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Treatment of Fatty Acid Industry Wastewater using Electrocoagulation Method

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ABSTRACT

The treatment of fatty acid industrial wastewater is a significant challenge due to the high content of organic and inorganic materials that can pollute the environment. One of the effective methods to overcome this problem is electrocoagulation. The purpose of this study was to analyze the effect of contact time and distance between electrodes in reducing the parameters of fatty acid industrial wastewater. In this study, the electrodes used were Aluminum (Al) as the Anode and Iron (Fe) as the Cathode. The electrocoagulation process was carried out using a voltage of 5 volts with a time variation of 75 minutes, 90 minutes, and 105 minutes and a distance between electrodes of 1 cm, 2 cm, and 3 cm. From this study, it was found that the contact time at 105 minutes and the distance between electrodes at 3 cm could raise the pH to 7.3, reduce the COD concentration to 70 mg/L, and reduce the TSS concentration to 2 mg/L contained in the fatty acid industrial wastewater. However, TSS levels often change due to particles that have not completely settled, which can result in sludge contamination when taking TSS test samples.

INTRODUCTION

Liquid effluents, originating from various human activities such as households and industries, contribute significantly to environmental pollution (Yurnalisdel, 2022). The discharge of industrial effluents into rivers has indeed significantly degraded water quality, severely impacting aquatic ecosystems. Studies from different regions highlight severe contamination of rivers with heavy metals, nutrients, and pollutants beyond safety limits, leading to low dissolved oxygen levels, altered macroinvertebrate communities, and eutrophication (Jain, 2023). The treatment of wastewater from oleochemical plants, which contains high levels of organic matter, can be effectively addressed through advanced oxidation processes such as UV-based methods with hydrogen peroxide. Studies have shown that UV-based advanced oxidation processes, such as UV/Cl2, UV/NH2Cl, UV/ClO2, and UV/peracetic acid, are efficient in degrading organic contaminants in water (Sun *et al.*, 2023). Moreover, the combination of UV with persulfate has been shown to efficiently degrade organic pollutants, although complete mineralization may not always be achieved (Zhu *et al.*, 2024). Furthermore, the application of UV/O3 and UV/acetylacetone processes has shown promising results in treating olive mill wastewater, significantly reducing COD, BOD5, phenols, TSS, oil, and grease levels (Radmehr *et al.*, 2022). This advanced oxidation technology offers an eco-friendly solution to reduce the negative impact of organic pollutants on the environment, although there are some challenges related to maintenance costs and continuous production (Lu *et al.*, 2022).

Electrocoagulation (EC) is a highly effective method for treating industrial wastewater, as discussed in several studies (Akhter *et al.*, 2021). This technique involves the generation of coagulant species through the electrolytic dissolution of sacrificial anode materials triggered by an electric current, which leads to the destabilization of colloidal pollutants. EC has been shown to efficiently remove various pollutants such as suspended solids, pigments, nutrients, heavy metals, pesticides, and even harmful microorganisms from wastewater. The process is environmentally friendly, cost-effective, and can achieve pollutant removal rates of up to 99.5%. While the main focus is on pollutant removal, the process does not involve the release of negative ions to generate active coagulants or positive ions to generate hydrogen gas through electrolysis. Instead, it relies on in situ coagulant generation through oxidation of the sacrificial anode, making it a sustainable and efficient solution for industrial wastewater treatment (Benekos *et al.*, 2022).

Electrocoagulation (EC) is indeed a versatile method for treating various industrial effluents, showing effectiveness in reducing several effluent parameters such as chemical oxygen demand (COD), total suspended solids (TSS), turbidity, surfactants, and organic grease (OG) (Guerreiro Crizel *et al.*, 2024). Studies have shown high removal efficiencies ranging from 60.0% to 99.0% for COD, color, chromium, turbidity, MBAS, and OG, emphasizing the wide application of EC in various industries such as tannery, pulp and paper, textile, beverage, and food industries (Guerreiro Crizel *et al.*, 2024). Furthermore, EC has been successfully applied in treating palm oil mill effluent (POME), reaching significant removal percentages for BOD, COD, and TSS, with optimal conditions identified for current density and reaction time (Ulfa *et al.*, 2024). The efficacy of this technique extends to the management of contaminants in drilling waste from oil rigs, with removal efficiencies of 72% for COD, 79% for TOC, 67% for TSS, and 63% for turbidity under optimized conditions (Ale-Tayeb *et al.*, 2023). Overall,

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EC is emerging as a promising method to address diverse industrial effluents and improve wastewater treatment processes. From the above problems, especially for wastewater originating from the oleochemical industry, in this case the Fatty Acid Industry, it is necessary to carry out alternative handling in processing the wastewater. for this reason, this study aims to determine the process of treating industrial fatty acid wastewater by utilizing the ectrocoagulation technique by varying the contact time and electrode distance in reducing the parameters of industrial fatty acid wastewater.

