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Electrocoagulation Coupled Fenton Process for Treating Refinery Wastewater Using a Cylindrical Design of Ti and Al Electrodes

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Abstract: Due to the serious wizards that industrial waste causes to humans, animals, and plants, besides the fact that wastewater from refineries contains many harmful compounds and that this type of industry is prevalent in most countries, the issue of protecting the environment from industrial waste is importance at the recent time. The organic contaminants elimination from the wastewater connected with the Iraqi refinery at Qayyarah served as our case study. The chemical oxygen demand (COD) was the organic contaminants measure. A titanium electrode (cathode) and an aluminum electrode (anode) were combined with the electrocoagulation and Photo-Fenton-processes. Using a Mini Tab program, the Taguchi method Utilizing statistical techniques, successfully obtained the outcomes and final values. The most effective removal of COD was 90.148. With a standard deviation of 2.651, the best conditions for this experiment were as follows: The time required to achieve this removal efficiency was 50 minutes, 8 pH, 400 mg/L of hydrogen peroxide, 20 mg/L of ferrous sulfate, and a current density of 15 mA cm^{-2}. Through ANOVA analysis of this process, it was found that the current density (C.D.) significantly influenced the removal efficiency, affecting it by 47.79%, followed by the electrolytic solution effect by 18.31%, and the hydrogen peroxide and ferrous sulfate concentrations effect by 12.55% and 2.36%, respectively. Also, a mathematical equation was found to describe the studied case. The reaction kinetics were also investigated, and the reaction rate constant (cm/s) was determined at ideal conditions, with km = 6.60546 x 10^{-5}.

التخثير الكهربائي المقترن بعملية فنتون لمعالجة مياه الصرف النفطية باستخدام تصميم أسطواني من اقطاب التيتانيوم والالمنيوم

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الخلاصة

بسبب الأضرار الجسيمة التي تسببها المخلفات الصناعية للإنسان والحيوان والنبات وكذلك حقيقة أن مياه الصرف من المصافي تحتوي على العديد من المركبات الضارة وأن هذا النوع من الصناعة منتشر في معظم الدول، فإن قضية حماية البيئة من المخلفات الصناعية هي ذات أهمية قصوى في الوقت الحالي. تهدف الدراسة الحالية الى التخلص من الملوثات العضوية من مياه الصرف الصحي المرتبطة بمصفاة النفط العراقية في منطقة القيارة شمال العراق. اعتمدت الدراسة على فحص المتطلب الكيميائي للأوكسجين (COD) لتمثيل عينات من الملوثات العضوية. تم استخدام قطب كهربائي من التيتانيوم (كاثود) وقطب ألومنيوم (أنود) في عمليات التخثير الكهربي ودمجها انيا مع عملية فنتون الضوئية. حصلنا على النتائج والقيم النهائية من خلال استخدام طريقة Takeuchi عبر تطبيق Mini Tap والتقنيات الإحصائية: اعلى كفاءة لإزالة COD هي: ٩٠,١٤٨, الانحراف المعياري ٢,٦٥١، كانت الظروف الفضلى لهذه التجربة: pH = ٨ ، ٤٠٠ ملجم / لتر من بيروكسيد الهيدروجين ، ٢٠ ملجم / لتر من كبريتات الحديدوز ، وكثافة التيار الكهربائي ١٥ مللي أمبير لكل سم٢ , زمن التجربة ٥٠ دقيقة. من خلال تحليل ANOVA لهذه العملية وجد أن كثافة التيار (CD) هي الأكثر تأثيراً على كفاءة الإزالة حيث أثرت عليها بنسبة ٤٧,٧٩٪ يليها تأثير المحلول الإلكتروليتي بنسبة ١٨,٣١٪ وتأثير التركيز. بيروكسيد الهيدروجين وكبريتات الحديدوز بنسبة ١٢,٥٥٪ و ٢,٣٦٪ على التوالي. كما تم إيجاد معادلة رياضية تصف الحالة المدروسة. تم أيضًا فحص حركيات التفاعل، وتم تحديد ثابت معدل التفاعل (سم / ث) في ظروف مثالية، مع km = 6.60546E-05.

