



## Electrochemical removal of Oil and COD from petroleum wastewater

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### Abstract

Recently, COD and oil concentrations in the water have increased, as a result of reduced water volumes and increased industrial waste being dumped into the river. Increased concentrations of these pollutants lead to health and environmental problems. As the water treatment plants use the usual methods of water treatment and could not reduce the concentration of oil and COD to the limit set by the World Health Organization, so an effective way to treat these pollutants became absolutely necessary. In this study, electrochemical method was used to treat water contaminated with oil and COD, using aluminium and iron electrodes as positive electrode and cathode electrode. A coagulation cell with a volume of 2 liters was also used in the work. Several factors affecting the process of treating oil and carbon dioxide pollutants were studied, and these factors were as follows: Submerge depth, Number of electrodes, the distance between the electrodes. From the results, it was found that the optimum removal was 94.2% for oil, and 99.5% for COD. It was achieved when the number of electrodes was 4 aluminium and 4 irons, the distance between the electrodes was 2 cm, the depth was 12 cm, and the function variables were acidic equal to 7, time 50 min, and voltage 10.5 V. The concentration of sodium chloride is 0.5 g/l and the electrode material is aluminium as anode and cathode and the initial oil concentration is 95 mg per liter, initial COD concentration is 710 mg per liter and the consumption of energy was estimated to be 12 kwh/m<sup>3</sup>, the TSS was 73 mg/l. The results demonstrated that the electrochemical is a feasible technique for treatment of oily contaminated petroleum refinery wastewater. Investigate the removal oil and COD of oily wastewater by using an electrochemical and investigate the electric energy cost.

**Keywords:** oil removal, COD removal, oily wastewater, Electrochemical.

**الخلاصة:** في الآونة الأخيرة زادت تراكيز الزيت و COD في المياه نتيجة الى نقصان في كميات المياه وزيادة النفايات الصناعية المطروحة الى النهر. وان الزيادة في تراكيز هذه الملوثات يؤدي الى حدوث مشاكل صحية وبيئية. كما ان محطات معالجة المياه تستخدم الطرق العتيادية لمعالجة الماء و قد عجزت عن انزال تركيز الزيت و COD الى الحد المقرر حسب منظمة الصحة العالمية. فعليه اصبح ايجاد طريقة فعالة لمعالجة هذه الملوثات ضروري جدا. في هذا الدراسة استخدمت طريقة الكهروكيميائية لمعالجة الماء الملوث بالزيت و COD وباستخدام اقطاب اللينيوم والحديد كاقطاب انود وكاثود. خلية تخثير بحجم ٢ لتر قد استخدمت ايضا في العمل. تم دراسة العديد من العوامل المؤثرة على عملية معالجة المياه الملوثة بالزيت و COD وكانت هذه العوامل كالتالي: عمق الغمر, عدد الاقطاب الكهربائية والمسافة بين الاقطاب. ومن النتائج وجد ان الزالة المثالية كانت ٩٤.٢% للزيت و ٩٩.٥% لل COD و قد تحققت عندما كان عدد الاقطاب الكهربائية اربعة اللينيوم واربعه حديد, وكانت المسافة بين الاقطاب ٢ سم وكان العمق ١٢ سم وكانت المتغيرات كالتالي: الدالة الحامضية تساوي ٧, الوقت يساوي ٥٠ دقيقة, الجهد ١٠.٥ فولت, تركيز كلوريد الصوديوم ٥٠.٥ غم/لتر, مادة القطب هي اللينيوم كانود وكاثود, تركيز الزيت اللولي ٩٥ ملغم لكل لتر, تركيز COD اللولي ٧١٠ ملغم لكل لتر, استهلاك الطاقة كان ١٢ كيلو واط/ ساعة لكل متر مكعب, TSS كانت ٧٣ ملغم لكل لتر. و اظهرت النتائج ان الكهروكيميائية هي تقنية مجدية وفعالة في معالجة مياه الصرف الصحي الملوثة بالزيت. تحقق من ازالة الزيت و COD لمياه الصرف الصحي الزيتية باستخدام الكهروكيميائية وتحقق من تكلفة الطاقة الكهربائية.

## 1. INTRODUCTION

Petroleum refineries consume vast quantities of water for operations like desalting, distillation, and hydrotreating [1], creating significant amounts of wastewater. [2] stated that the refining process determines the composition of the wastewater produced by petroleum refineries. For instance, [3] stated that high concentrations of aromatic petroleum hydrocarbons and aliphatic acid in wastewater are often a result of refining processes. [2] explained that these refining effluents often contain toxic substances such as cyanide, oil, benzene, and sulfide, which can adversely affect plants. [4] the wastewater also has high chemical oxygen demand (COD) and biological oxygen demand (BOD). [5] developments in electrochemical technology (with special emphasis on electrocoagulation, electro-oxidation, and electro-Fenton) to treat petroleum industry effluents (offshore and hydraulic fracturing extraction, as well as refinery effluents). In addition, an overview is given of what these processes face to position themselves as consolidated technologies. The electrocoagulation was proven to be efficient and reliable technique for treatment Al-Dewaniya petroleum refinery effluent to get effluent with features in agreement with the standard limits for discharge to environment at lower cost [6]. Moreover, and his fellows [7] stated that it can impact the environment by negatively affecting plants, rivers, oceans, and surface and groundwater sources. [3] also mentioned that wastewater treatment plants employ various techniques in their pre-treatment stage to decrease the absorption of organic pollutants before the final biological purification process. Commonly used methods include adsorption, coagulation aided by coagulants, ultrafiltration, and electrochemical techniques to ensure that the wastewater is in a form that microorganisms can effectively treat.