LITERATURE REVIEW

Electrocoagulation involves the use of two electrode electrodes placed in a container containing water that needs to be purified or treated. The two electrodes are then supplied with direct current (DC) to produce an electrochemical reaction that allows cations to move to the cathode and anions to move to the anode, thus forming a flocculant that can capture contaminants and particles in the raw water. In electrochemistry, Al3+ ions will be removed from the anode and form Al(OH)3 precipitates to capture contaminants and waste particles (Fauzi, 2019). According to (Muliyana, 2019), there are three main steps in the electrocoagulation mechanism: (a) oxidation at the anode produces an active coagulant, (b) the coagulant destabilizes colloidal particles and separates the emulsion in solution, and (c) the destabilized colloidal particles coalesce into flocs.

Basically, electrocoagulation is a developed form of electrolysis that utilizes electrodes to control how the electrocoagulation unit works. The electrolysis process involves the separation of electrolyte substances with the use of direct electric current and both types of electrodes. In this situation, the electrodes used are the cathode and the anode. In the process, the cathode performs the role of a negative terminal. In the cathode, a reduction process occurs where positive ions are drawn and receive electrons so that the oxidation value is reduced (Fauzi, 2019). Electrocoagulation is influenced by various factors that affect its efficiency in pollutant removal. The main variables that affect the process include electric current, electrode type, electrode configuration, initial pH, electrode spacing, NaCl concentration, initial concentration of pollutants, operating temperature, and electrolysis time (Abed AL-Rubaye *et al.*, 2024). In addition, electrocoagulation performance is affected by factors such as electrode material, solution pH, and applied current (Ramya Sankar, 2023). Studies have shown that the success of the electrocoagulation process depends on optimization parameters such as current density, electrode type (aluminum or iron), and minimum electrolysis time (Salim *et al.*, 2022). Furthermore, the removal efficiency of pollutants such as lead in the electrocoagulation process is affected by parameters such as applied voltage, rotational anode speed, and Hydraulic Retention Time (HRT) (Salim *et al.*, 2022). Understanding and controlling these factors is critical to maximizing the effectiveness of electrocoagulation in the water treatment process. pH plays an important role in the electrocoagulation process, impacting the efficiency of pollutant removal in various wastewater treatment applications. Studies have shown that the pH level significantly affects the degradation of dye effluent, with optimal results achieved at pH 10 for both electrocoagulation and photocatalysis processes, leading to a reduction in dye effluent of up to 71.6% (Kustiningsih *et al.*, 2022). In addition, a study on the removal of Escherichia coli using electrocoagulation revealed that the initial pH of the solution affected the effectiveness of bacterial removal, with the best removal rates observed at slightly acidic and alkaline pH levels (Ndjomgoue-Yossa *et al.*, 2022). Furthermore, an investigation into pulp and paper mill wastewater treatment showed that maintaining a constant pH of 6.45 resulted in the highest removal efficiency for pollutants such as turbidity and color, improving overall process performance (Camcıoğlu & Özyurt, 2024). Fluctuations in pH during electrocoagulation were found to be influenced by factors such as the presence of carbonate and ion exchange, highlighting the complexity of pH dynamics during the process (Weiss *et al.*, 2021). The efficiency of the electrocoagulation process is significantly affected by the pH level. Studies have shown that pH plays an important role in removing pollutants such as dyes, grease, oil, turbidity, color, and microorganisms from wastewater through electrocoagulation (Weiss *et al.*, 2021). For example, in removing oil and grease, higher efficiencies are achieved at lower pH levels, with aluminum electrodes showing better performance and being more sensitive to pH variations compared to iron electrodes (Bi-Ngül Reçber *et al.*, 2022). In addition, the pH of treated water can be affected by factors such as the presence of carbonate ions, leading to changes in coagulation efficiency (Weiss *et al.*, 2021). The optimum electrocoagulation efficiency for dye removal has been reported at pH 10, indicating The importance of pH control in achieving effective pollutant removal through the electrocoagulation process (Kustiningsih *et al.*, 2022).

