# Improving the efficiency of the electrocoagulation process for Palm Oil Mill effluent: a case study in POME processing in a palm oil processing factory in Meulaboh, West Aceh Regency

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**Abstract.** Palm oil mill effluent (POME) is a by-product of palm oil processing, which poses a significant risk to environmental integrity due to its high production volume and pollutant content. Therefore, this research offers the POME treatment process using electrocoagulation, a case study in a palm oil processing factory in Meulaboh, West Aceh Regency. Specifically, this study aims to investigate the effect of voltage variation on the removal efficiency of key parameters such as BOD, COD, pH and TSS. The electrode used is made of aluminium (Al) plate with a gap of 2 cm, and the electrolysis time is 60 minutes. The results show that the higher the applied voltage, the greater the parameter removal efficiency, with the best voltage in this result being 25 volts. However, overall, these results have only two parameters that meet wastewater quality standards, which are COD and pH. Further optimization is required to achieve acceptable BOD and TSS levels, highlighting the importance of extended electrolysis times and proper parameter control.

## 1 Introduction

Palm oil has been recognized as a high-quality commodity on the international market. In recent years, it has become increasingly prominent among the world's top ten export commodities. However, the exponential growth of the palm oil industry has resulted in environmental challenges, most notably in the form of Palm Oil Mill Effluent (POME). This waste stream, a by-product of palm oil processing, poses a significant threat to environmental integrity [1].

Processing one ton of fresh palm oil fruit bunches requires 5-7.5 tons of water, of which 50-79 percent is converted to POME during production. Although POME is non-toxic, it poses an environmental risk by lowering oxygen levels in aquatic ecosystems. The annual volume of POME production continues to increase, resulting in a surge in sludge

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accumulation [2]. This effluent has high levels of chemical oxygen demand and biochemical oxygen demand. Fresh POME presents as a brownish colloidal sludge containing water, oil, and fine cellulose residues from the fruit. On average, each ton of crude palm oil (CPO) produces approximately 0.9-1 $m^3$ of POME [3].

POME water quality is determined by a number of parameters including BOD (biological oxygen demand), COD (chemical oxygen demand), TSS (total suspended solid), and oil and grease [4]. These parameters must be carefully managed as their excessive presence can lead to pollution and physical damage to the environment. They play an important role in determining the quality of the environment and, in particular, serve as benchmarks for POME liquid waste. If these parameters exceed established quality standards, appropriate action must be taken immediately. Therefore, it is necessary to adopt effective solutions or approaches to minimize and treat these wastes in an efficient way.

Various methods have been used to treat POME wastewater, including a combination of adsorption and ultrafiltration [5], chemical coagulation [6], anaerobic biofilm reactors [7], and phytoremediation [8]. Among these methods, there is a recent method that is of interest to many researchers, which is electrocoagulation. This method is considered to be a simple, effective and powerful process for the removal of organic and inorganic contaminants. Compared to previous conventional methods, electrocoagulation is expected to be more practical and cost effective because it does not use chemicals and is therefore easier to handle. The basic principle of the process is to apply a direct current source to the electrode plate in contact with the wastewater. The mechanism that occurs is the reaction of the cathode and anode with water, which spontaneously forms metal hydroxide, which acts as a coagulant. The resulting coagulant can break down and then aggregate the contaminants [9,10].

Considering the important role of oil palm in the plantation subsector in Aceh Province, mitigating the environmental impact of POME is very important. The research is a case study to optimize the electrocoagulation process in POME processing in a palm oil processing factory in Meulaboh, West Aceh Regency. Specifically, this research aims to study the effect of voltage variation on the removal efficiency of BOD, COD, pH and TSS. Through understanding the interaction between voltage regulation and pollutant removal, this study proposes to design a more effective waste management strategy. Finally, it is expected that these findings will contribute to the development of sustainable practices in the palm oil industry and promote environmental awareness.

## 2 Material and Methods

### 2.1 POME sample

The sample was collected from the palm oil mill factory located in Nagan Raya, Meulaboh, West Aceh Regency, Indonesia. This sample was then stored at temperatures below 0$^oC$ to prevent waste degradation by bacteria.

### 2.2 Set-up batch electrocoagulation reactor

The electrocoagulation process was carried out in an acrylic batch reactor with dimensions of 10 cm (P) x 10 cm (L) x 15 cm (H). The electrode used is made of aluminum (Al) plate with a thickness of 0.4 cm; it is functional as anode and cathode, placed vertically and parallel with a gap of 2 cm. The anode and cathode are connected to a DC power supply (30 V/5 A) with the current set at 5 amperes. The batch electrocoagulation reactor set-up is

shown in Figure 1. The experiments were carried out at room temperature for the POME sample (1000 mL) with an operating time of 60 min.

