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(Research Article)

Eliminate turbidity and oil from polluted water by using the electrocoagulation process

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Abstract

The study aims to treat polluted water before it is released into the environment or used in reinjected oil wells. The test runs were done by an electrocoagulation unit that was collected and introduced in the lab. The current was utilized as a part of the unit with various densities to test the turbidity-expelling effectiveness. The exploratory outcomes revealed that the grouping of oil was diminished to (10.7, 11.2, 11.7, 12.3) mg/l when distinctive current densities of (0.00253, 0.00633, 0.01266, 0.0253) A/cm2 were utilized separately. We conclude from this research that the best current in terms of stagnation removal is 0.0126 A/cm2 and the minimum distance between the electrodes, and in terms of oil removal, the highest removal at the current is 0.0253 A/cm2.

Keywords: Produced water; Polluted Water; Electrocoagulation; Oil content; Anode; Cathode

1 Introduction

The extraction of conventional oil and gas, as well as coal bed methane, is frequently accompanied by the extraction of large amounts of produced water [1].

This water is known for produced water (PW), and it's one of the single most significant waste streams in the oil and gas industry [2]. Generally, the ratio of oil to PW is 1:3 for most of the oil wells [3]. The chemical composition of PW is complex. It includes a mixture of various components such as dispersed oil, dissolved hydrocarbons, organic acids, phenols, and metals, as well as residues of chemical compounds added to the production line or separated [4]. There is a wide variation in this water's composition level due to geological formation, the lifetime of the reservoir, and the type of hydrocarbon produced [5].

Ezechi et al. [6] studied the removal of boron from the water produced by electrocoagulation. The removal efficiency of an iron electrode was 97.6% under optimal conditions. Gargouri et al. [7] used electrochemical technology to remove petroleum hydrocarbons from produced water using lead dioxide and boron-doped diamond electrodes. The results were satisfactory, but the energy consumption and process time made anodic oxidation useless for eliminating pollutants from produced water.

However, in recent years, electrocoagulation (EC) treatment has been widely used for the treatment of wastewater containing oil sludge, turbidity, or suspended solids [8]. Writing overviews demonstrated that EC has the capacity to expel turbidity and the vast majority of the water contaminants in slick wastewater and delivered water [9, 10]. Electrocoagulation (EC) is a confusing procedure that includes numerous concoctions and physical marvels that utilize

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conciliatory terminals, for example, Al, Fe, and others, to supply particles into the water [11]. Coagulants are created in situ during the EC procedure by electrically dissolving the consumable cathodes (Fe and Al). The metal particle era happens at the anode; hydrogen gas is discharged from the cathode [12]. Metal cations formed in the arrangement as a result of anode oxidation, with hydroxyl particles (OH) forming as a result of water forming an extremely charged coagulant. On account of the aluminum anode, the Al3+ reacts with H2O to shape Al(OH)3, and on account of the magnesium anode, the Mg2+ reacts with H2O to frame Mg(OH)2. This study aimed to treat produced water before it was released to surface water or reinjected into oil wells by electrocoagulation methods.

2 Material and methods

2.1 Characteristics of oilfield-produced water

Oilfield-created water utilized as a part of the present examination was compassionately given by Oil Innovative Work Center staff from the Center Oil Organization.

It has a pH of approximately 7, an EC of 144300 s/cm, turbidity of 120 NTU, oil content of 46.6 mg/l, TDS of 133477 mg/l, and TSS of 90 mg/l.

Monopole aluminum and iron terminals were utilized as a part of the electrocoagulation cell to frame coagulants to expel oil and turbidity from the created water. Trial work was directed at the research facilities of the Concoction Building Division of Innovation College in Baghdad. The cathodes utilized were made with business materials. The anode was a rectangular aluminum plate with a thickness of 1.72 mm, a height of 60 mm, and a length of 140 mm; these were punctured so as to build the contact surface territory, which expands the electron exchange. The cathode was developed with press work, giving a substantial response zone. For the preparatory investigation of the procedure factors (connected current, distance between the cathodes, and electrolysis time), the reactor is made of the material Perspex, with a limit of roughly 2.5 liters. As shown in Figure 1, the dimensions were 20 cm long, 14 cm wide, and 16 cm tall. Variables separated the terminals utilized as a part of this cell.