Contact time plays an important role in determining the efficiency of the electrocoagulation process. Several studies have shown that prolonged contact time during electrocoagulation can lead to increased reduction of heavy metal concentrations, such as iron (Fe) and manganese (Mn), due to increased coagulant formation (Alam *et al.*, 2024). In addition, studies have shown that varying contact time significantly impacts the removal efficiency of micromanics from wastewater, with longer duration resulting in higher removal rates (Fadhila *et al.*, 2024). Furthermore, the duration of contact time has been found to influence the reduction of turbidity and chemical oxygen demand (COD) in electrocoagulation combined with zeolite processes, with optimal results achieved at specific time intervals. Moreover, in domestic wastewater treatment, it has been observed that different contact times affect the removal efficiency of contaminants, such as COD and Total Suspended Solids (TSS), emphasizing the importance of optimizing contact time for effective pollutant removal (Oktiawan *et al.*, 2021).

Electrode spacing plays an important role in the efficiency of the electrocoagulation process. Studies have shown that varying the distance between electrodes can significantly affect the removal of contaminants from water. Studies have shown that shorter inter-electrode distances lead to increased liquid velocity, promoting floc formation and improving pollutant removal (Martínez-Villafañe *et al.*, 2022a). In addition, the optimal electrode spacing for reducing lead in water was found to be 20 cm, resulting in the best lead reduction compared to other spacings tested (Winarko *et al.*, 2022). Furthermore, the removal efficiency of reactive red 120 dye decreased as the electrode gap increased, suggesting that a smaller gap between electrodes is more effective in dye removal (Abdulhadi *et al.*, 2019). These findings highlight the importance of electrode spacing in optimizing the electrocoagulation process for efficient pollutant removal from water.

Electrode spacing plays an important role in determining the efficiency of the electrocoagulation process. Studies have shown that varying electrode spacing impacts the reduction of contaminants in water treatment. Studies have shown that optimal reduction of heavy metals such as iron and manganese occurs at different electrode spacings, emphasizing the important role of spacing in electrocoagulation efficiency (Alam *et al.*, 2024). In addition, experiments focusing on lead removal revealed that the best reduction occurred at an electrode spacing of 20 cm, demonstrating the influence of spacing on contaminant reduction (Alam *et al.*, 2024). Furthermore, galvanic wastewater treatment investigations highlighted that metal ion removal efficiency increases with electrode spacing, with an optimal spacing of 3 cm for effective pollutant removal (Konduru *et al.*, 2023). These findings underscore the importance of electrode spacing in improving the overall effectiveness of the electrocoagulation process in wastewater treatment applications.

MATERIALS AND METHODS

Tools and Materials used: DC power suppy, Aluminum and Iron electrodes measuring 30cmx20cmx20cm, fatty acid wastewater.

Research Procedure:

Prepare an electrocoagulation unit with a size of 30 cm x 20 cm x 20 cm, a sample of fatty acid industrial liquid waste prepared where the fatty acid industrial liquid waste is analyzed first before being processed into the electrocoagulation unit to determine the characteristics of liquid waste such as pH, chemical oxygen demand, total suspended solids, and oil and grease If the characteristics of the fatty acid industrial liquid waste sample before processing have been obtained, then enter the fatty acid industrial liquid waste sample into the electrocoagulation reactor as much as 5 liters. Variations in the distance between aluminum electrodes and iron electrodes that are connected are 1 cm, 2 cm, and 3 cm. Aluminum electrodes and iron electrodes are connected using cables connected to an electrical power source. The power supply is turned on at a voltage of 5 V, a current of 1 A, and a variation time of 75, 90, and 105 minutes. Wastewater samples that have been treated in the electrocoagulation reactor are taken to analyze pH, COD, TSS in each treatment.