Reference [8] established that Electrochemistry (EC) is a modern approach to water and wastewater treatment with several benefits, like a simple operation, rapid treatment time, minimal sludge production, and no chemical needs. [9] demonstrated that EC had been applied to clean up pollutants from refinery wastewater, including arsenic [10], boron [11], dyes [12], phosphate [13], and viruses [14]. It has also been found to be prevalent in breaking down emulsions in wastewater from water & paper mills, dairy operations, landfill leachate, and more. While the application of EC for hydrocarbon removal has been limited, studies have shown its effectiveness in removing hydrocarbon from water from the ground. Results showed that using stainless steel or aluminium electrodes did not affect the removal efficiency, reaching 99.5%. and his colleagues [15] stated that the EC process involves three steps: The process of removal of contaminants from aqueous solutions involves multiple steps, including "electrochemical reactions occurring at the electrode surfaces, the formation of coagulating agents in the water phase, and the adsorption of soluble pollutants or colloids onto these coagulating agents. Subsequently, the combined particles are removed from the solution through either sedimentation or flotation. [8] reported that Iron (Fe) and aluminium (Al) has been commonly used for the sacrificial electrodes in EC. The sacrificial electrode dissolves from the anode, releasing metal ions that hydrolyse to produce polymeric iron or aluminium oxide hydroxides as coagulating agents. Results showed that electrocoagulation was more effective in reducing total dissolved solids (TDS) and demonstrated improved turbidity removal. However, there are also some drawbacks of electrocoagulation as a treatment method, such as the generation of secondary pollutants like hydrogen gas, which can harm the environment [16]. Additionally, the EC process can be expensive, as it requires high energy consumption and the maintenance of the electrocoagulation system is complex [8].

Therefore, a proper balance between the benefits and limitations of electrocoagulation must be considered when choosing the most appropriate wastewater treatment method for a petroleum refinery. Despite these limitations, electrocoagulation has been recognized as an effective treatment method for refining effluent and has the potential for wider application. Previous literature demonstrated that electrocoagulation was more effective for reducing total dissolved solids (TDS) and turbidity levels than chemical coagulation. The authors concluded that electrocoagulation is a more efficient method and that the treated textile effluent can be safely reused or released into the environment [17]. [18] also concluded that the electrochemical process of treating water and wastewater is becoming increasingly prevalent, especially in Europe and South America, as a means of treating industrial wastewater containing metals. EC treatment is becoming more common in North America for use in industries such as the paper and pulp industry, mining, and metal processing. Researchers have been studying

the potential of EC treatment for a variety of contaminated water sources and waste streams, including food waste, oil, dyes, suspended particles, landfill leachates, defluorinated water, synthetic detergent effluent, mine waste, and solutions containing heavy metals. In order to optimize the EC process, researchers conduct experiments to determine the most effective operating parameters for a particular type of waste stream.

This study, an electrochemical unit (EC process) was used as a pre-treatment for a petroleum wastewater, with the two reactor systems linked in a series and operating in batch flow mode. In addition, electrode design and material, as well as the applied direct current field between the electrodes, have an impact on submerged membrane bioreactor treatment performance. To determine the optimum surroundings for extraction, various parameters like pH, time, voltage, sodium chloride concentration and initial concentration.

The main goal of the present study is to evaluate the Investigation the COD and Oil removal from oily wastewater by Electrochemical mode.

## 2. METHODOLOGY

The current study used refinery wastewater to create EC (as illustrated in Figure.1).

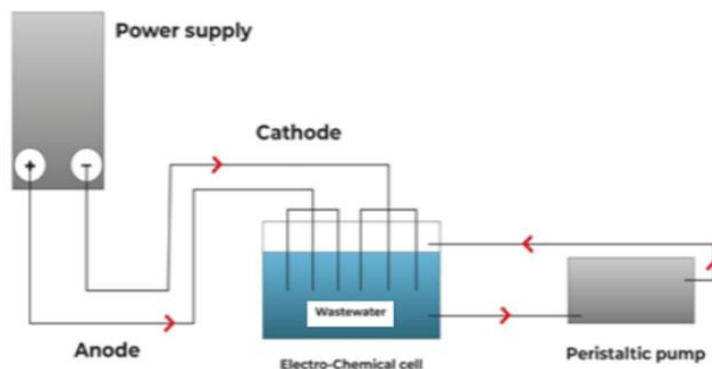


Figure 1: Schematic diagram for the experimental setup.

At the end of each electrochemical trial, the quantity of produced sludge was determined through the measurement of Total Suspended Solids (TSS) following the standard 2540D procedures (as outlined by Clessery and Eaton, 1998). The researchers used a UV-vis and visible electrophoretic method, similar to that utilized in the 2002 Danube Joint Survey, to measure the concentration of diesel present in the sample. However, they modified the method slightly by measuring UV-vis absorption at 250 nm with a Unico-2100 spectrophotometer instead of 254 nm, as it was found to have the highest absorption in the range of 220 to 300 nm. To determine the hydrocarbon type and diesel concentration, the researchers used GC-MG (Agilent Technologies-7890). The solution's pH was recorded using a digital pH meter. The efficiency of the wastewater treatment was calculated by using the following formula [19]:

$$R = \frac{c_o - c_e}{c_o} \times 100 \quad (1)$$

The removal efficiency (R) is determined by comparing the initial concentration (Ci) of a substance in mg/L to its final concentration (Ce) in mg/L. Cost analysis is a crucial aspect of determining the feasibility of any wastewater treatment method. According to [16], the operating cost of electrocoagulation (EC) processes is influenced by several factors, including the cost of materials, energy consumption, labour, maintenance, sludge dewatering and disposal, and fixed costs. Energy consumption is the largest contributor to the overall cost of EC processes, which can be calculated using the formula provided [19].

$$E = \frac{V \cdot I \cdot t}{\text{Treated volume (m}^3\text{)}} \quad (2)$$

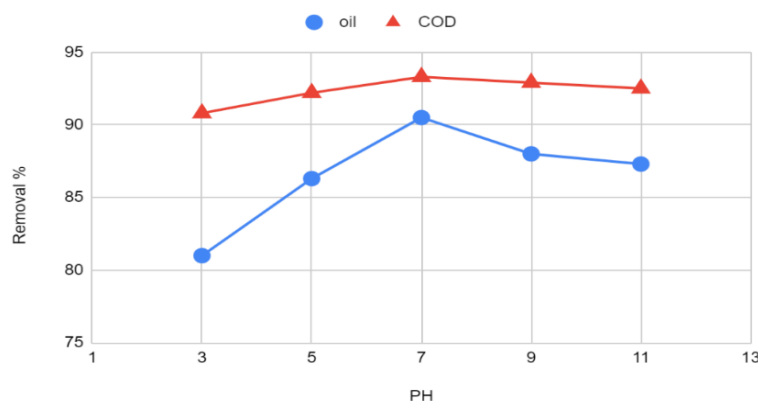
Where E is the energy consumption (kwh/m<sup>3</sup>), V is the cell voltage (V), I is the current (A), and t is the operating time (h). To obtain accurate results, the resistance of the electrode was monitored throughout the experiments, and a weighted average was used for calculation purposes.