الكلمات الدالة: التخثير الكهربائي, فنتون, مياه صرف المصافي النفطية, تيتانيوم, المنيوم, COD, معامل انتقال المادة ,تاكوشي.

1.INTRODUCTION

In the next four decades, world energy consumption will double the recent [1]. Over the next two decades, the world demand for oil will increase to more than 107mbpd, with world energy production accounting for 32% of this demand by 2030. These data show that the oil industry keeps building and dumping wastewater into the world's most important water sources. These contaminants influence the environment. As a result, the conversion of petroleum, i.e., oil, becomes more important. Crude oil and natural gas are important. Crude oil is a complex mix of organic liquids and natural gas. Environmental engineering students need to know a lot about how to treat wastewater from factories [2,3]. Many researchers studied how to treat wastewater from oil and petrochemical industries. Because there is much oil in these streams, it is hard to clean them up. How the effluent from a refinery is made depends on the crude quality, which depends on how the machine is used [4]. In the refinery, things not made of hydrocarbons are taken out, and the oil is broken down into different parts and mixed with other things to make useful products. So, petroleum refineries make a lot of wastewater quantities, including well-produced oil water brought to the surface during oil drilling. This water often has compounds that are hard to break down and is full of organic pollutants, making it hard to be treated biologically [5,6]. Pollutants from production lines must be removed from the water to be used again and meet environmental standards [7]. The wastewater amount made from processing crude oil is between 0.4 and 1.6 times that of crude oil processed. If the oil wastewater containing much organic matter were dumped into an aquatic environment that needed 2 mg/l of dissolved oxygen for a normal life, the bacteria would reduce the amount of dissolved oxygen [8,9]. These wastes are made up of grease and petroleum compounds, which are made up of three main hydrocarbon groups: Paraffin, i.e., very few carbon atoms (C_1 to C_4), such as Methane, Ethane, and Propane; Naphthene, such as Cyclohexane and Dimethyl Cyclopentane; and Aromatics, the more carbon atom. Also, Naphthenic acids are a group of compounds found in wastewater from the oil industry that are known to be toxic. Removing them from oilfield wastewater is a significant problem for cleaning up large amounts of petrochemical effluents [10]. The petrochemical effluents reach streams and affect the water supply's quality. The pretreatment methods include adsorption, coagulation, chemical oxidation, forward osmosis, activated carbon, and biological processes. New technologies, such as membranes and catalytic microwave oxidation in moist environments, have also been investigated [11,13]. In most cases, using just one technology to treat wastewater is insufficient for optimal results. To remove heavy contaminants from the textile effluent, combined methods involving chemical, physical, and biological treatment are used [14]. Typically, these procedures require chemicals to transfer from one medium to another. Therefore, a subsequent step is required to extract organic molecules characterized by low performance, sludge production, and can only function within a narrow pH range [15]. Chemical oxidation is another alluring technique. Even so, its applicability is limited by the extremely low reaction rates and many oxidants necessary when processing large amounts of waste (usually industrial waste) [16]. This method has been used to remove different pollutants, including dyes, heavy metals, and organic substances. EC is a powerful approach for improving oily wastewater treatment using redox reactions generated by applying an electric current via electrodes. Fig. 1 shows the electrocoagulation mechanism [17,18].

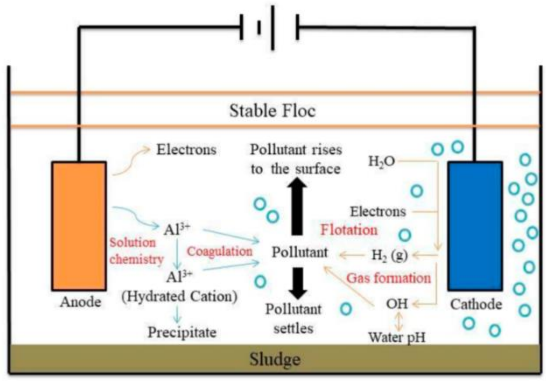

Fig.1 Process of Electrocoagulation Schematic [19].