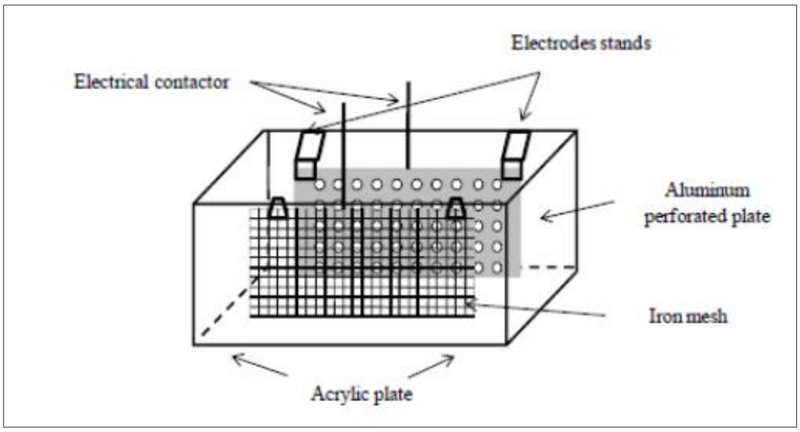

Figure 1 Electrocoagulation cell

In a parallel-plate cell, assurance of the current thickness's impact on the electrocoagulation response was completed. In these tests, 2 L of the delivered water was exchanged with the electrochemical cell with parallel plates shown in Figure 2. Once the water to be dealt with was exchanged (the attractive stirrer was at moderate speeds), the terminals were associated with the power supply, and the work circuit momentum (ran 0.2 A - 0.5 A - 1 A - 2 A) was set up. The underlying turbidity was resolved, and the framework was then permitted to respond, measuring turbidity at various time intervals. After trying different things with various streams, the separation between terminals was kept steady. Once the trial was finished, the method depicted above was rehashed, however, with an adjustment out there between the extended terminals (0.5 cm, 1 cm, 2 cm, 3 cm).

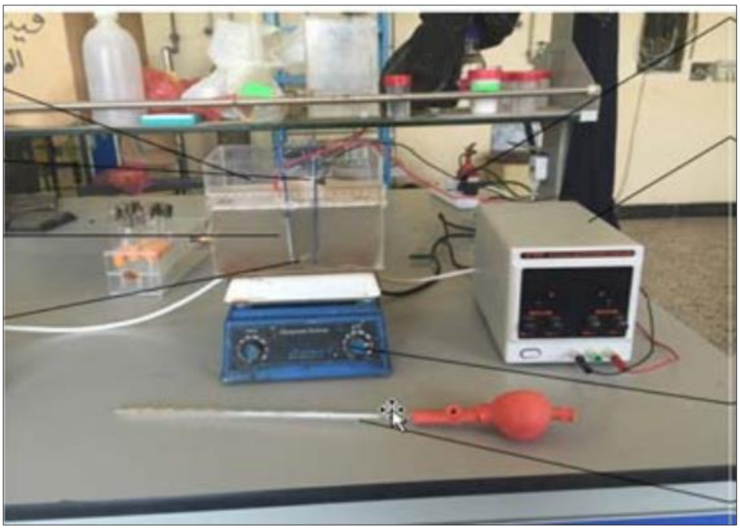

Figure 2 Photograph of an EC cell at the Chemical Engineering Lab of the University of Technology—Iraq in Baghdad