### 3.RESULTS AND DISCUSSION

The study aimed to assess the effect of several variables, including pH, reaction time, voltage, electrode materials, support electrolyte, and initial diesel concentration, on the effectiveness of electrocoagulation (EC) in reducing chemical oxygen demand (COD) and oil from refinery wastewater. It also evaluated the energy consumption and sludge production related to this process. The findings are presented and analysed in the following section. In this study, we investigated the impact of various factors such as pH, reaction time, voltage, electrode materials, support electrolyte, and initial diesel concentration on the performance of electrocoagulation (EC) in removing chemical oxygen demand (COD) and oil from refinery wastewater. Additionally, we evaluated the energy consumption and sludge production associated with this method.

#### 3.1 Effect of PH on electrochemical

The highest removal efficiencies for oil and COD were recorded at 90.5% and 93.3%, respectively. Figure (2) shows the effect of pH on COD and oil removal efficiency



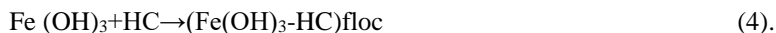
**Figure 2.** Effect of pH on the removal of COD and oil (20min, 4.5V, NaCl concentration of 0.5 g/L, Fe-anode Al-cathode, initial oil concentration EC1 and EC2=90mg/l, EC3=94, EC4=95mg/l, initial COD concentration EC1 and EC2=700mg/l, EC3=710, EC=730mg/l).

It is obvious that oil and COD removal effectiveness were significantly affected by pH value, an increase in pH value can be noticed when pH value was neutral in the carried-out tests. This increment can be attributed to the emission of oversaturated carbon dioxide due to the development of hydrogen at the cathode. Furthermore, one can notice that in basic conditions, the pH value of the sample reduced throughout the treatment process; this took place because of hydroxide ions precipitation with the cation. The results mentioned above emphasized that the EC process can be applied as a pH buffer. The obtained removal efficiencies of oil and COD were reduced in basic and acidic conditions. The arrangement of ionic species of iron demonstrated the obtained result. These species were important in removing the contaminants that are insoluble and stable. According to the Fe (III) predominance zone diagram by [8], the type of ionic species present in wastewater depends on the pH level. In acidic conditions, Fe<sup>3+</sup>, Fe (OH)<sup>+2</sup>, and Fe (OH)<sup>+2</sup> ions are prevalent, whereas alkaline conditions result in the dominance of soluble Fe

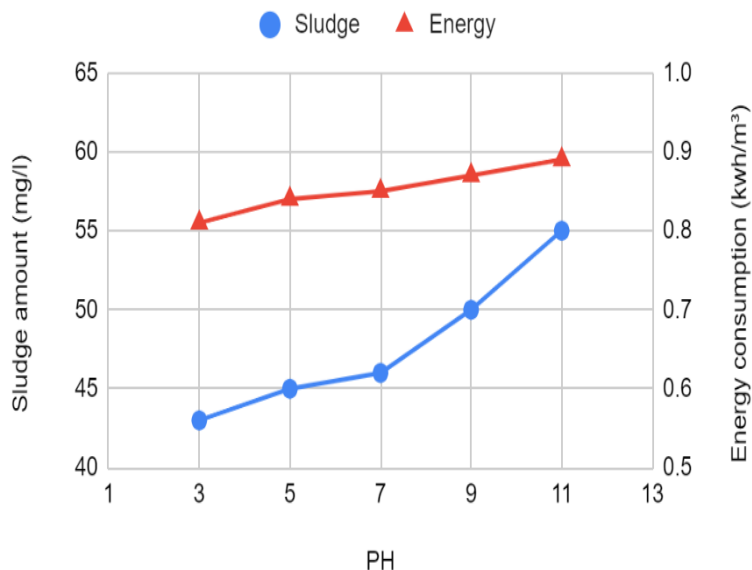
(OH)<sup>4-</sup> ion. These species play a significant role in eliminating COD and oil from wastewater. At neutral pH, Fe(OH)<sub>3(s)</sub> is stable, insoluble, and readily available for pollutant adsorption. The hydrophobic and nonpolar nature of neutral hydrocarbon molecules make them suitable for removal from wastewater through the formation of surface complexes with Fe(OH)<sub>3(s)</sub> precipitation, as described by the equation [19]:



The active zones on hydrocarbon molecules provide surfaces for the growth of ferric hydroxide flocs, which can then physically adsorb onto the amorphous Fe(OH)<sub>3(s)</sub> flocs through van der Waals forces. The following equation can describe this process [19]:



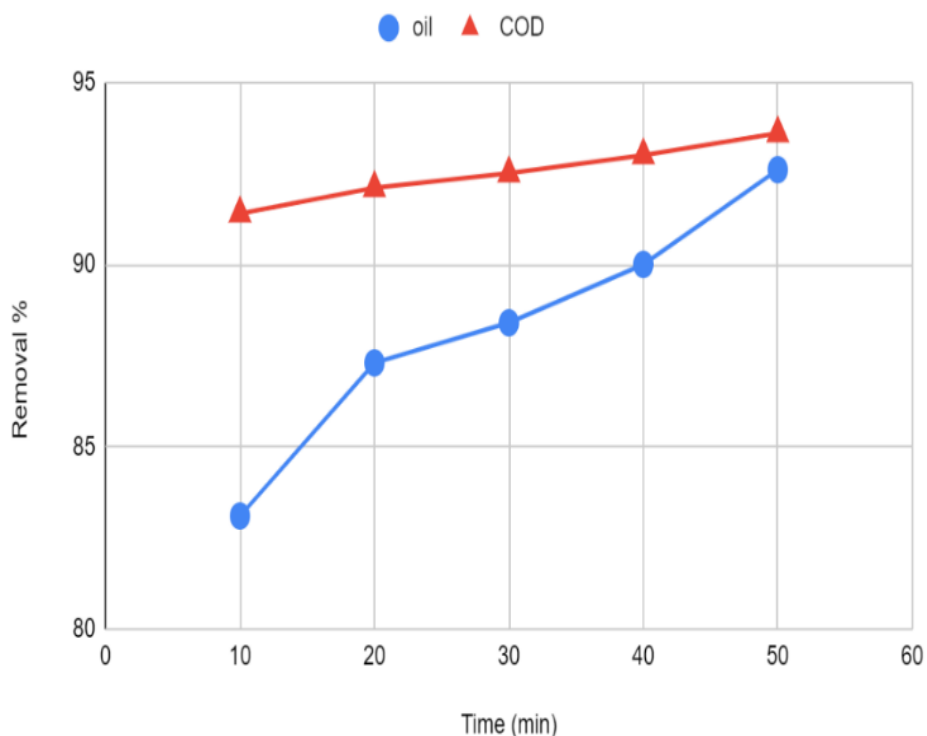
The flocs can then be separated from the wastewater through settling, flotation, or filtration, as confirmed by [20]. The studies conducted by [21,22, 23] support the effectiveness of this process, as they found that increasing the number of electrodes and electrode submergence depth leads to higher removal efficiency. The highest removal efficiencies were observed at a 12 cm electrode submergence depth due to the increased surface area and coagulant release. Figure 3 illustrates the results of energy consumption and sludge production, with the maximum sludge amount and energy consumption recorded at a pH of 11 (55 mg/l and 0.89 kWh/m<sup>3</sup>, respectively).