Electrocoagulation (EC) is the process of making coagulants right where they are required by electrolyzing aluminum or iron electrodes [20]. Metallic ions (Al^{+3} or Fe^{+2}/Fe^{+3}) can react with different OH ions near the cathode and pick up pollutants. When EF and EC are put together, the EC system is improved [21,22]. The Fenton method is based on the fact that a hydroxyl radical can quickly and without preference oxidize organic matter that does not want to change. When Fe^{2+} reacts with H_2O_2 in an acidic environment, the H_2O_2 breaks apart in a way called homolysis [23]. The Fenton process can degrade refractory contaminants that conventional treatment procedures cannot successfully remove. Furthermore, when applied to water, the Fenton oxidation process can produce no intrinsic harmful or dangerous compounds. With readily available chemicals, the Fenton method is straightforward and safe to employ [24]. Photo-Fenton processes are the best way to improve the catalytic capacity, make treatment more efficient, and reduce the amount of iron sludge made. Radiation speeds up the change from Fe^{3+} to Fe^{2+} and raises the rate at which organic pollutants break down. The key is to use photochemical processes to break down metal catalysts [25]. This paragraph presents numerous previous studies related to the present study. The study by researcher Hernández-Francisco et al. [26] is one of the closest studies to the present study. The two studies are similar in terms of the wastewater source and changing the connecting electrodes method. The study did not use titanium as an electrode for the cathode and only used aluminum and iron in the anode and the cathode alternation. To treat wastewater from olive oil, Kadhim et al. [27] studied the electrocoagulation process using different electrodes of stainless steel 304 and 316, aluminum, and iron with different roles between the anode and cathode. The best result was achieved when the anode was Fe and the cathode was stainless 304. The COD removal efficiency was about 65%. Alkurdi and Abbar [28] performed a study entitled "Performance of Combined Electrocoagulation and Advanced Electrochemical Oxidation Used for Oil Field Produced Water Treatment." Two aluminum plates (purity > 99%) with effective surface areas of 40 cm^2 were employed as electrodes, one as an anode and the other as a cathode. The space between the electrodes was 2 cm. The electro-Fenton procedure was conducted at room temperature (252 °C) in a 1 L cylindrical glass electrochemical cell with two electrodes. The cathode was a cylindrical (338 cm) activated carbon fiber felt (ACFF). The anode was a Ti-RuO_2/IrO_2 mesh (83 cm) placed in the cell's middle. Ibrahim [29] studied the COD removal from petroleum refinery wastewaters by using an electrocoagulation process, with an initial COD of 0.25 g/L, a pH of 7.8, a TDS of 1.610 g/L, a turbidity of 4.17 NTU, and a conductivity of 3130 S/cm. Anode and cathode electrodes were made of aluminum and stainless steel, respectively. The impacts of current density (4 to 20 mAcm-2), pH (3 to 11), and the amount of NaCl (0 to 4000 mg/L) on the COD removal were studied. The results showed that the COD removal increased with the current density; however, this effect decreased when NaCl increased. Whenever the pH was below 7, COD was less taken out of the water. The current density of 12 mA/cm^2, pH of 7, and NaCl concentrations of 2,000 mg/L were observed to be the best for a 1h treatment period leading to the best COD removal efficiency of 96.8%, phenol removal efficiency of 64.7%, and dissolved inorganic solid (TDS) removal efficiency of 20.6%, with a power consumption of 29.12 kWh/kg COD. This study showed that the COD was 8 mg/L, which is less than the amount that oil refineries allow to release. Ibarra [30] studied the oil wastewater treatment from the Central Refineries Company in Iraq, using the electrocoagulation and electro-oxidation processes. Aluminum and graphite were used as electrodes for the anode (Al in the EC process, graphite in the EO process) and stainless steel as an electrode for the cathode in the form of plates. C.D.= 20 mA/cm^2, pH= 7, duration= 40 min, and NaCl concentration= 2.5 g/l were the best parameters for treating wastewater applying the in-situ EC-EO method. Under these conditions, nearly 90% of the COD reduction was accomplished with electrical energy consumption (ENC) of around 15.46 kWh/m^3. This study used titanium as the cathode and aluminum electrodes as the anode and connected them electrically using the (MP.P) method. This research focuses on cleaning up the contamination (COD) in the wastewater from the Qayyarah refinery in Iraq, which is part of the North Refineries Company. This reaction was then joined with the Fenton reaction by directly adding H_2O_2 and Fe^{3+}. Then, the percentage elimination of the process's behavior was determined, and the optimal settings were set to achieve the best results in terms of reducing COD from wastewater. Also, the time required to remove organic materials from wastewater, reaction kinetics, variance analysis, and a mathematical model for each case were studied.