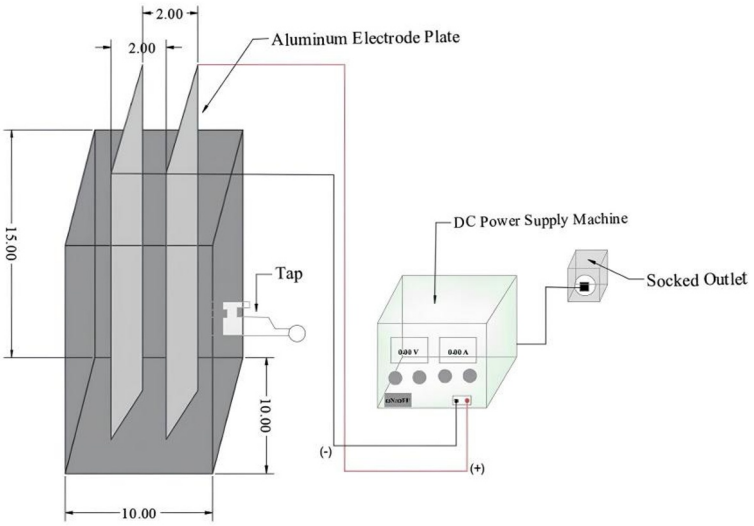


**Fig. 1.** Set-up batch electrocoagulation reactor.

### 2.3 The sample analysis

The sample (before and after electrocoagulation treatment) was analysed for BOD, COD, pH, and TSS using standard methods. The BOD is measured by the respirometric method using a BOD sensor (VELP Scientifica Srl, Italy). Meanwhile, the COD was measured using a HACH spectrophotometer (UV-1800, Shimadzu, Japan). The pH was measured with a microprocessor pH meter (HANNA Instrument). The TSS was measured with using the gravimetric method, the Indonesian national standard (Standar Nasional Indonesia or SNI) that applies is SNI 06-6989-2004. The results obtained are then compared with the waste water quality standards, referring to the Minister of Environment Regulation (PERMEN LHK) No. 5 of 2014.

### 2.4 Effect of voltage

The research variables are carried out by varying the voltage to the electrocoagulation set-up, which were 5, 10, 15, 20 and 25 volts. After the electrocoagulation process is completed, the effluent is collected for analysis of BOD, COD, pH, and TSS parameters. The effectiveness of each parameter can be calculated using Equation (1).

$$reduction\ efficiency\ (\%) = \frac{C_o - C_i}{C_o}\ x\ 100\% \quad (1)$$

where $C_o$ and $C_f$ are the level before and after electrocoagulation, respectively.

## 3 Results and Discussion

### 3.1 Experimental Result

POME is a sludge-like liquid waste with a high colloidal suspension, characterized by its thick, brownish appearance and offensive odor. Because of these characteristics, it is

subject to environmental quality standards that serve as benchmarks for assessing the quality of wastewater from palm oil industry processing operations. These standards are specified in the Minister of Environment Regulation (PERMEN LHK) No. 5 of 2014 and are detailed for various parameters in Table 1. According to this regulation, the palm oil industry must ensure that its liquid waste meets these quality standards before it is discharged into the watershed. In this case, the characteristics of the POME sample, as shown in Table 2, show values that exceed the permissible limits. Therefore, treatment is necessary to reduce the levels of BOD, COD, TSS and pH neutralization as required by the quality standards.

**Table 1.** Waste water quality standards.

| Parameter | Unit | Maximum Content |
|---|---|---|
| BOD | mg/l | 100 |
| COD | mg/l | 350 |
| pH | - | 6 – 9 |
| TSS | mg/l | 30 |

Source: The Minister of Environment Regulation (PERMEN LHK) No. 5 of 2014.

