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Effect of Different Electrodes and Spacing Gap in Treating Suspended Particles of UMK Lake using Electrocoagulation Process

Wan Muhammad Nazrul Wan Ibrahim[1], Nadiah Ameram[1] and Siti Roshayu Hassan[1,2,*]

[1]*Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan, Jeli Campus, 17600, Jeli, Kelantan, Malaysia*
[2]*Bioproduct and Bioprocessing Technology Research Group, Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia*

**Corresponding author: roshayu.h@umk.edu.my*

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ABSTRACT

Water quality is crucial for ecological balance, making the removal of suspended solids (SS) essential. This study examined the efficiency of electrocoagulation (EC) in reducing SS from UMK Lake. Various parameters, including current density, electrode material, pH, and treatment time, were analysed to assess removal efficiency. Laboratory experiments using aluminium electrodes were conducted, treating water samples under different conditions. Removal efficiency was determined by comparing turbidity and total suspension concentration before and after treatment. Results showed that electrocoagulation effectively removed SS from UMK Lake, with efficiencies ranging from 60% to 90%. The findings highlight electrocoagulation as a promising technology for improving water quality in natural bodies. Additionally, this study provides valuable insights into factors influencing SS removal efficiency in EC processes. The results contribute to optimising treatment protocols for real-world applications.

Keywords: Electrocoagulation; wastewater; electrode

1. Introduction

1.1 Electrocoagulation in Suspended Solids (SS) Removal

Electrocoagulation is an advanced process that leverages both chemical and physical mechanisms to eliminate contaminants from wastewater. When reactive electrodes such as iron or aluminium are employed, metal ions are generated in situ, facilitating the removal of suspended particles. The procedure unfolds in three primary stages: the production of coagulants via metal ion dissolution from the anode, the destabilisation of particulate or colloidal suspensions, and the aggregation of destabilised particles into flocs [1].

In iron electrodes, electrolytic oxidation releases ferrous ions (Fe^{2+}) into the solution. Depending on the pH, these ions undergo hydrolysis, forming monomeric and polymeric hydroxide complexes. The highly charged hydroxides destabilise negatively charged colloidal particles, prompting their aggregation into flocs. Furthermore, when the iron concentration surpasses the solubility of the metal hydroxide, amorphous precipitates initiate sweep-floc coagulation [2].

This study explores electrocoagulation's potential for eliminating suspended particles, turbidity, and particulate BOD from municipal wastewater. The influence of the current application and iron production on removal efficiency is assessed. Electrodes are arranged in pairs, serving as anode and cathode sheets. Through electrochemical principles, oxidation at the cathode reduces water content, enhancing wastewater treatment. Metal released upon cathode interaction with wastewater generates hydroxide complexes that neutralise particles, forming agglomerates that are removable via filtration. These clusters settle at the tank's bottom or float atop through hydrogen bubbles generated at the anode in electrocoagulation-flotation setups, where skim removal is applied.

Several operational parameters affect reactor efficacy, including wastewater type, pH, current density, electrode material and configuration, electrode count and size, and ion arrangement. These variables influence kinetics, removal efficiency, and treatment duration.

1.2 Electrocoagulation Efficiencies in Suspended Solids (SS) Removal

Electrocoagulation is an electrochemical process that employs an electric current to destabilise and aggregate suspended particles and colloidal matter, facilitating their removal from water or wastewater. Several factors influence its efficiency, including the selection of appropriate electrode materials, which play a crucial role in enhancing the process. Iron, aluminium, and graphite electrodes are commonly used, with their effectiveness depending on surface area, roughness, and chemical reactivity. Additionally, the configuration and arrangement of electrodes affect efficiency, as optimal spacing ensures uniform current distribution and maximises the surface area for coagulation. Another critical factor is current density, expressed in A/m^2, which impacts metal dissolution rates and the production of coagulant species. While higher current densities improve coagulation speed, excessive levels may cause electrode passivation, reducing effectiveness. The pH of the water or wastewater undergoing electrocoagulation also significantly affects the process, with slightly acidic or alkaline conditions optimising coagulation and flocculation. Water chemistry, including ion composition and organic matter presence, further influences efficiency, making it necessary to adjust coagulant dosage or pH for improved treatment. By optimising these parameters, electrocoagulation becomes more effective in removing suspended solids, leading to enhanced water and wastewater purification.

Optimising these parameters enhances electrocoagulation efficiency, ensuring effective removal of suspended solids and improved wastewater treatment outcomes. Throughout electrocoagulation, current density remains a pivotal factor, directly influencing reaction rates and removal efficiencies for BOD, SS, and COD. For optimal functionality, key parameters include a pH range of 3 to 7.5, an electric current between 0.03 and 0.09 A, an electrolyte concentration from 1 to 3 g/L, electrode spacing between 1 to 2 cm, and electrolysis duration ranging from 20 to 60 minutes [3].

