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Treatment of Palm Oil Mill Effluent (POME) Using Continuous Column Plate Electric Reactor

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Abstract: *Palm oil mills produce palm oil mill effluent (POME) which contains various dissolved organic compounds in the form of short fibers, hemicellulose, and their derivatives, protein, free fatty acids, a mixture of minerals and organic pigments such as anthocyanins, carotene, polyphenols, lignin and tannins. Organic compounds in this waste will cause problems such as increasing the value of TSS, TDS, and COD which can be a crucial environment for processing liquid waste in palm oil mills. One possible method to reduce the content of TSS, TDS, and COD is the electrocoagulation method. This study aims to determine the effect of variable flowrate, voltage, and distance between plates in the electrocoagulation process with a plate column electric reactor, and determine the optimum conditions for flowrate, voltage, and distance between plates. Optimum conditions are obtained at fflowrate3 L/min, 28 V voltage, 2 cm distance between plates with percent removal of TSS, TDS, and COD, respectively 49.30%; 49.40%; 60.30%.*

Keywords: *distance between plates, electrocoagulation, flowrate, POME, voltage.*

INTRODUCTION

Palm oil mills produce the main products in the form of Crude Palm Oil, Palm Kernel Oil and Palm Kernel, as well as by-products in the form of solid waste, liquid waste, and pollutants into the free air. Palm Oil Mill Effluent (POME) is one of the main wastes from the palm oil industry with the greatest potential for environmental pollution compared to other types of waste (Ibe et al., 2014). The potency for liquid waste pollution also comes from the amount of waste produced, as much as 1 ton of crude palm oil production which requires 5-7.5 tons of water; more than 50% of it ends up as POME. POME is a liquid with a thick consistency with a brownish color, which contains water (95-96%), oil (0.6-0.7%), and 4-5% total solids which mainly comes from fruit debris with very high BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) values (COD values are often greater than 80,000 mg/l) (Bala et al., 2014). If the waste is disposed of directly into the environment, some of it will settle, and decompose slowly, consuming dissolved oxygen in the water, causing turbidity, emitting a sharp odor and damaging the ecosystem. Therefore, it is necessary to treat POME waste which is relatively cheap and quite efficient. One of the treatments that can be used is the electrocoagulation method with a plate column electric reactor.

A study on this environmentally friendly electrocoagulation method was carried out by Agung et al., (2012), researching the electrocoagulation process with iron and aluminum electrodes. The highest COD concentration removal percentage was obtained at 29.83%. Sutanto & Artanti (2019) have conducted research to treat cosmetic liquid waste by electrocoagulation. The best processing optimum conditions were obtained with values Fe is 31 mg/L (80.38% decrease); COD is 280 mg/L (a decrease of 74.19%); DO is 6.9 mg/L; TSS is 88 mg/L (86.21% decrease); pH is 9.96. Amri & Awalsya (2020) have conducted research using a continuous electrocoagulation process to treat liquid waste from the metal plating industry. Optimal conditions were obtained at flowrate of 0.78 L/min and 2 A with a pH value of 6.6 TSS 1.2 mg/L and a percent removal of Cr of 82.4%. In this study, the column plate electric reactor was used to treat POME waste continuously using variable flowrate of 0.3, 1.2, and 2.5 L/min, voltage 24, 26, and 28 volt, and the distance between plates 2, 3, and 4 cm. This research is expected to be able to reduce the levels of TSS, TDS, COD in POME waste.

RESEARCH METHODS

Materials and Tools

The material used is palm oil industrial liquid waste taken from waste tank number 4 at PTPN V Sei Pagar, Kampar. The tool used is 1 set of electrocoagulation equipment in fig 1 and aluminum plate with a height of 50 cm and a diameter of 10 cm, with volume of 38 liters.

Methods

Initial Sample Test

The wastewater from the initial palm oil industry before the electrocoagulation process was tested for TSS, TDS and COD content.