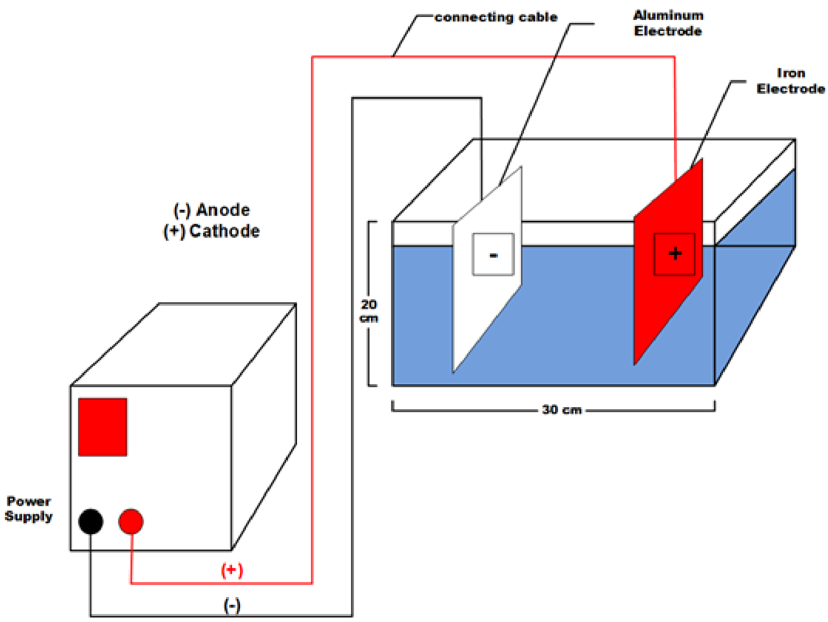

Figure 1: Electrocoagulation reactor

RESULTS AND DISCUSSION

In this study using fatty acid industrial wastewater, the following can be seen in Table 1.

pH is commonly referred to as the degree of acidity or basicity in a solution. Generally, the acidity level in wastewater is 6-9. Based on Table 1, the measurement result of the initial pH value is 5. The results of the research with electrocoagulation treatment obtained a

Table 1: Characteristics of Fatty Acid Industrial Liquid Waste Before Processing to the Electrocoagulation Unit

Parameter	Test Results
pH 5.3	pH 5.3
COD 137	COD 137
TSS 6	TSS 6
Oil and Fat <1.00	<1.00

change in pH value which is increasing so that it has made the pH value meet the applicable quality standards based on PERMENLHRI No. 5 of 2014, with a pH value range of 6 - 9. Changes in pH value in the electrocoagulation process are very significant, because water can undergo electrolysis to form hydrogen gas (H2) and hydroxide ions (OH-). If the longer the contact time, the faster the formation of hydroxide ions which can cause the pH value to rise (Andili & Agung, 2021). The graph of the test results of changes in pH value by the effect of contact time and distance between electrodes can be seen in Figure 2.

Measurement of COD value is carried out to determine the amount of organic content contained in wastewater. COD (Chemical Oxygen Demand) is the amount of oxygen content needed to chemically oxidize organic matter. Based on Table 1, the measurement result of the initial COD value is 137 mg/L. In the electrocoagulation process, the decrease in COD value in wastewater occurs because organic pollutants are destabilized by the influence of coagulants and electric fields (Masthura *et al.*, 2022). This destabilization causes a break in the linkages between the organic matter molecules, allowing them to bind with the coagulant floc and then settle at the bottom of the electrocoagulation basin (Munawarah, 2023). The graph of COD value test results by the effect of contact time and distance between electrodes can be seen in Figure 3.

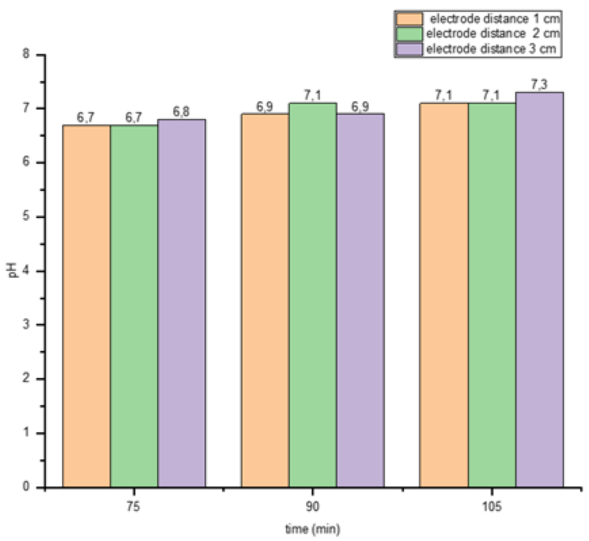

Figure 2: Effect of contact time and distance between electrodes on changes in pH value in wastewater.