3 Results and discussion

3.1 The influence of current density on turbidity

The impact of current thickness on the turbidity expulsion efficiencies is delineated in Figures. 3–6. The expulsion capability grows in proportion to the connected current thickness. The evacuation efficiencies of turbidity were 91.6, 91.9, 92.3, and 85%, with lingering turbidity (10, 9.7, 9.2, and 18) of current densities, separately. It has been discovered that the best value is the place where the present thickness (0.01266 A/cm2) gives the best outcomes for evacuation effectiveness (92.3%). At higher current densities, the viability of current thickness on expanding expulsion effectiveness diminishes. The rate of anodic disintegration of aluminum is expanded at higher current densities, bringing about a more noteworthy measure of coagulant and precipitant generation. This way, this results in higher expulsion effectiveness of turbidity. Air pocket measure diminishes, while bubble era rate increments with current thickness, which brings about higher expulsion proficiency of turbidity by means of H2 buoyancy, notwithstanding the impact of coagulation, which concurs with this outcome [13].

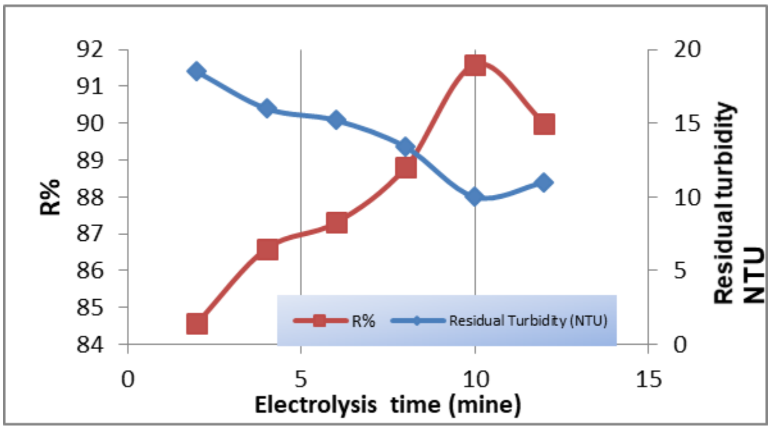

Figure 3 Effect of the current density (0.00253 A/cm2) on the turbidity

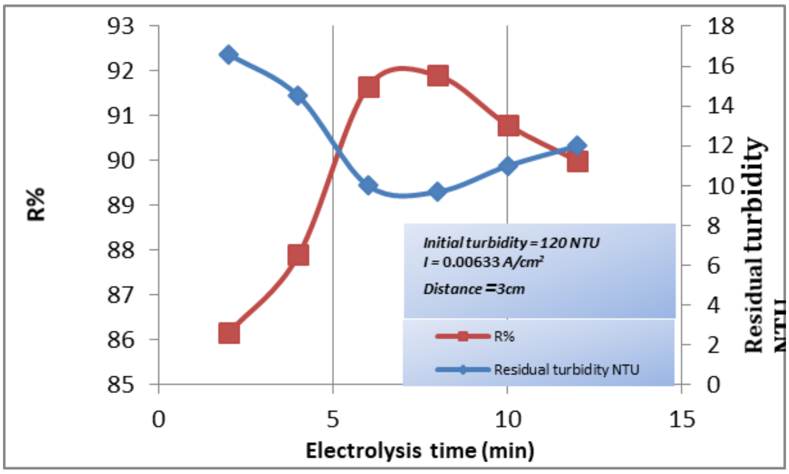

Figure 4 Effect of the current density (0.00633 A/cm^2) on the turbidity