Electrocoagulation Process

Palm oil industrial liquid waste tested for its initial characteristics flows continuously into the reactor through pipes. After that, the DC Power Supply is connected to an electric current, with voltage variations of 24, 26, and 28 V at flowrates of 0.3, 1.2 and 2.5 L/min and a distance between plates of 2, 3, 4 cm. Then, samples from the electrocoagulation process were tested for TSS, TDS and COD content (Amri & Awalsya, 2020)

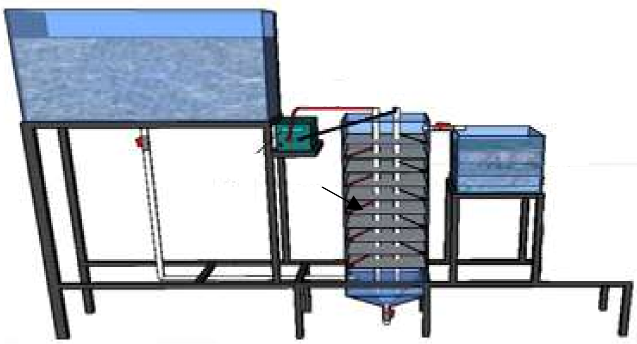

Figure 1. Column Plate Electric Reactor

RESULTS AND DISCUSSION

Characteristics Pome

POME obtained from PTPN V Sei Pagar. The analysis carried out on the initial samples included TSS, TDS, and COD. The results of sample analysis before electrocoagulation treatment using a plate column electric reactor continuously can be seen in Table 1.

Table 1. Results of Initial Sample Analysis

Parameter	POME (mg/L)	Standard * (mg/L)	Inspection Method
TSS	2150	250	SNI 06-6989.3-2004
TDS	1634	-	SNI 06-6989.27-2004
COD	1310	350	SNI 06-6989.73-2009

*Regulation of The Minister of Environment Republic of Indonesia No. 5/2014

Total Suspended Solid (TSS)

TSS is an important factor that will be easily recognized in measuring the quality of water because physically it can be seen if wastewater contains high TSS, it can be immediately concluded that the waste is of poor quality and has the potential to damage ecosystems, especially in aquatic. Analysis of suspended solids content (TSS) is important in the need to regulate or determine waste treatment processes both biologically and physically and is one of the key requirements for licensing the disposal of wastewater into the environment (Efendi, 2013). The results of the TSS analysis in various variations are shown in Figure 2, 3, and 4.