**Figure 3:** The effect of pH on the sludge amount and energy consumption (20min, 4.5V, NaCl concentration of 0.5 g /L, Fe-anode Al-cathode, initial oil concentration EC1 and EC2=90mg/l, EC3=94, EC4=95mg/l, initial COD concentration EC1 and EC2=700mg/l, EC3=710, EC=730mg/l).

### 3.2 Effect of Time on electrochemical

The study explored the relationship between time and the effective reduction of COD and oil in the EC process. and it is shown in Figure (4).



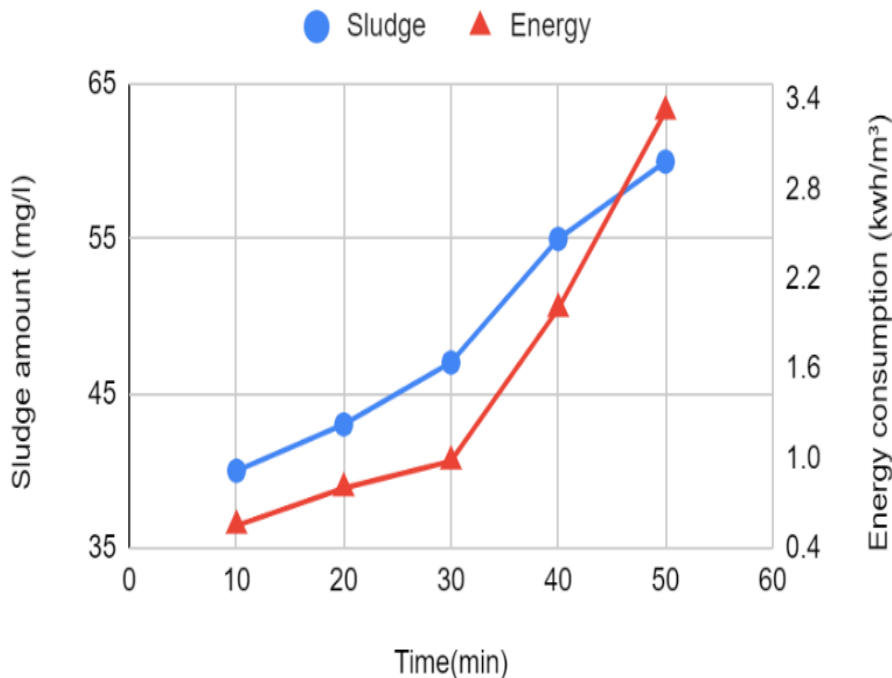
**Figure 4:** Effect of contact time on the removal of COD and oil (PH 7, 4.5V, NaCl concentration of 0.5 g /L, Fe-anode Al-cathode, initial oil concentration EC1 and EC2=90mg/l, EC3=94, EC4=95mg/l, initial COD concentration EC1 and EC2=700mg/l, EC3=710, EC=730mg/l).

It was found that the highest removal efficiencies for COD and oil were achieved after 50 minutes, reaching 93.6% and 92.6%, respectively. The study concluded that the duration of electrolysis has a direct impact on the production of metal ions from the electrodes, which then affects the removal efficiencies of COD and oil. This correlation was supported by Faraday's law, which states that the amount of coagulant is directly proportional to the current applied, time, and the volume of wastewater being treated. The formula for calculating the concentration of metal ions produced during the EC process was also provided, represented by the equation [19]:

$$C = \frac{Mit}{n F V} \tag{5}$$

where M, I, t, n, F and V stand for the molecular weight of the metal (g/mol), and the current (A), time (s), metal valency (3 for Al and 2 for Fe), Faraday's constant (96500 C/mol) and wastewater volume, respectively. At the beginning of the EC process, in the experiments the COD and oil removal efficiency is low since the rate at the initial times the production of metal ions from the electrodes is low; However, when the time of electrolysis increases, the concentration of metal ions and their hydroxide clusters increase; thus, COD and oil removal efficiencies increase [17]. electrolysis is required to generate adequate amount of Al<sup>+3</sup> ions and aggregated flocs

need the time to be formed. It is well known that the electrolysis time is proportional with coagulant concentration in the reaction medium which leads to higher pollutant removal [24]. The effect of time on the amount of sludge produced and energy consumption is shown in Figure (5). The maximum Sludge amount and energy consumption are 60 mg/l and 3.32 respectively at time 50 min.

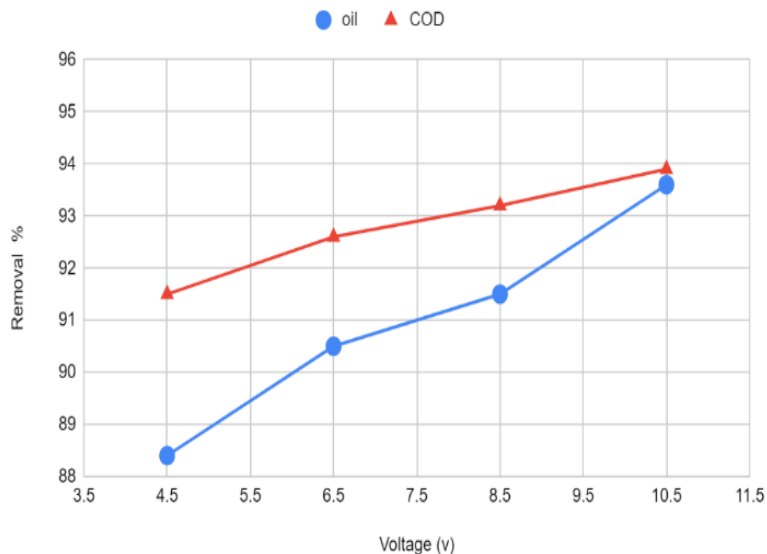


**Figure 5:** The effect of time on the sludge amount and energy consumption (PH 7, 4.5V, NaCl concentration of 0.5 g /L, Fe-anode Al-cathode, initial oil concentration EC1 and EC2=90mg/l, EC3=94, EC4=95mg/l, initial COD concentration EC1 and EC2=700mg/l, EC3=710, EC4=730mg/l).

