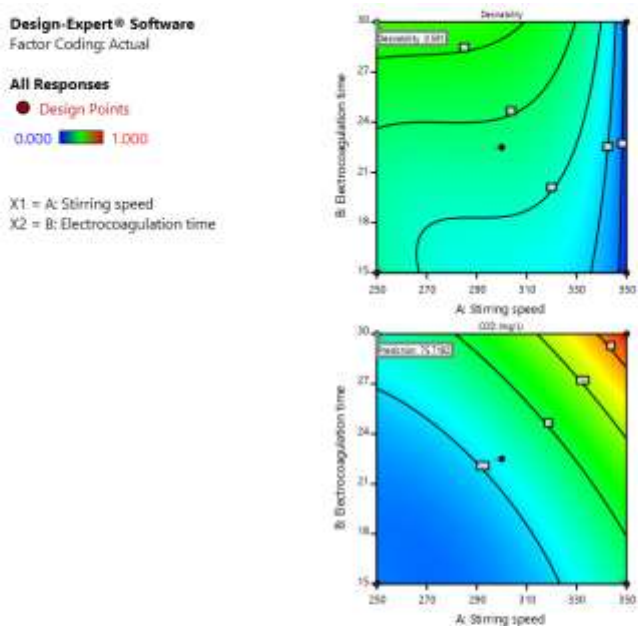

Figure 6: 2D desirability plots for the optimization of %COD in the electrocoagulation treatment system.

3.4. Comparison of treatments

As a final result, the optimal operating conditions obtained were used in another experimental run to validate the predicted values. Consequently, COD removal of 61.79% and 75.71% were obtained experimentally, which is expected to confirm the reliability of the electro-remediation treatment model since all model parameters were within the 95% CI while variation is expected concerning the coagulation-flocculation treatment.

Table **8** shows the comparison between predicted and experimental values, it can be noted that the electrocoagulation treatment has expected results.

For comparative purposes with the Maximum Allowable Values (MAV) of effluent discharge to the sewer system according to Supreme Decree 021-2009-Vivienda, different parameters were measured according to this regulation. The comparison is made with the coagulation-flocculation treatment, electrocoagulation and a combined treatment between coagulation-flocculation followed by electrocoagulation.

Table **9** shows that the flocculation treatment does not meet the standard for COD and BOD parameters, but it does show a high reduction of oils and fats while all electrocoagulation treatment values are below the AMV in the same way as the combined system.

4. DISCUSSION OF RESULTS

Table **3** shows that the coagulant dosage, flocculant dosage and slow agitation speed have a significant effect on the treatment; based on these parameters, a maximum COD removal of 66.17% and an average removal rate of 46.31% were obtained. It should be taken into account that the percentage of organic matter removal depends on the type of coagulant, as in the case of aluminum sulfate and ferric chloride, which have high removal efficiencies at slow speeds. [14]. Using the Box-Behnken response surface method there is a minimal relationship between the coagulant/flocculants dosage and COD reduction rate [15]. When simple load neutralization plays a major role, the low coagulant/flocculant dosage is not sufficient to destabilize all colloidal particles in the wastewater [16].

The studies [17] found that residual turbidity and biochemical oxygen demand decreased when coagulants such as ferric chloride and aluminum sulfate and microbial consortia were increased, and [18] reports high ferric sulfate removal. In other words, coagulation/flocculation of ferric chloride has a high advantage. exhibiting high removal efficiencies [19]. For inorganic coagulants/flocculants such as aluminum salts, iron salts and inorganic polymers, the pH directly affects the hydrolysis and polymerization reaction of aluminum, iron ions. The forms of aluminum ions in water do not depend on other elements, but only on the dosage of aluminum salts and pH [20]. In this investigation the pH was kept neutral.

The electrocoagulation treatment consists of anode and cathode electrodes fed by a direct current and are partially immersed in a tank containing a contaminated solution. These electrodes can vary in shape, size, and number, but often rectangular-shaped plates are used [9].