**Table 2.** Characteristic of POME sample.

| Parameter | Unit | Result |
|---|---|---|
| BOD | mg/l | 261.59* |
| COD | mg/l | 452.24* |
| pH | - | 4.5* |
| TSS | mg/l | 290* |

*Compliance with waste water quality standards

**Table 3.** The experimental data after electrocoagulation.

| Voltage (volt) | Result | | | |
|---|---|---|---|---|
| | BOD (mg/l) | COD (mg/l) | pH | TSS (mg/l) |
| 10 | 127.65 | 232.11* | 5.1* | 111 |
| 15 | 125.33 | 205.63* | 5.5* | 106 |
| 20 | 114.35 | 133.53* | 5.9* | 100 |
| 25 | 105.71 | 101.71* | 6.3* | 92 |

*Compliance with waste water quality standards

Electrocoagulation is a method which uses a direct current to submerge both the anodes and cathodes in a wastewater. When an electric current is applied, the dissolution of the anode (metal) releases metal species into the environment. In the presence of air, these metal species then spontaneously convert to metal hydroxide (coagulant) [11]. There are several factors that affect the electrocoagulation process, including electrode material, electrode voltage, electrolysis time, electrode gap, and electrode support [12,13]. In this case study, the electrode voltage was varied and the results are summarized in Table 3. These results are compared with the quality standards (Table 1), only two parameters meet the quality standards, which are COD and pH. Meanwhile, the BOD and TSS parameters still exceed the maximum allowable content range. Further optimization is needed to achieve standards-compliant values.

### 3.2 Effect of voltage on reduction efficiency

#### *3.2.1 BOD*

BOD is the mass of dissolved oxygen required by aerobic biological organisms to degrade organic matter. High BOD levels in water bodies can lead to decreased oxygen levels, which may harm aquatic life and degrade water quality [14]. Figure 2 shows the efficiency of BOD reduction in POME liquid waste, the figure shows that the increase in efficiency is directly proportional to the voltage. The BOD reduction efficiency was 51.2; 52.09; 56.08; 59.58% using 10, 15, 20 and 25 volts, respectively. The results show that the increase is not so significant at 10 and 15 volts with a change of only 0.89%, but when using voltages 20 and 25 V, the efficiency increase is more than using low voltages, with an increase of 3.5%. Unfortunately, the greatest efficiency only reached 59.58% which shows that the lack of contact time, so it is believed that increasing the operating time will affect the efficiency of BOD abatement.

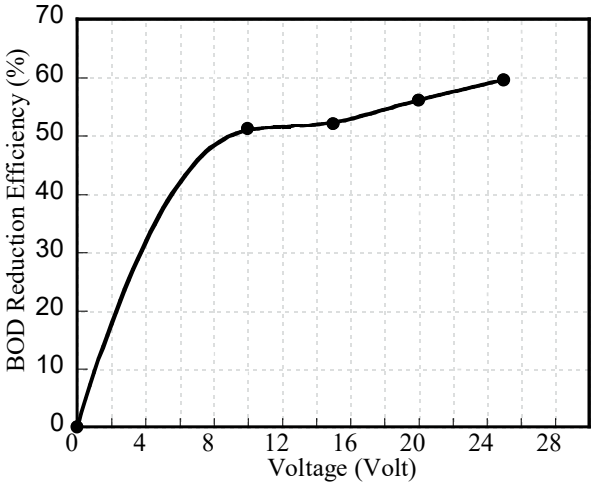


**Fig. 2.** Effect of voltage on BOD reduction efficiency.

#### *3.2.2 COD*

COD is the number of organic compounds in water, which refers to the mass of oxygen consumed per liter. The higher the COD level, the more polluted the water [14]. COD removal showed better efficiency results compared to BOD reduction. Figure 3 shows the percentage of COD reduction against the voltage used, the results show no change at the beginning of the voltage increase, but when it was increased to 20 volts from 15 volts, the separation efficiency increased very drastically from 40.47% to 70.47%. After increasing the next 5 volts, the separation efficiency still increased but only up to 77.5%. The decrease in concentration occurs of COD and BOD due to oxidation and reduction reactions in electrocoagulation. Electrodes produce gases, such as oxygen and hydrogen. Apart from that, floc formation by organic compound ions also plays a role, where these ions bind to the positive coagulant ions produced.

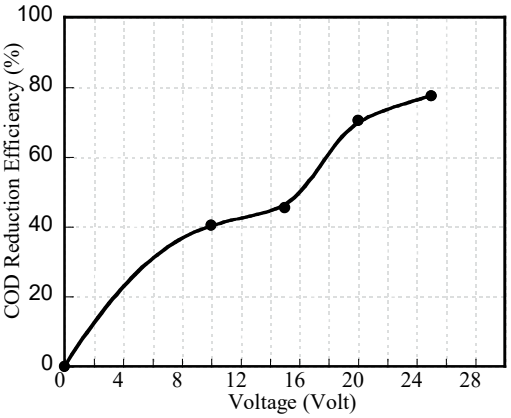


**Fig. 3.** Effect of voltage on COD reduction effeciency.

### *3.2.3 pH*

pH testing is important in the electocoagulation process, because pH has a major influence during the electrocoagulation process. Figure 4 shows the effect of increasing the voltage on the resulting pH. Figure 4 shows that the more the voltage increases, the higher the pH produced during the process (tend to be neutral). The increase in pH was 5.1; 5.5; 5.9; 6.3; with voltages of 10, 15, 20, and 25 volts, respectively. The increase in pH occurs due to the amount of -OH formed from the reduction of water, so that when the voltage is increased, the reduction process will occur more often which results in an increase in pH [15].