The results showed that sludge production and energy consumption were proportional to time. According to Faraday's law the amount of formation of metal hydroxide and coagulants is directly proportional to time; Thus, with increasing time, the resulting sludge increases. energy consumption is directly proportional to time; Thus, by increasing the time, the energy consumption is increased. In addition, the amount of sludge generated and energy consumption increase by increasing the removal of COD and oil.

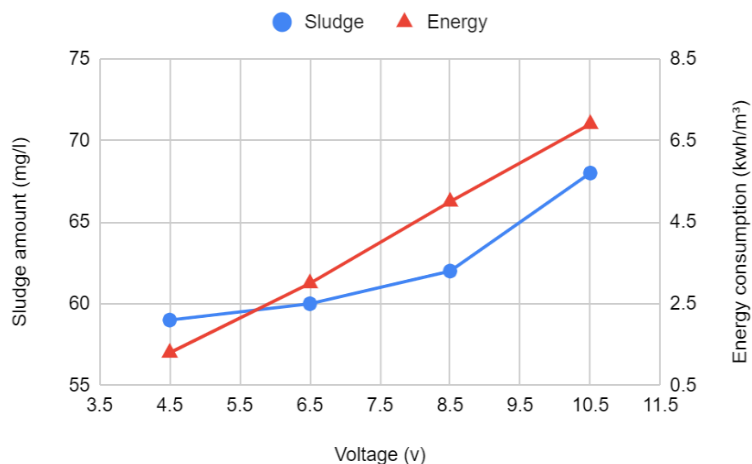
### 3.3 Effect of Voltage on electrochemical

The voltage applied to an electrochemical (EC) system significantly impacts the coagulant dosage rate and the removal efficiency of COD and oil. As demonstrated in Figure 6, the highest removal efficiencies of COD and oil, 93.6% and 93.9% respectively, were achieved at a voltage of 10.5V.



**Figure 6:** Effect of voltage on the removal of COD and oil (PH 7, 50 min, NaCl concentration of 0.5 g /L, Fe-anode Al-cathode, initial oil concentration EC1 and EC2=90mg/l, EC3=94, EC4=95mg/l, initial COD concentration EC1 and EC2=700mg/l, EC3=710, EC=730mg/l).

An increase in voltage results in an increase in the removal efficiencies of COD and oil, which can be attributed to the effect of voltage on the concentration of metal ions and their hydroxide flocks, which are crucial in removing hydrocarbons. Faraday's law states that an increase in voltage leads to an increase in the concentration of metal ions and hydroxide flocks, which absorb the hydrocarbons and result in improved removal efficiency. Furthermore, a higher voltage leads to a higher bubble generation rate and smaller bubble size, as noted by [25], which improves the flotation process and enhances the removal of pollutants. As seen in Figure (7), the maximum sludge amount and energy consumption were recorded at a voltage of 10.5V, with values of 68 mg/l and 6.9 kwh/m<sup>3</sup> respectively.



**Figure7:** The effect of voltage on the sludge amount and energy consumption (PH 7, 50 min, NaCl concentration of 0.5 g /L, Fe-anode Al-cathode, initial oil concentration EC1 and EC2=90mg/l, EC3=94, EC4=95mg/l, initial COD concentration EC1 and EC2=700mg/l, EC3=710, EC=730mg/l).

The findings indicated an association between sludge production and energy consumption in applied voltage. Faraday's law states that the formation of metal hydroxides and coagulants is directly proportional to the

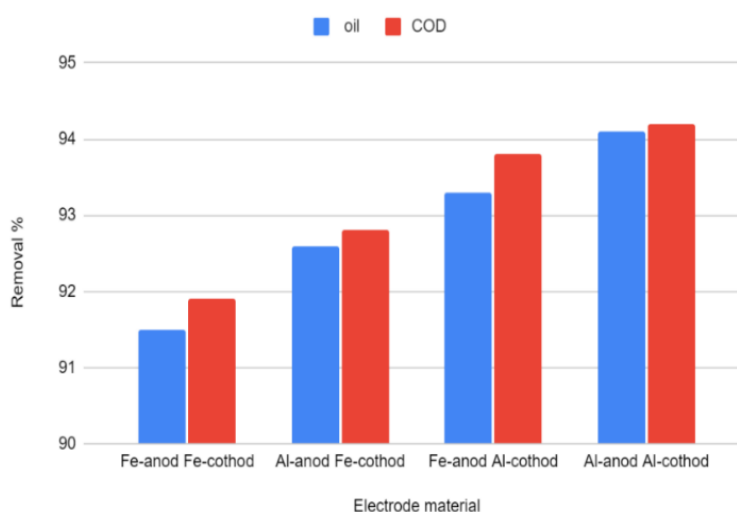
voltage, leading to an increase in sludge production as the voltage increases. The equation can represent this relationship [19].

$$E = \frac{V.I.t}{\text{Treated volume (l)}} \quad (6)$$

The energy consumption (E) also directly depends on the voltage, resulting in a rise in energy consumption as the voltage increases. Furthermore, the results concur with a study conducted by [19] that an optimal level of COD and oil removal result in a greater amount of sludge produced and increased energy consumption.