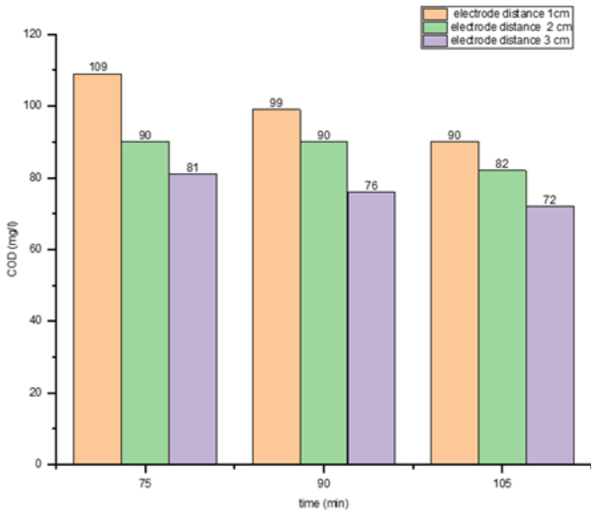

Figure 3: Effect of contact time (minutes) and distance between electrodes (cm) on changes in COD values in wastewater effluent

TSS (Total Suspended Solid) is the amount of solid particles suspended in a solution. TSS can be interpreted as the concentration of solid materials in the waste water. Based on Table 1, the measurement results of the initial value of TSS fatty acid liquid waste is 6 mg/L. Changes in the results of the research carried out through electrocoagulation there is an increase in TSS fluctuating as shown in Figure 4. because the particles float to the top of the surface of the results. The longer the contact time, the particles formed will grow larger and will eventually settle to the bottom of the electrocoagulation basin. The increase in total solid suspension (TSS) during the electrocoagulation process can be attributed to the formation of coagulants that trap organic matter, leading to an increase in particle size until a size sufficient for settling is reached (Solis-Marcial *et al.*, 2023).

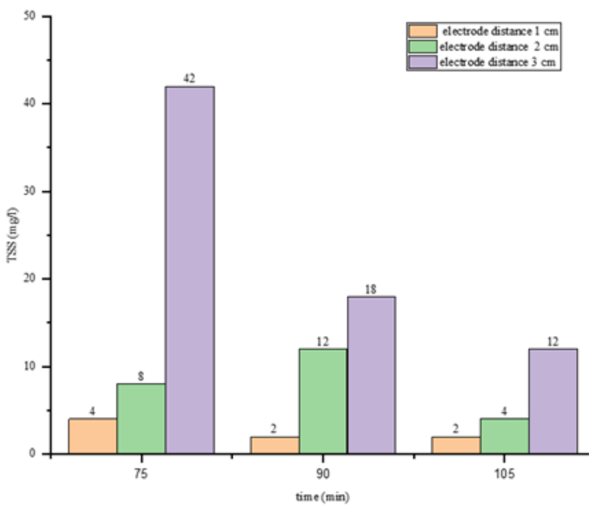

Figure 4: Effect of contact time and distance between electrodes on changes in TSS values in wastewater effluent

Some things that can affect the electrocoagulation process are the length of contact time, the amount of voltage, and the distance between electrodes. The longer the contact duration in the electrocoagulation process, the greater the amount of Al3+ produced (Apriyanti *et al.*, 2023). This causes the formation of more Al(OH)3 which plays a role in the absorption of waste contaminants. Moreover, the size of the distance between the electrodes will affect the level of electrolyte resistance, the greater the distance between the electrodes will produce greater resistance, causing the electric current to flow lower (Han *et al.*, 2021). The difference in distance between the electrodes will affect the rate of electron transfer between the anode and cathode. The greater the distance between the electrodes, the higher the resistance of the flowing current. When the distance between the electrodes is too large, the interaction between molecules is weakened. Conversely, if the distance is too close, the amount of coagulant will increase and cause disruption to the system due to the too-close electrode relationship (Martínez-Villafañe *et al.*, 2022b).

CONCLUSIONS

In this study using the electrocoagulation method is one of the wastewater treatment methods that involves the use of two Al and Fe electrodes that are supplied with direct current (DC). Contact time and distance between electrodes to pollutants can cause changes in the results of tests carried out such as pH, COD, and TSS. The contact time is 105 minutes and the distance between electrodes is 3 cm which can increase the pH to 7.3, reduce the COD concentration to 70 mg/L, and reduce the TSS concentration to 2 mg/L contained in fatty acid industrial wastewater.

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