Arslan et al. [4] investigated factors influencing electrocoagulation during malachite green dye removal from synthetic wastewater. Published in Environmental Science and Technology, their study examined dye concentration, electrolyte dosage, mixing speed, current density, electrolysis duration, pH levels, and electrode spacing. Based on prior findings, electrolysis time and electrode distance were controlled as primary parameters in this research.

2. Materials and Methods

2.1 Raw Materials Preparation

10 L of untreated water are collected from UMK Lake. In-situ analysis using a YSI multiparameter was used to determine the following water quality parameters: temperature, TDS, pH, DO, and salinity. These values are related to the water quality in the UMK lake.

2.2 Electrocoagulation Set Up

A DC power supply is required for the electrocoagulation setup to supply electricity to the electrodes during the electrocoagulation process. The set-up for batch electrocoagulation is as shown in Fig. 1. The next step is to pour 500 ml of UMK lake water into the used container. The water must have characteristics such as pH, colour, and temperature. The use of electrodes varies according to size to establish the level of efficacy of the electrode in the electrocoagulation process. After the material has been prepared, the electrocoagulation process is started by turning on the DC power. Due to the passage of electricity from DC power to electrodes that absorb suspended solids when the electrocoagulation process is carried out, the electrocoagulation process is capable of eliminating suspended solids from wastewater. The electrocoagulation process is conducted using various electrode materials, including aluminium. Mild steel and stainless steel, with electrode spacing set at 2, 4 and 6 cm. To enhance efficiency, each setup is replicated three times.

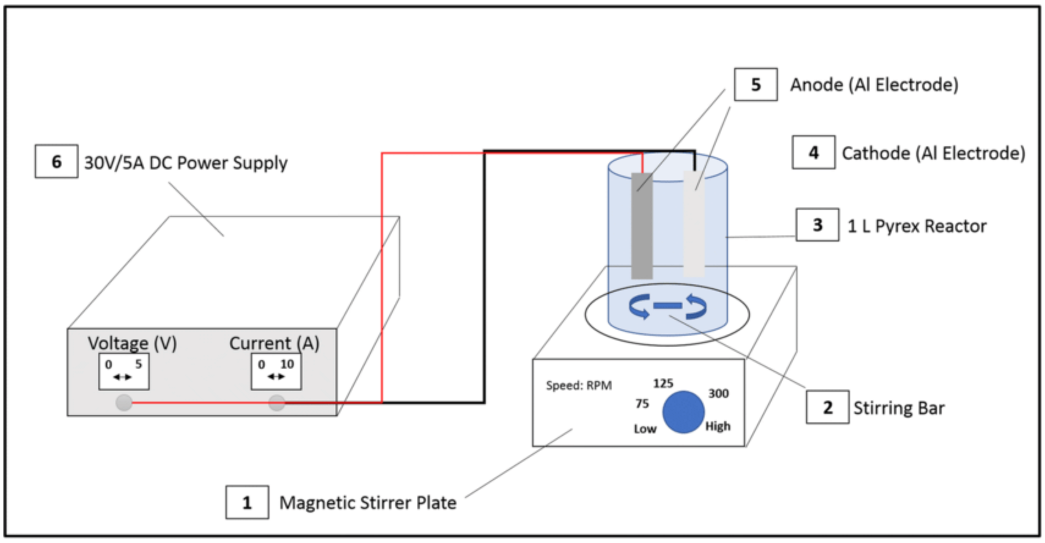


Fig 1: Electrocoagulation Set Up

3. Results and Discussion

3.1 Physicochemical characteristics of wastewater

Table 1: Physico-chemical characteristics of UMK lake

Parameter	
Temperature (°C)	26.1
TDS (mg/L)	147.55
DO (DO mg/L)	8.33
Salinity (sal)	0.11
pH	6.76
Turbidity	56.9

The findings of the in-situ analysis were obtained using YSI Multiparameter Professional Plus devices, and the recorded data were used to generate the readings in Table 1. The measured temperature during the analysis was 24.4°C, which falls within the typical range for room temperature water (20–25°C). According to Table 1, the dissolved oxygen (DO) level in the wastewater was measured at 8.33 mg/L, which is within the acceptable range for fisheries, indicating that the water quality is suitable for aquatic life. DO levels below 5 mg/L can create stress conditions for aquatic organisms, negatively affecting fish farming. Additionally, the pH value recorded in the fishpond was 6.76, classifying it as neutral and within the permissible range for safe water conditions.