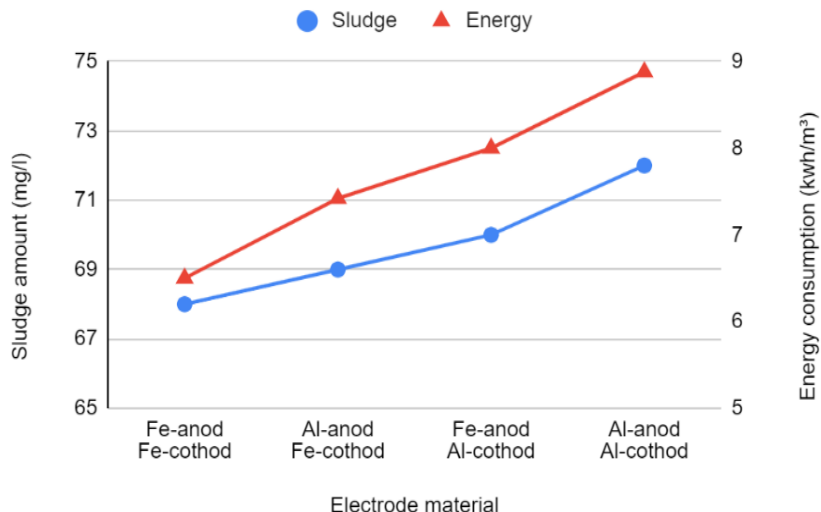
### 3.4 Effect of Electrode Material on electrochemical

The study evaluated the impact of different electrode materials on the removal of COD and oil from oily wastewater. Aluminium and iron electrodes were used to create an electrochemical cell, and the removal efficiency of COD and oil was evaluated the effect of electrode material on the removal efficiency of COD and oil is shown in Figure (8).



**Figure 8:** Effect of electrode material on the removal of COD and oil (PH 7, 50 min, 10.5 V, NaCl concentration 0.5mg/l, initial oil concentration EC1 and EC2=90mg/l, EC3=94, EC4=95mg/l, initial COD concentration EC1 and EC2=700mg/l, EC3=710, EC=730mg/l).

The results showed that aluminium electrodes as both anode and cathode lead to the highest removal efficiencies of oil and COD at 94.1% and 94.2%, respectively. As well as, the use of iron electrodes as sacrificial anodes showed initial discoloration, changing from green to yellow, due to the presence of  $Fe^{+2}$  and  $Fe^{+3}$  ions in the effluent. This makes iron electrodes an unfavourable choice compared to aluminium electrodes' clear and stable effluent. The higher conductivity of aluminium electrodes compared to iron electrodes leads to the formation of a stronger coagulant of aluminium in the media. These findings support the selection of aluminium electrodes over iron electrodes. The study also found that when aluminium electrodes were utilized as both anode and cathode, the highest amount of sludge produced was 72 mg/l, and the maximum energy consumption was recorded as 8.88 kWh/m<sup>3</sup>. However, compared to iron electrodes, the sludge formation and energy consumption by aluminium electrodes were higher. The effect of electrode material on the amount of sludge produced and consumption of energy is shown in Figure (9).

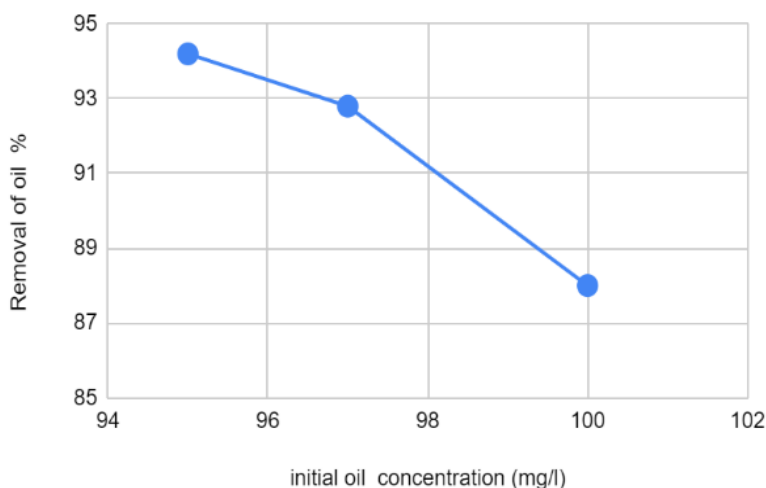


**Figure 9:** Effect of electrode material on the sludge amount and energy consumption (PH 7, 50 min, 10.5 V, NaCl concentration 0.5mg/l, initial oil concentration EC1 and EC2=90mg/l, EC3=94, EC4=95mg/l, initial COD concentration EC1 and EC2=700mg/l, EC3=710, EC=730mg/l).

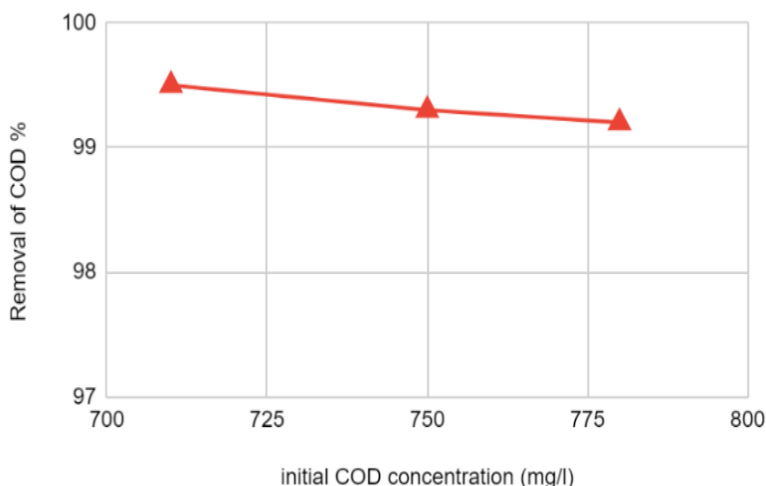
The sludge formed and consumption of energy by aluminium electrodes were more than the sludge formed and consumption of energy by iron electrodes. As a result, the conductivity and coagulant formation by aluminium electrode are greater than those by iron electrode, these results agreed with [22,24,26].

### 3.5 Effect of initial concentration on electrochemical

The relationship between the starting concentrations of oil COD and the efficiency of removing COD and oil is shown in Figures 10 and 11. The experiments were based on considering the initial concentration (Co).



**Figure 10:** Effect of initial oil concentration on the removal of oil (PH 7, 50 min, 10.5 V, NaCl concentration 0.5mg/l, AL-anode AL- cathode)



**Figure11:** Effect of initial COD concentration on the removal of COD (PH 7, 50 min, 10.5 V, NaCl concentration 0.5mg/l, AL-anode AL- cathode).