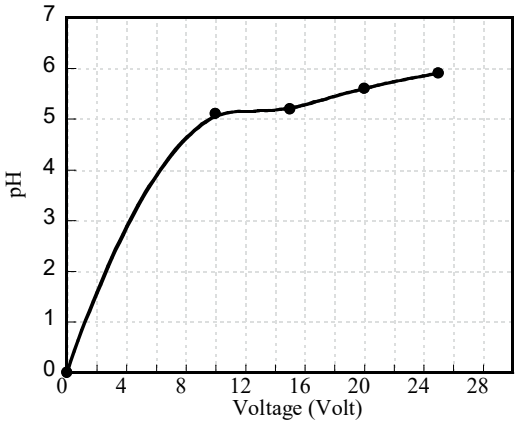


**Fig. 4.** Effect of voltage on pH.

### *3.2.4 TSS*

TSS represents the total amount of solid particles, including organic and inorganic materials, suspended in the liquid waste produced during the processing of palm oil. POME typically contains various suspended solids such as fibers, oil residues and other organic matter from the palm oil extraction process. These suspended solids give POME its characteristic thick, sludge-like appearance. The effect of voltage on TSS reduction efficiency can be seen in Figure 5. The TSS separation also tends to increase from 10 volts to 25 volts with the largest TSS reduction being at 25 volts of 68.27% and the smallest TSS

reduction being at 10 volts of 61.72%. Although the TSS reduction efficiency tends to increase, in fact the TSS reduction efficiency only increased by 6.55%. The TSS value is still high and above the maximum quality standard, (as well as BOD), it could be cause of a short electrolysis time. In general, longer electrolysis times result in higher removal efficiencies. This is due to the increased opportunity for electrochemical reactions that promote coagulation and flocculation of contaminant [15,16].

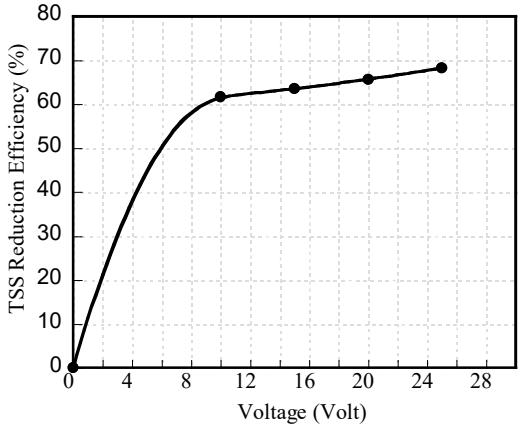


**Fig. 5.** Effect of voltage on TSS reduction efficiency.

## 4 Conclusion

In conclusion, electrocoagulation presents a promising method for the treatment of palm oil mill effluent (POME). In this study, varying the electrode voltage gave different results, only COD and pH met the quality standards, referring to the Minister of Environment Regulation (PERMEN LHK) No. 5 of 2014. The analysis of BOD parameters shows an increase in efficiency proportional to the voltage, although the maximum efficiency obtained is 59.58%. In contrast, COD removal showed a significant improvement with increasing voltage, reaching efficiencies up to 77.5%. The control of pH during electrocoagulation was found to be important, with pH levels increasing with increasing voltage. Meanwhile, TSS reduction efficiency shows a moderate increase with increasing voltage. Although electrocoagulation is promising for POME treatment, further optimization is needed to achieve standard values for all parameters. Therefore, future work will be conducted to verify the optimal electrolysis time to achieve maximum reducing efficiency.

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**Data availability statement:** The authors declare the data of this study are available within the article.

**Author contribution statement: Muhammad Daudsyah**: Investigation, Data Collection, Analysis, Writing – original draft. **Sri Mulyati**: Funding, Supervision, Validation, Writing – review. **Cut Meurah Rosnelly**: Supervision, Project administration**. Aulia Chintia Ambarita**: Analysis, Writing – original draft.

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