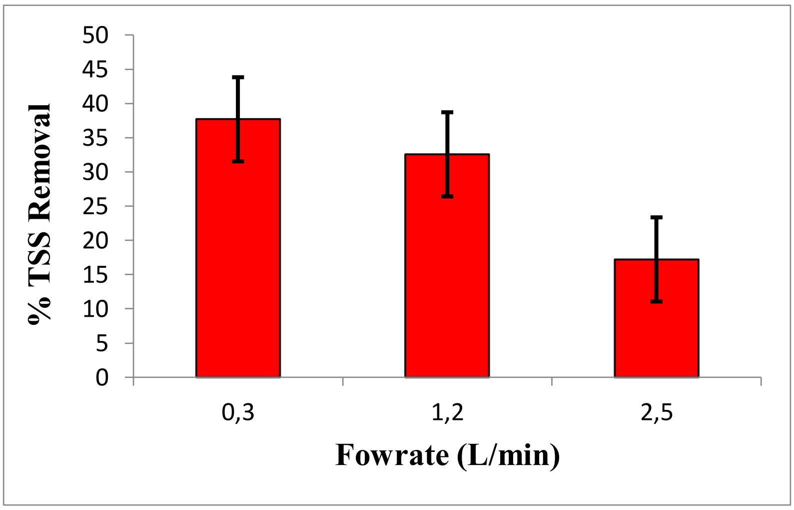

Figure 2. The Effect flowrate vs % TSS removal

In Figure 2, the results of the processing of the column plate electric reactor show that the highest percentage of TSS removal was obtained at a flowrate of 0.3 L/minute with a voltage of 26 V, which was 37.674%. Meanwhile, the lowest percent removal was obtained at a flowrate of 2.5 L/min with a voltage of 26 V, which was 17.209%. In Amri & Destinefa, (2020) using a column plate electric reactor to treat tofu waste, the percentage of TSS removal was 72.17% with flowrate of 0.09 L/min. The decrease in TSS concentration in the study of Kim et al., (2002) reached 99.5% with a flowrate of 0.5 L/min. In this study, the percentage of removal obtained was lower than research from Amri & Destinefa, (2020) and Kim et al., (2002) because the flowrate used was higher, namely 0.3 L/min.

According to Siringo-ringo et al, (2013) the change in TSS value is due to the longer the contact time and the higher the current and the applied voltage, the ions released by the aluminum electrode will produce aluminum hydroxide which can bind organic materials to form flocs which can agglomerate suspended solids in water, so that TSS levels in palm oil industrial wastewater will be reduced. According to Mollah et al, (2004) the phenomenon of decreasing TSS concentration shows the agreement between the results of the study with Faraday's law, namely: the increase in current is directly proportional to the increase in electrical voltage and the amount of metal anode as a source of dissolved coagulant. The downward trend can be clearly observed in the image above. The process of reducing pollutants occurs by forming coagulant $Al(OH)_3$ produced by Al anode and OH- ions from H_2O molecules. This $Al(OH)_3$ coagulant then adsorbs the existing pollutants into the molecular cavity.

The oxidation of the aluminum metal caused the decrease in TSS levels to Al^{3+} ions at the cathode and the formation of OH- ions at the anode. Al3+ and OH- ions will then form $Al(OH)_3$ which acts as a coagulant. The coagulant will bind the suspended solids in the liquid waste to form a floc. The floc that has been formed will be lifted to the surface by the hydrogen formed at the cathode. The process of reducing TSS can be understood because TSS is a pollutant that is in a suspended form. When a material is suspended, it is solid with a certain size. This solid material can easily be adsorbed into the Al(OH)x coagulant or air bubbles. The adsorption results with a slower flowrate allow the coagulants produced by electrochemical dissolved from the electrodes and pollutants in the wastewater to mix well, resulting in a decrease in the concentration of TSS in the wastewater (Hanum et al., 2015).