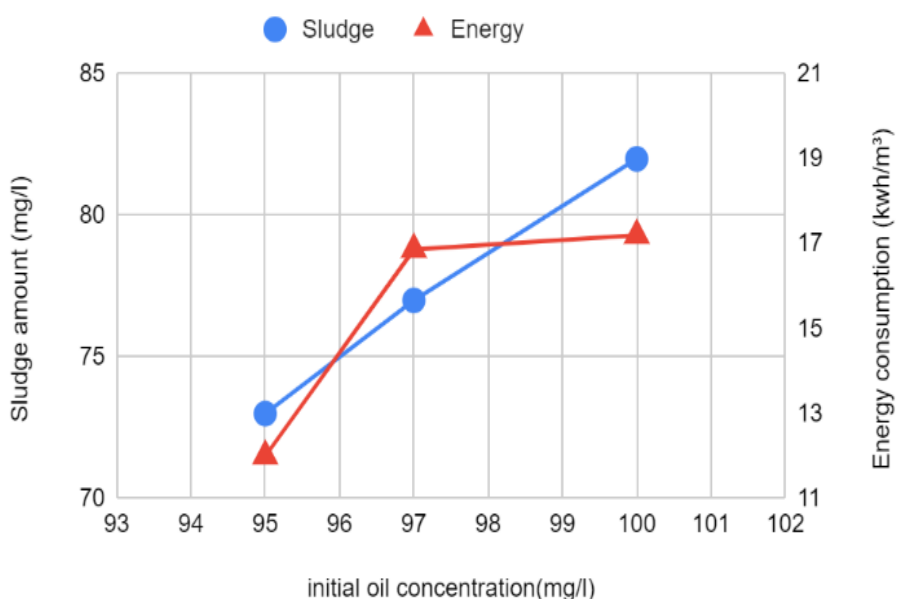
It was observed in the experiments that the removal efficiency for higher concentrations of COD and oil was lower compared to that of lower concentrations when optimized conditions were used. The reduced efficiency can be attributed to insufficient coagulant production, which leads to a longer processing time and a higher voltage requirement for the EC process to achieve the same removal efficiency as with lower concentrations. This conclusion is in line with previous research conducted by [19], who noted a decrease in the removal efficiency of COD and oil from oil in water emulsions with increasing concentrations of COD and oil. The results of the removal efficiency of COD and oil for the four experiments at their initial concentrations are presented in Table 1.

**Table 1:** The initial concentrations with removal efficiencies of COD, oil, sludge and energy.

Co oil	Co COD	PH	Time (min)	Voltage (V)	NaCl concentration (g/l)	Electrode material	C <sub>e</sub> oil(mg/l)	Removal of oil (%)	C <sub>e</sub> COD (mg/l)	Removal of COD (%)	Sludge (mg/L)	Energy (kwh/m <sup>3</sup> )
95	710	7	50	10.5	0.5	Al-anode Al-cathode	5.5	94.2	3	99.5	73	12
97	750	7	50	10.5	0.5	Al-anode Al-cathode	9	92.8	5	99.3	77	16.87
100	780	7	50	10.5	0.5	Al-anode Al-cathode	12	88	6	99.2	82	17.2

**Table2:** Results of efficiency remove of [19]

Co oil	Co COD	P H	Time (min)	Voltage (V)	NaCl concentration (g/l)	Electrode material	C <sub>e</sub> oil(mg/l)	Removal of oil (%)	C <sub>e</sub> COD (mg/l)	Removal of COD (%)	Sludge (mg/L)	Energy (kwh/m <sup>3</sup> )
3500	3500	7	40	10.5	0.5	Al-anode Al-cathode	5.5	99	3	99	2000	7
7000	7000	7	40	10.5	0.5	Al-anode Al-cathode	9	62	5	64	3400	14
11000	11000	7	40	10.5	0.5	Al-anode Al-cathode	12	50	6	57	4500	16

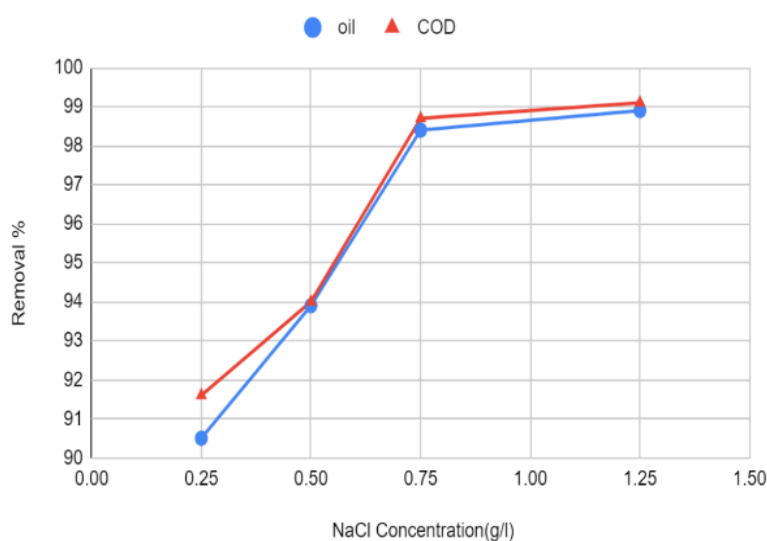


**Figure 12:** Effect of initial oil concentration on the sludge amount and energy consumption (PH 7, 50 min, 10.5 V, NaCl concentration 0.5mg/l, AL- anode AL- cathode).

The current study investigated electrochemical methods for removing oil and COD from oily wastewater. The researchers used aluminium and iron electrodes to establish an electrochemical cell and evaluated COD and oil removal efficiency. They considered multiple parameters, such as pH, time, voltage, NaCl concentration, and initial concentration, to determine the optimal conditions for removal. The study found that as the initial concentration increases, the current during the process also increases, leading to a rise in the formation of metal hydroxides, sludge production, and energy consumption. These findings align with the results of [19]. In conclusion, it was determined that sludge production and energy consumption are dependent on voltage, time, initial oil concentration, and supporting electrolyte concentration. A direct relationship was also revealed between the number of surges formed and the effectiveness of removed COD. Further monitoring of oil and lubricants is necessary to ensure the success of the Storm Water Pollution Prevention Plan (SWPPP), as stated by the EPA (2014). In addition, it was noted that EC, at its optimal situation, was not able to resolve oil and COD. However, removing nearly 99.5% of the influent concentration was possible from the above procedure, making it a suitable method for the preliminary treatment of this type of wastewater.