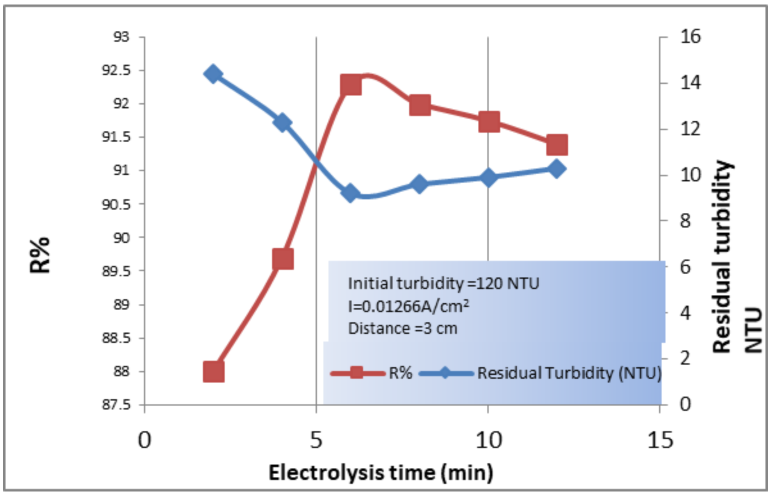

Figure 5 Effect of the current density (0.01266 A/cm2) on the turbidity

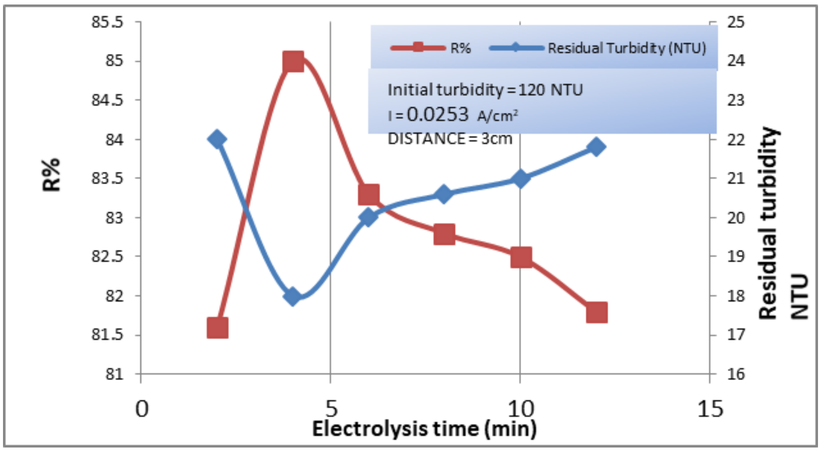

Figure 6 Effect of the current density (0.0253 A/cm2) on the turbidity

3.2 Effect of the distance between the electrodes on the turbidity

Four experiments were performed under a fixed operational condition (pH = 6.98, current density I = 0.01266 A/cm2, electrolysis time (2–12 minutes), and varying distances (0.5, 1, 2, and 3 cm) between electrodes. The results show in Figure 8 that the turbidity decreased slightly when the distance was increased from 0.5 to 1 cm (from 7.9 to 7.79 NTU), but the turbidity increased to 9 NTU when the distance between electrodes was 2 and 3 cm. Thus, the optimal distance was shown to be approximately 1 cm. This can be explained by the fact that decreased space between electrodes results in low resistance through the solution, which increases the rate of aluminum dissolution and Al+3 releases and consequently leads to more turbidity removal from the solution. On the other hand, decreasing the space could enhance the flotation process by limiting the generated bubbles in a narrow space, which results in higher removal efficiencies.

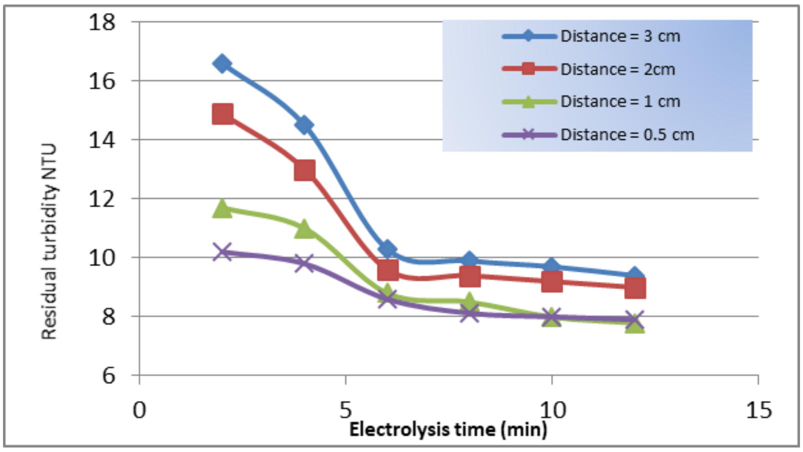

Figure 7 The effect of electrode distance on turbidity (t = 2-12 minutes, pH = 6.98, I = 0.01266 A/cm2)