The average turbidity level of the UMK lake sample was 56.9 NTU, indicating slight pollution compared to the standard NTU level, which should ideally be below 10 NTU. Regarding environmental water quality regulations, the U.S. Environmental Protection Agency (EPA) provides guidelines for acceptable turbidity levels in different water bodies. For recreational streams and rivers, a turbidity level of 50 NTU may still be considered acceptable. In the European Union, the Water Framework Directive sets turbidity standards for surface waters, where good ecological status is typically maintained at a turbidity level of 10 NTU in rivers and lakes.

3.2 Effect of Different Electrode Materials and Spacing Gap on TSS Removal

Table 2: Removal rate of suspended solids

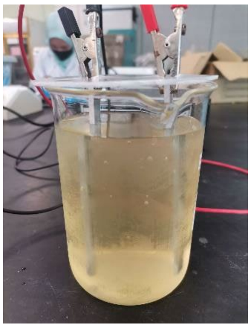
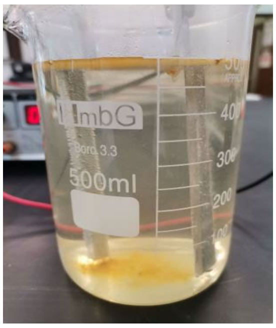
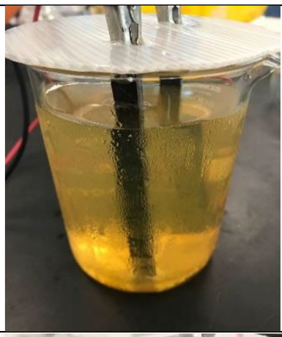
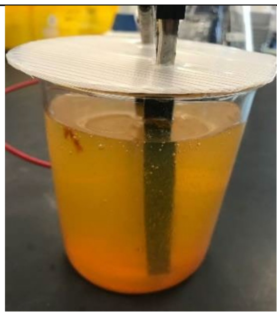
Parameter	**Untreated**	**Treated**	**Removal Rate**
Aluminium			87%
Mild steel			75%
Stainless steel			73%

Table 2 above shows the removal rate of suspended solids using different electrode materials. The result indicates that aluminium has the highest removal efficiency with a 87% removal rate compared to stainless steel and mild steel with 73% and 75%, respectively. This might be due to its high electrochemical reactivity, allowing it to readily release electrons during the process. This characteristic leads to the formation of aluminium hydroxide flocs, which play a crucial role in capturing and removing suspended particles, colloids, and contaminants from wastewater. Additionally, aluminium facilitates effective coagulant formation through electrochemical reactions that generate aluminium hydroxide and aluminium oxyhydroxide species. These coagulants neutralise charged particles and promote the aggregation of suspended matter, making their removal more efficient through precipitation or settling.

The effect of different electrode spacing is then conducted using aluminium as the optimum electrode material. The results indicate that an electrode spacing of 2 cm achieves a higher removal efficiency of 89% compared to 4 cm and 6 cm, with a removal rate of 80% and 77% respectively. Electrode spacing plays a crucial role in electrocoagulation, particularly in the removal of Total Suspended Solids (TSS). A narrow spacing creates a more intense electric field, which enhances the generation of coagulant species and improves coagulation efficiency. When electrodes are positioned close together, coagulants disperse more quickly and uniformly throughout the treatment volume, ensuring effective interaction with suspended solids. This optimised contact contributes to increased TSS removal efficiency, particularly for fine particulate matter. Results indicate that the distance between the electrodes affects the electrical field strength and the distribution of current within the treatment system. A smaller electrode spacing typically leads to a higher electric field intensity, promoting more efficient coagulation and flocculation. However, a smaller spacing may also increase the chance of short-circuiting or electrode fouling, requiring regular cleaning and maintenance.

4. Conclusion

Electrocoagulation has demonstrated its effectiveness as a reliable method for removing suspended solids from laboratory wastewater. This study evaluated the performance of aluminium electrodes in destabilising and aggregating suspended particles, facilitating their removal. Experimental findings showed a significant reduction in suspended solid concentrations following electrocoagulation treatment, with aluminium hydroxide flocs playing a crucial role in coagulating and settling particles.

The efficiency of suspended solids removal was influenced by key parameters such as different electrode materials and spacing, with optimisation enhancing removal performance. Electrocoagulation also presents several benefits, including simplicity, cost-effectiveness, and minimal chemical usage, making it a more sustainable alternative to conventional coagulation methods. The natural formation of aluminium hydroxide flocs further supports its environmentally friendly application in water treatment.

Beyond laboratory settings, this study provides valuable insights into electrocoagulation’s potential for broader wastewater treatment applications. Future research could focus on scalability, optimisation, and integration with complementary technologies to enhance treatment efficiency. The success of this study underscores electrocoagulation’s role as a sustainable and efficient solution for suspended solids removal, contributing to both environmental protection and regulatory compliance. As water treatment technologies evolve, this research highlights the importance of innovative approaches to wastewater management.

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