2. MATERIAL AND METHOD

2.1 *Wastewater Resource*

The wastewater designated for treatment was collected from the first unit of the Qayyarah refinery. Table 1 indicates the utilized wastewater parameters.

Table 1 The Characteristics of Effluent at the Qayyarah Refinery.

No.	Tests	Wastewater
1	pH	7.2
2	Temperature, ºC	26-32
3	COD, ppm	750-900
4	T.D.S, ppm	230
5	Oil, ppm	8.6
6	Conductivity, ms	380
7	Turbidity, Ftu	97
8	NaCl %	0.7

2.2 *The Procedure*

A Pyrex glass cylindrical reactor with a 2-liter capacity and a 13-cm diameter was used for the tests. The reactor was mounted on a magnetic stirrer worked at 700 rpm throughout the procedure. Aluminum was the anode, while titanium was the cathode in the coagulation process. To avoid contact between the magnetic mixture and the electrodes, the electrodes were placed 4 cm from the reactor's bottom. The electrodes were organized in the shape of (Ti, Al, Ti, Al) with diameters of 11, 9, 7, and 5 cm from the outside to the inside, respectively. As indicated in Fig. 2 and Fig. 3, the electrodes were linked in parallel before being attached to a power supply. For each experiment, the required H_2O_2 and Fe^{+3} quantity was added to the electrocoagulation vessel for Fenton's reaction. To boost the water's electrical conductivity, sodium sulfate, an electrolytic component, was added. Several amounts of H_2SO_4 and NaOH solutions were created to adjust the procedure acidity. Table 2 shows the properties of these agents.

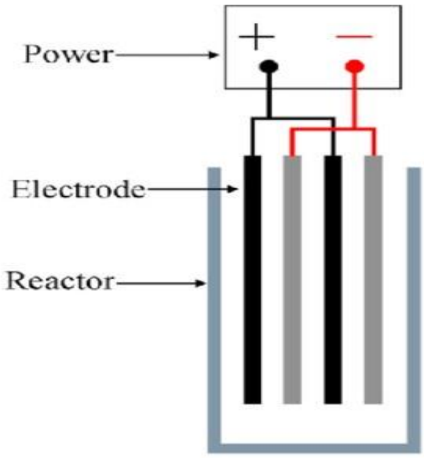

Fig.2 Electrocoagulation Reactor: Monopolar Electrodes with Parallel Connection (MP.P)(LU, 2021).

Fig.3 An Image of the Experimentation System.

Table 2 Chemicals Used in this Study.