3.3 The Influence of the Initial pH

Aluminum ions may be found in different forms and phases, depending on the pH and chemical characteristics of the solution. Aluminum ions released from electrodes are found in the form AI (H2O)6+3 at pH values less than 4, while at pH values 5 to 6, aluminum changes to the form AI(OH)3; pH values greater than 8.8 may cause the dissolution of aluminum as ions again.

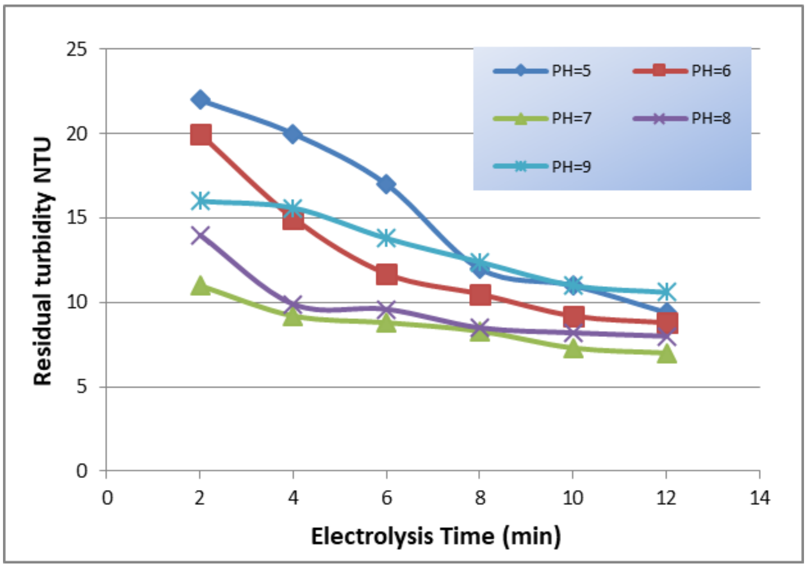

Figure 8 Effect of initial pH on the turbidity (t = 2–12 minutes, distance = 1 cm, *I* = 0.01266 A/cm2). 3 cm content distance and 46.6 mg/l initial oil content

Based on the effect of pH on the chemical form of aluminum, it is expected that electrocoagulation efficiency would be somewhat dependent on pH. Five experiments at initial pH values of 5, 6, 7, 8, and 9 were performed to investigate this effect. The results presented in Figure 8 show that the optimal residual turbidity is achieved at a pH value of 7. He also found that the formation of ferrous ions and their posterior oxidation to ferric ions cause the precipitation of Fe(OH)3. It is likely that this oxidation by oxygen becomes higher as the pH increases. The higher value of removal efficiency at neutral pH may be due to the formation of Fe(OH)3. This compound may be responsible for removing the major part of the impurities in textile wastewater [14].

3.4 Effect of the current density on the Oil Content Distance = 3 cm and initial oil content 46.6 mg/l

The results shown in Figure 9 depict the effect of the current density on the oil content removal. It was found that oil content removal increases with increasing current density. It was found that the best removal occurred when the current was 0.0253 A/cm2, and the oil content reached 10.7 mg/l after 10 min. The higher (0.0253 A/cm2) current density has no significant effect on oil removal efficiency. This is ascribed to the fact that at high current densities, the dissolution of the anode electrode increases according to Faraday's law, and the resulting metal hydroxides produce more sludge.