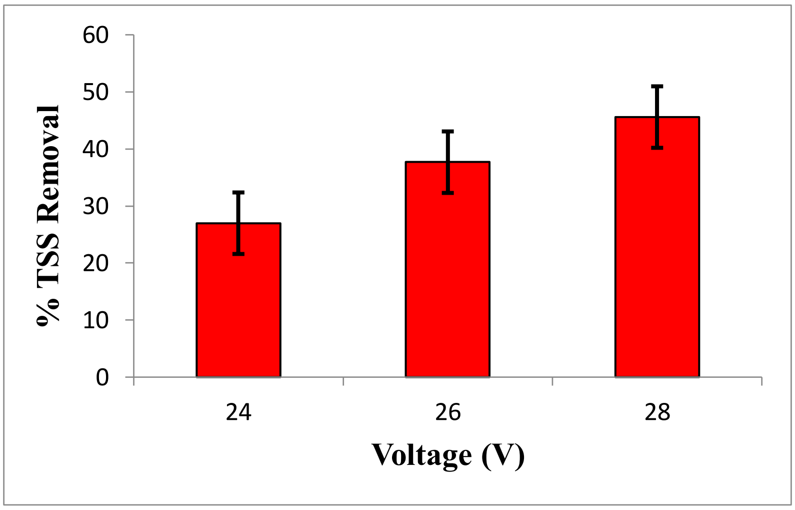

Figure 3. The effect of voltage vs % TSS removal

In Figure 2, the results of the processing of the column plate electric reactor show that the TSS concentration decreased by 45.58% at a voltage of 28 V, a flowrate of 0.3 L/min and a distance between plates of 3 cm. While the lowest TSS concentration decrease was 26.98% at voltage of 24 V, at flowrate of 0.3 L/min and distance between plates of 3 cm. In the research of Bazrafshan et al., (2013) obtained a percent removal of 97.75% using a voltage of 60 V. The high percent removal of TSS in Bazrafshan et al, (2013) research is due to the use of very high voltage. The function of stress in this study is to produce sufficient OH- (hydroxyl free radicals) to destroy pollutants (Picard et al, 2000). OH- (hydroxyl ion) is also known as one of the most reactive liquid radicals, which will oxidize organic components in wastewater because it has a high affinity. The resulting hydroxide will attract suspended particles, causing coagulation. The gas produced also helps the removal of suspended substances, causing an increase in the removal of TSS (Nasution et al., 2014).

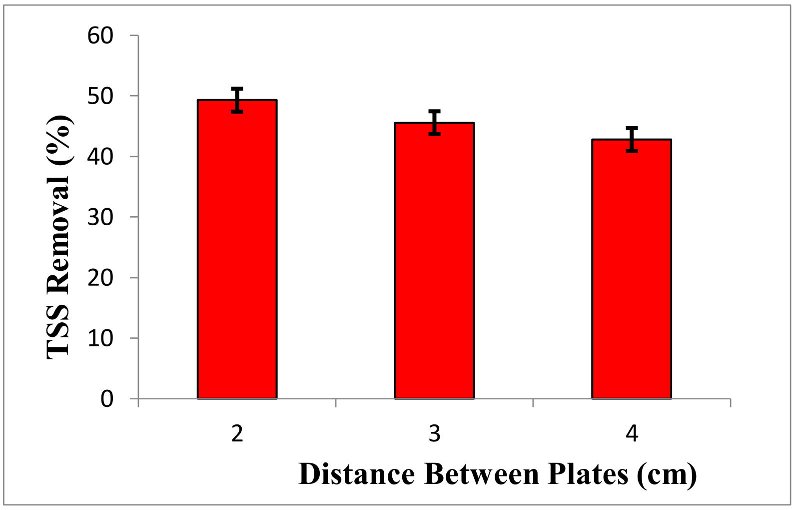

Figure 4. The effect of the distance between plates vs % TSS removal

In Figure 4, the processing results of the electric reactor show that the highest percent reduction in TSS removal was obtained at a variation of the distance between plates of 2 cm, which was 49.30%. Meanwhile, the lowest reduction in allowance was in the variation between plates of 4 cm, which was 42.79%. Al-Shannag et al (2012) have conducted research using an electric column plate reactor to decompose paper industry waste and obtained the best percentage removal of 64% using a distance between plates of 3 cm. Based on Figure 3, the concentration of TSS decreases along with the decrease in the distance between the plates. This is in accordance with the research conducted by Naje et al., (2015) which stated that a decrease in the percentage of treatment allowance occurred when the distance between the electrodes was enlarged due to the presence of a large current resistance, causing the conductivity to decrease. In the electrocoagulation reaction, $Al(OH)_3$ compound is produced which functions as a coagulant that adsorbs organic substances and metal ions, collects and then precipitation and flotation occurs by H_2 gas causing the trapped colloid to be separated from the solution so that the TSS level decreases. The distance between the electrodes has an impact on the speed of electron transfer between the anode that receives electrons and the cathode as the site of the reduction process. If the distance between the electrodes is too close it will cause the amount of coagulant to increase but the system will experience interference due to a short circuit between the electrodes. However, a decrease in processing efficiency occurs when the distance between the electrodes is enlarged because of the large current resistance so that the conductivity decreases (Saputra and Hanum, 2016).