No.	Chemical Name	Chemical Form	Purity	Manufacturing Company
1	hydrogen peroxide	H_2O_2	50%	PanReac AppliChem(Spain)
2	ferrous sulfate	Fe^{+3}	99%	Fluka (Switzerland)
3	sodium hydroxide	NaOH	99%	Fluka (Switzerland)
4	sulfuric acid	H_2SO_4	96%	Fluka (Switzerland)
5	Sodium sulfate	Na_2SO_4	98%	Fluka (Switzerland)

2.3. *Methods of Analysis*

It was necessary to remove enough effluent, which was then processed. Conductivity, temperature, and pH were measured. The measurement of COD analysis (COD Set-Up MD 100 model, Lovibond manufacturing, Germany) was used to assess how effectively organic matter was removed. COD was calculated using the Lovibond device, which was occasionally repeated two to three times. A TDS meter (TDS-EZ model, HM Digital, Inc, China) was used to measure the wastewater's total dissolved solids after and before each experiment.

2.4. Design of Experiment

The experiment was set up using the Taguchi method. The study looked at six variables: COD removal efficiency was the dependent variable, and current density, Na_2SO_4, pH, $[H_2O_2]$, and $[Fe^{+3}]$ were the independent variables by taking 5 points of each parameter.

3. RESULTS AND DISCUSSIONS

3.1. The Effect of the Selected Variables on the Removal Efficiency

The study used six variables, with efficiency serving as one dependent variable. The five independent factors (illustrative or explanatory) were current density, Na_2SO_4 concentration, pH, H_2O_2 concentration, and Fe concentration. The statistical breakdown of the investigated variables is presented in Table 3.

Table 3 Statistical Description of the Studied Variables.

	Case Summaries					
	Efficiency	Current Density	Na_2SO_4	pH	H_2O_2	Fe
N	25	25	25	25	25	25
Missing Value	0	0	0	0	0	0
Mean	78.41	400	3.0	6.	400.	100.
Std. Deviation	6.62	216.5	1.44	2.88	216.5	21.6
Minimum	62.26	100	1.00	2.0	100	20
Maximum	90.19	700	5.00	10.0	700	150

The statistical description of the statistical indicators indicated by the arithmetic mean, standard deviation, and maximum and minimum values for each variable are found in Table 3. The efficiency variable arithmetic mean was 90.188, with a standard deviation of 6.626, and the variable's lowest and greatest values were 62.264 and 90.188, respectively. Fig. 4 shows the current density and Na_2SO_4 effects on the removal efficiency. The influence of current density and electrolyte concentration on COD removal efficiency is depicted in this figure. The most effective elimination occurred at a concentration of 2 g/L and a current of 15 mA/cm². It was observed that more energy was consumed and higher electrolyte concentration. Fig. 5 shows the relationship between the current density and pH effects on the COD removal efficiency. The best removal efficiency was reached at 8 pH when the solution was neutral or at the transition point from neutral to alkaline. When this result was compared with the researcher's [31], an agreement on the acidity function was found. The researcher found that the best results were achieved when the pH was 7.98. Researchers [28,29] found the best results when the pH values were 7.74 and 7. While researchers [32], who used aluminum and titanium/platinum electrodes as anode and cathode, found that the best result was achieved when the pH value was 6.6. Fig .6 shows the behavior of the two variables' effect (current density and hydrogen peroxide concentration) on the efficiency of COD removal. The significant impact of current density compared to the hydrogen peroxide concentration can be noticed. The increase begins gradually and progressively with the current density. On the contrary, there was no effect, or it was insignificant when the H_2O_2 concentration increased. Fig. 7 shows the behavior and effects of the Fenton reaction represented by hydrogen peroxide with ferrous ions. As is known in advance for this type of reaction, the peroxide attacks the organic pollutants either by direct reaction with them or through the production of free radicals of hydroxyl, while the ferrous ions improve and stimulates the peroxide to produce more free radicals. The H_2O_2 effect can be seen more clearly in Fig. 7. In addition, there is another effect simultaneous with and interfering with Fenton reactions in this study, which is the presence of aluminum ions that also interact with organic pollutants in the same pot and cathode reactions that produce hydrogen gas, which in turn produces additional free radicals with these reactions. Thus, a new behavior appears that cannot be compared with the resulting behavior of known Fenton processes.