Increasing the current density enhances the generation of hydrogen and oxygen gases at the electrode surfaces. This leads to an increase in the number of gas bubbles inside the cell; consequently, the attachment step between gas bubbles and oil drops is enhanced, and more oil drops are carried up by gas bubbles. However, increasing the current density above the optimum value greatly increases the gas bubbles generated. There is then a greater possibility that bubbles will coalesce instead of attaching to oil drops [15].

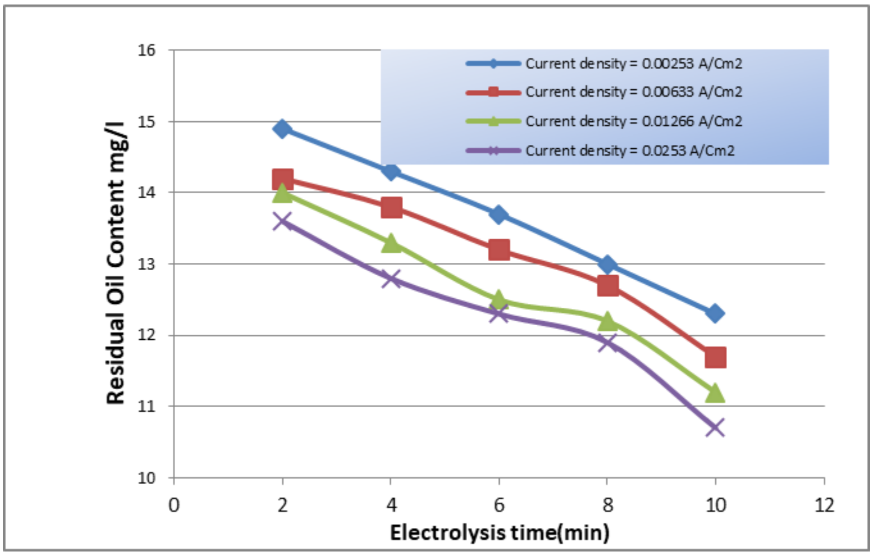

Figure 9 Effect of current density on the oil content Distance = 3 cm, initial oil content = 46.6 mg/l (pH = 6.98)

3.5 Effect of the distance between the electrodes on the oil content

The results shown in Figure 10 shows that the oil content decreased slightly from 0.5 to 10.2 mg/l. Thus, the best distance was shown to be approximately 0.5 cm. The inter-electrode distance is an important variable in optimizing electrolysis systems' operating costs. Researchers report that when the conductivity of the effluent is high, a larger spacing between the electrodes is possible. On the other hand, when conductivity is low, as in the case of this work, the spacing should be smaller [16].

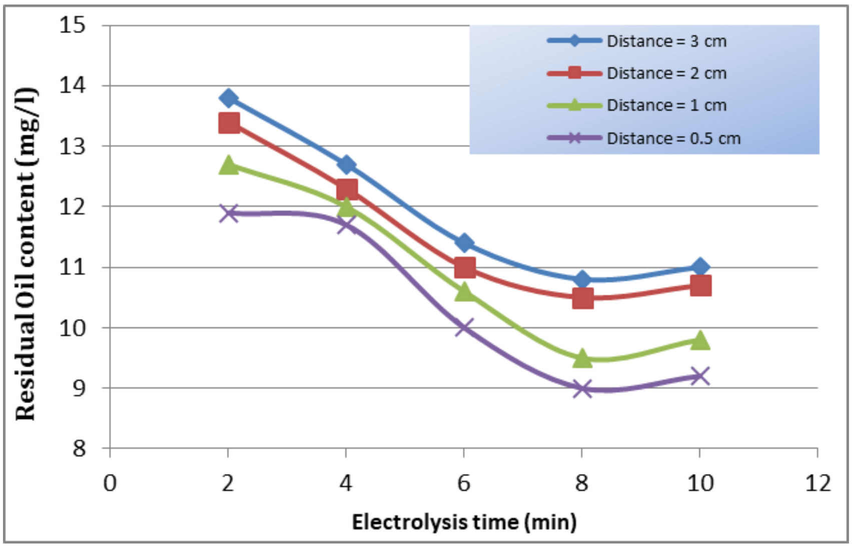

Figure 10 Effect of the distance between the electrodes on the oil content at (I = 0.0253 A/cm2) (t = 2–10 min)