All the studies report that the application of electrocoagulation in either batch or continuous operation generates maximum COD removals of 70%, while the research conducted reports an optimum removal of 75.99% (Table 8),

Table 9: Comparison of results with predictive models

Parameters	Unit	Initial values	Treatments			VMA
			Coagulation-Flocculation	Electro	Coagulation-Flocculation + Electro	
Chemical Oxygen Demand	Mg COD_2 /L	4005.4	1280.25	983.75	521.75	1000
Biochemical Oxygen Demand	Mg BOD_5 /L	759	677.25	470.57	138.54	500
pH	pH unit	6.88	7.09	9.09	8.27	-
Turbidity	NTU	485	30.4	11.54	9.77	-
Conductivity	mS/cm	2.12	5.32	4.82	5.15	-
Oils and Fats	mg/L	25	<0.48	2.5	2.5	100

which is in the range of removal reported by the different studies, and also presents the agitation speed and electrocoagulation time as significant factors in electrocoagulation.

Several studies applied electrocoagulation for the treatment of slaughterhouse water, e.g. [21] performed batch poultry slaughterhouse water treatment using electrocoagulation/electro-flotation obtaining COD (76-85%), color (93-99%), TSS (95-99%), turbidity (95–99%) removal values. [22] applied electrocoagulation in continuous mode to poultry slaughterhouse wastewater obtaining COD removals (88.5% and 96.26%) for horizontal and vertical arrangements, respectively. BOD_5 (97 %), fecal coliforms (100 %), TSS (85 %). [23] performed the treatment of wastewater from livestock slaughterhouses obtaining a COD removal (92.8%) with continuous mode operation. [24] performed in electrocoagulation treatment of slaughterhouse water and obtained as results 96.849 % of BOD; 94.538 % of COD; 92.685 % of TSS; 98.646 % in turbidity; 96.729 % in oil and fat content and 87.118 % in nitrogen content. [25] presented the removal of BOD_5 in 96.28%, ST in 97.8%, nitrates in 70.2% and phosphates in 63.2%.

The reactions developed by the cathodes and anodes generated by electrocoagulation allow the removal of inorganic pollutants due to their high ionic charge, while organic pollutants tend to be weakly polarized. For this reason, studies such as [23] perform electrocoagulation in slightly acid medium (pH 5) for the improvement of the removal.

The studies report that the operating parameters with the greatest influence is the amount of amperage induced to the treatment, the best material reported being aluminum electrodes; likewise, this study carried out the experience using aluminum electrodes. Another parameter that influences is the agitation speed in the batch system, but none of the studies report experiences with agitation speeds. On parameters such as pH is not affected by the treatment, all the studies report a neutral range of pH variation, as does this study. The application of electrocoagulation allows compliance with the Maximum Allowable Values (D.S N°010-2019-VIVIENDA) for the discharge of pollutants into the sewage system with the values reported in this research.

Table **9** shows that the combined effect of coagulation/flocculation and electrocoagulation shows higher removal of parameters such as COD, BOD and turbidity than the coagulation treatment or the electrocoagulation treatment. These results coincide with the research of [10] used a combined process of chemicals and electrocoagulation to treat effluents from a slaughterhouse reaching efficiencies higher than 70% removal in pollutants.

This study shows that the use of coagulation-flocculation treatment is not sufficient to meet the parameters established by D.S N°010-2019-VIVIENDA, while electrocoagulation meets the requirements, as well as a combined treatment. Both coagulation/flocculation treatment and electrocoagulation have advantages and disadvantages, so recommending combined use would be a good alternative, but requires further studies.

CONCLUSIONS

We were able to compare the treatment of the wastewater from the Conchucos slaughterhouse using the electrocoagulation and coagulation/flocculation processes to achieve the reduction of pollutants. The characteristics of the water from the Conchucos slaughterhouse show high levels of organic matter, oils and fats that exceed the AMVs. In addition, the water is characterized by no acidity, but high turbidity. An average of 75.99% and 46.31% of COD removal was reduced in the electrocoagulation and coagulation/flocculation treatments, respectively, concluding the higher efficiency for the electrocoagulation system. Coagulation/flocculation presents coagulant dosage, flocculant dosage and slow agitation speed as significant operating parameters and for electrocoagulation both time and agitation speed are significant.

Also, the study showed that electrocoagulation is a viable alternative to coagulation/flocculation for the removal of inorganic contaminants in slaughterhouse wastewater, with the advantage of not adding other ions to the water and thus avoiding a possible addition of another treatment step to remove them. In comparison, the removal efficiency of the electrocoagulation treatment was 75.71 % COD higher than that of coagulation/flocculation which was 61.7% COD. Of the two treatments compared, the electro-remediation is below the maximum allowable values (MAV) in COD, BOD and Oils and Fats meeting the parameters required for discharge to the sewage system.

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