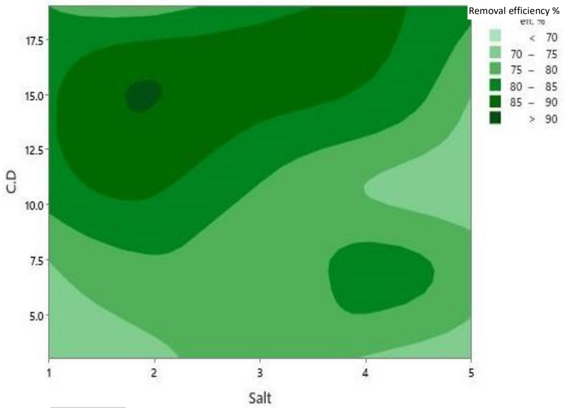

Fig. 4 Response Surface to the Effect of Current Density (C.D) and Salt (Na2SO4) on the Removal Efficiency (%).

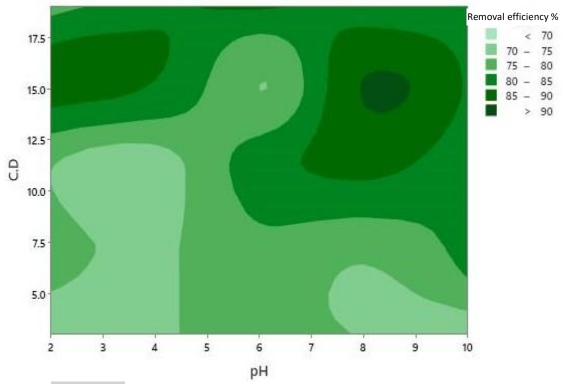

Fig. 5 Response Surface to the Effect of Current Density (C.D) and (pH) on the Removal Efficiency (%).

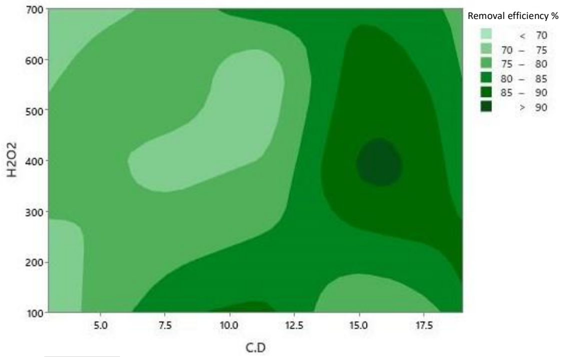

Fig. 6 Response Surface to the Effect of Current Density (C.D) and (H2O2) on the Removal Efficiency (%).

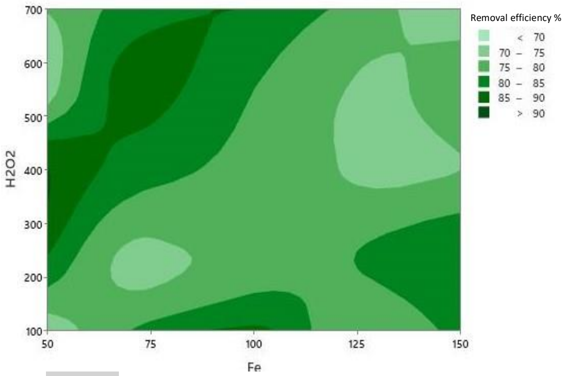

Fig .7 Response Surface to the Effect of Current Density (H2O2) and Salt ($Fe3+$) on the Removal Efficiency (%).

3.2.The Results of the Kinetic, Modeling, and Time on the Efficiency

Table 4 includes many statistical data points related to this case. The most important one is the contribution of each of the five variables and their impact on removal efficiency. The Variance Inflation Factor and the Tolerance Factor values were found to detect the presence of such an issue.