3.6 Comparisons between Experimental and Theoretical Sacrificial Aluminum Anode Consumption

A comparison between experimental and theoretical sacrificial aluminum anode consumption has been achieved by calculating the theoretical Al loss from the anode using Faraday's equation and comparing the results with those obtained experimentally [17].

$$w = \frac{itM}{Nf}, \qquad \text{Faraday's law}$$

N = 3 is the number of electrons relating to aluminum oxidation, M is the atomic weight (mg/mol), f is Faraday's constant (96 500 C/mol), i = current (A), t = time (sec), and the second esteem is resolved from the aluminum anode utilization by measuring the terminal prior to and then after the test. The results shown in Figure 11 and Table (1) show that the amount of Al produced by an anode consistently exceeded the amount predicted by Faraday's condition. The explanation behind this might be because of the way that Faraday's law does not consider the effect of salt in PW on metal disintegration. In contrast, salt strongly affects the disintegration rate by expanding the arrangement's conductivity.

Table 1 Experimental and Theoretical Sacrificial Aluminum Anode Consumption

Current density A	Al consumption based on Faraday's law (gm Al)	Al consumption (gm) experimental
0.2	0.0111	0.01566
0.5	0.0279	0.039
1	0.0559	0.071
2	0.1119	0.17948

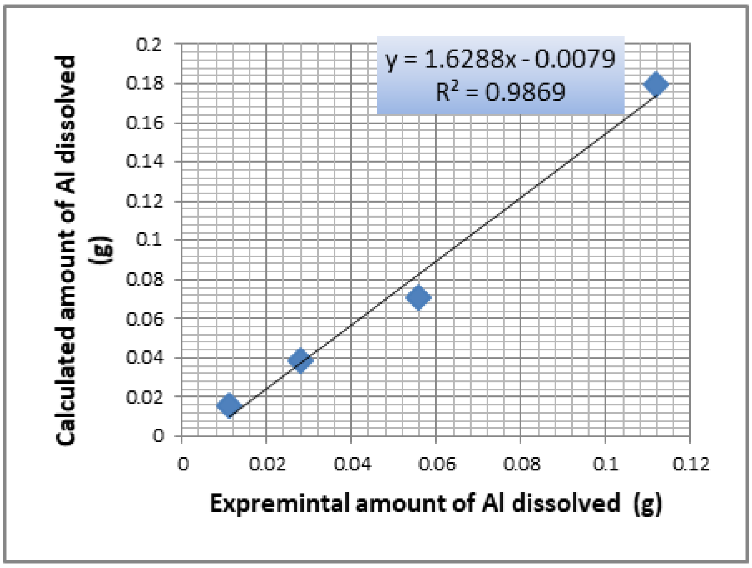

Figure 11 Measured vs. the calculated amount of Al released from the anode

4 Conclusion

In the electrocoagulation method, the use of different current densities has found that the best current density is (0.01266 A/cm2) to reduce turbidity removal efficiency and residual turbidity up to (92.3%) and (9.2 NTU), respectively, at the constant distance between electrodes of 3 cm. Experiments carried out using different distances between electrodes showed that the best distance to reduce removal turbidity up to 7.79 NTU is 1 cm. The experimental results observed the effect of initial pH on turbidity removal efficiency with electrocoagulation treatment. The best PH value for turbidity removal efficiency (94.1%) is 7. In the electrocoagulation methods, the oil content could decrease when different distances between electrodes are at constant currents (0.0253 A/cm2).

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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