### 3.6 Effect of supporting electrolyte on electrochemical

The objective of the present study was to examine the effect of different NaCl concentrations on the performance of EC in removing pollutants from oil refinery wastewater. The results indicated that a NaCl concentration of 0.5 g/L resulted in the most effective removal of COD and oil, at 94.1% and 93.9%, respectively. The effect of supporting electrolyte on the removal efficiency of COD and oil is shown in Figure (13). NaCl concentration was set in the range from 0.25 to 1.25 g/L. the removal efficiency of COD and oil was in four Experiments when we used NaCl concentration 1.25g/l it was removal efficiency of COD and oil very high Hence, the experiments were performed at 0.5 g/L NaCl due to the negligible increase in removal.



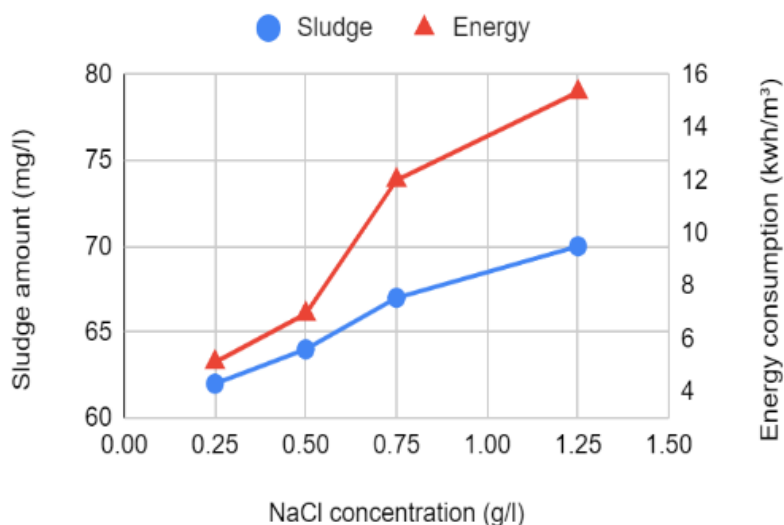
**Figure 13:** Effect of NaCl concentration on the removal of COD and oil (PH 7, 50 min, 10.5 V, Fe-anode Al-cathode, initial oil concentration EC1 and EC2=90mg/l, EC3=94, EC4=95mg/l, initial COD concentration EC1 and EC2=700mg/l, EC3=710, EC=730mg/l).

This finding was supported by the ability of NaCl to reduce the negative impact of other anions and improve the conductivity of the solution, which enhances the efficiency of EC in removing pollutants. The authors recommended maintaining a minimum chloride ion concentration of 20% to ensure optimal EC operation in water treatment. [26] stated that the optimal removal of pollutants was observed at a concentration of 0.5 g/L of NaCl. Without NaCl, the removal efficiency was found to be low as oil refinery wastewater lacks high electrical conductivity, which is necessary for EC. NaCl solution was chosen as the Electrolyte due to its benefits, such as reducing the negative effects of other anions like HCO and SO. The presence of the carbonate ion can result in the precipitation of ions such as Ca<sup>2+</sup> or Mg<sup>2+</sup>, which forms an insulating layer on the electrode surface, reducing the current efficiency and treatment conversion. Similarly, [27] explained that molecular chlorine is produced during the electrolysis of chloride salts. The reaction can be written as [19]:



The molecular chlorine produced can then undergo hydrolysis to form hypochlorous acid and hypochlorite ions, which have high oxidative potentials and play a significant role in pollutant removal. Research study conducted by

[26] supports the idea that increasing the concentration of the supporting electrolyte leads to improved removal efficiency Figure (14).



**Figure14:** Effect of NaCl concentration on the sludge amount and energy consumption Effect of NaCl concentration on the removal of COD and oil (PH 7, 50 min, 10.5 V, Fe-anode Al-cathode, initial oil concentration EC1 and EC2=90mg/l, EC3=94, EC4=95mg/l, initial COD concentration EC1 and EC2=700mg/l, EC3=710, EC=730mg/l).

This was observed in the correlation between the concentration of supporting electrolyte and sludge production and energy consumption in an electrochemical process. A concentration of 1.5 g/L of NaCl resulted in a maximum sludge amount of 70 mg/l and maximum energy consumption of 15.33 kwh/m<sup>3</sup>. The research findings were in line with a study conducted by [19] that revealed as the concentration of the supporting Electrolyte increased, so did the current and conductivity, leading to a corresponding increase in metal hydroxide formation, sludge production, and energy consumption.

## 4.CONCLUSIONS

The current study evaluated the efficacy of electrochemical (EC) treatment in removing chemical oxygen demand (COD) and oil from oily wastewater." The researchers analysed various "parameters such as pH, time, voltage, supporting Electrolyte, electrode material, and initial concentration to determine their impact on the removal efficiency. The results indicated that EC is an effective method for removing COD and oil from refinery wastewater," the study noted. The most favourable conditions for COD and oil removal were found to be a pH of 7, four aluminium electrodes with four iron electrodes arranged with a distance of 2 cm, a submerged depth of 12 cm, and initial concentrations of 95 mg/L and 710 mg/L for oil and COD, respectively.

1-The study found that pH significantly impacted COD and oil removal, with a pH of 7 providing optimal conditions.

2-The arrangement of aluminium and iron electrodes proved to be the most effective for reducing COD and oil.

3-An increase in voltage, time, and NaCl concentration led to improved removal efficiency, but also increased sludge production and energy consumption, the researchers explained. Without NaCl, the removal was almost non-existent because of the low conductivity of oily wastewater. However, higher primary concentrations decreased removal efficiency but increased sludge production and energy consumption.

4-The study confirmed that EC is a promising process for treating oily wastewater and the EC process's buffering effect allows for direct discharge without adjusting the pH, the researchers concluded. The highest removal efficiency was achieved at a pH of 7, 50 minutes, 10.5 V, a NaCl concentration of 0.5 g/L, aluminium electrodes,

and initial oil and COD concentrations of 95 mg/L and 710 mg/L, respectively. The removal efficiencies for oil and COD were 94.2% and 99.5%, respectively, with sludge production and energy consumption of 73 mg/L and 12 KWh/m<sup>3</sup>, respectively.

5-The energy cost was found to be an acceptable value of 0.3\$.

6-Additionally, the researchers developed two empirical models to predict removal efficiency for oil and COD, with coefficients of determination of 0.995 and 0.988, respectively.

7- The Mahalanobis distance and standard residuals for oil, COD, and sludge were within acceptable limits

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