Table 4 Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
C.D	4	329.83	47.79%	329.83	82.457	3.90	0.108
Salt	4	126.39	18.31%	113.06	28.266	1.34	0.392
pH	4	46.61	6.75%	47.43	11.857	0.56	0.705
H_2O_2	4	16.31	2.36%	16.23	4.058	0.19	0.930
Fe	4	86.61	12.55%	86.61	21.652	1.03	0.491
Error	4	84.47	12.24%	84.47	21.117		
Total	24	690.22	100.00%				

Table 4 also shows each study parameter's effect on efficiency. Noticeably, the current density had the greatest effect, followed by the electrolytic salt, which directly influences the current density. It also shows that the effect of pH was insignificant due to the Fenton reaction presence in conjunction with the electrocoagulation reactions that favor the acidic medium, while electrocoagulation favors the neutral and basic medium. The difference in the acidity function of the reaction medium is useful in this case. As the effect of the electrocoagulation reaction decreases in an acidic medium, the Fenton reactions offset it. Table 4 shows that all values of (F-Value) are less than 10, indicating no linear relationships between the interpreted variables. The tolerance coefficient (Tolerance) values were greater than 0.1indicating no issue at the multiplicity of linear relationships between the explanatory variables. The removal process samples were studied. The samples were tested every 10 minutes to find the best time for the removal process. The behavior is shown in Fig. 8. It is noticed that the removal process stabilized at the 50-minute mark, and there was no further development in the removal process. Unlike chemical oxidation therapy, which is slower than electrocoagulation, electrocoagulation is a quick and incomplete process, whereas electro-oxidationEOx) is a complete process. Combining the two processes resulted in a functioning hybrid. The initial concentration of pollutants in wastewater, the nature of these pollutants, their molecular formula, physical and chemical properties, the electrode employed type, and the electrode and reactor geometries influenced the treatment process time. While researcher [31] discovered that the COD removal period from Cardboard (actual) wastewater was 60 minutes for a removal rate of 85.3%. While the other researcher found 49 removal time was 60 minutes, with a COD removal rate of 72%when treated in anaerobic reactor effluent (real) wastewater. Also, a study by the researcher [33] removed phenol and COD. The removal percentage was 97% in 25 minutes when applied to the steel industry wastewater.

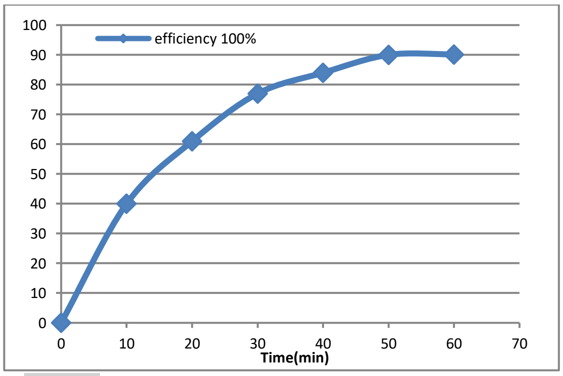

Fig. 8 The Time Required to Remove COD.

Fig. 9 shows the reaction kinetics in the organic compounds' removal from wastewater. The plot on "ln (CA / CA_O) versus time" could be used to calculate the mass transfer coefficient km, and this plot will result in a straight line with a slope equal to (km A / VT). The calculation results from this figure are illustrated in Table 5. For various initial pH values, the mass transfer coefficient (K_m) might be predicted from this figure.

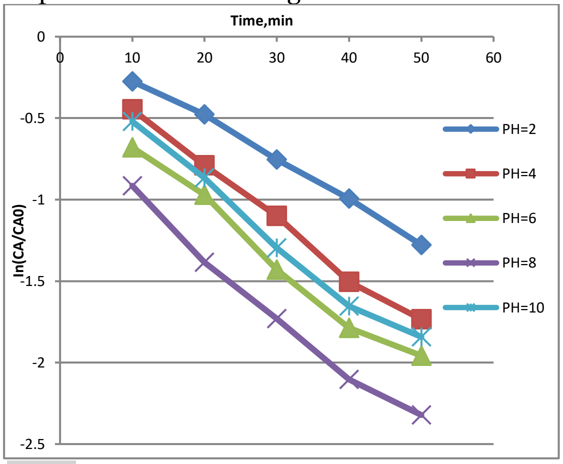

Fig.9 The Process Kinetics at Different pH.

Table 5 The Mass Transfer Coefficient (Km) for Different pH.

Initial pH	K_m (m / s)
2	1.95605×10^{9}
4	2.6700543×10^{9}
6	2.600764×10^{9}
8	2.7808533×10^{9}
10	2.745652×10^{9}

Noticeably, all Km values almost followed the first-order reaction, the common reaction of organic compounds found in wastewater. According to some studies, the interaction between pollutants and electrodes is theoretically a pseudo-first-order type. It can eventually change to a pseudo-zero reaction only if there is a significant increase in the pollutants' initial concentration [34,35]. The organic pollutants concentration in the present study was not extremely high but falls into the intermediate values range. The special case of the present study followed the interaction of the first degree, which is consistent with the findings of the mentioned researchers. Table 6 and Table 7 show the model summary and the equations of the final mathematical model for all anode electrodes at parallel connections. Table 6 explains some statistical information obtained from Minitab. This information explains that the obtained results are statistically sound, and there is no overlap between the variables. Table 7 describes the mathematical model equation for this study. The accuracy of this equation is shown in all variables chosen for the study, with all the points of each variable and the extent of their impact on the removal efficiency. The equation also shows no overlap between the variables, as each variable has its limit separate from the effect of other variables.

Table 6 Model Summary of the Study.

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)	AICc	BIC
4.59532	90.76%	26.57%	3435.07	0.00%	651.38	172.20

Table 7 Regression Equation of the Study

Removal efficiency 100%	=	79.252 - 5.73 C.D_3 - 1.66 C.D_7 - 0.02 C.D_11 + 4.92 C.D_15 + 2.49 C.D_19 - 0.42 Salt_1 + 1.76 Salt_2 + 1.62 Salt_3 + 1.06 Salt_4 - 4.02 Salt_5 - 1.65 pH_2 - 1.50 pH_4 + 0.80 pH_6 + 2.20 pH_8 + 0.16 pH_10 + 0.21 H2O2_100 + 1.32 H2O2_250 + 0.20 H2O2_400 - 0.68 H2O2_550 - 1.05 H2O2_700 - 0.62 Fe_50 + 2.19 Fe_75 + 1.88 Fe_100 - 2.88 Fe_125 - 0.56 Fe_150

4.CONCLUSION

This study proved its efficacy in reducing organic compounds represented by COD from wastewater produced by oil refineries. The effect of the selected variables on removal efficiency was investigated during this study by investigating the effect of each two variables simultaneously to understand their behavior during the removal process. Also, in this study, a lot of statistical data were extracted through the Analysis of Variance. The optimal time was extracted to achieve the best removal efficiency, and the reaction kinetics was studied to find the mass transfer constant. A model Summary for the study was also presented, in addition to the Regression Equation of the study. With its innovative cylindrical shape consisting of four consecutive electrodes, the system achieved good results for treating industrial wastewater from the Qayyarah refinery containing 830 mg/L of COD before treatment. After treatment, its value was within the range of 50 mg/L, within the internationally permitted limits for industrial wastewater, which is 250 mg/L. The study showed that combining the electrocoagulation process with Photo-Fenton achieved an outstanding result. The optimum conditions for this experiment were as follows: The time required was 50 minutes, pH= 8, H_2O_2= 400 mg/L, Fe^{3+}= 20 mg/L, and a current density of 15 mA cm^{-2}.

ABBREVIATIONS

Symbol	Description
COD	Chemical oxygen demand
EC	Electro coagulation
EO_x	Electro oxidation
H_2O_2	Hydrogen Peroxide
MP. P	Mono Polar, Parallel
Na2SO4	Sodium sulfite
NaOH	Sodium hydroxide
PbO2	Lead dioxide
TDS	Total Dissolved Solid

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