Total Dissolve Solid (TDS)

One of the parameters analyzed in this study is TDS with a content of 1634 mg/L. The results of the TDS analysis at various flowrates are shown in Figure 5, Figure 6 and Figure 7.

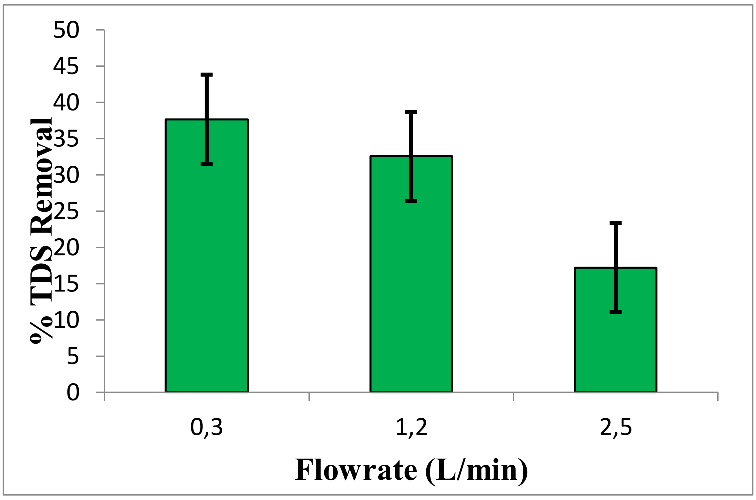

Figure 5. The effect of flowrate vs %TDS removal

From Figure 5, the results of the processing of the column plate electric reactor can be obtained that the effect of the flowrate on TDS is that the faster the flowrate, the value of the percent removal of TDS will decrease. This happens because when the flowrate is faster, the contact time will also be faster so that the reaction that occurs will be shorter, resulting in the percentage value of TDS removal decreasing. This is in accordance with the research of Roihatin and Kartika (2009) which stated that the longer the flowrate in the reactor, the opportunity for contaminants in the wastewater to settle and the electrocoagulation process to take longer so that the TDS level of the wastewater will be smaller and the percentage of TDS removal will be greater. The highest TDS removal percentage was obtained at a flowrate of 0.3 L/min, which was 37.67%. Meanwhile, the lowest percentage of TDS removal was obtained at a flowrate of 2.5 L/min, which was 17.21%.

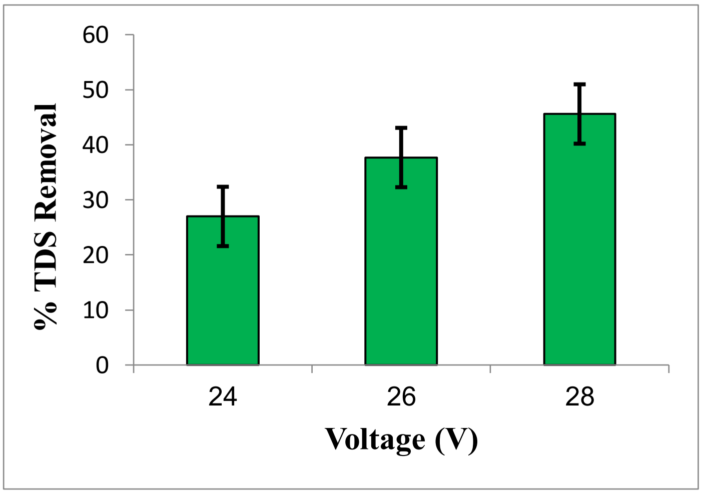

Figure 6. Effect of voltage vs % TDS Removal

In Figure 6 from the results of the processing of the electric reactor, it can also be seen that the percent removal increases with the increase in the voltage used. The highest percentage removal was obtained at a voltage of 28 V, 45.58%, while the lowest percentage removal occurred at a voltage of 24 V, which was 26.98%. This is in accordance with research conducted by Nurajijah et al., (2014) which states that if the voltage is increased, it causes the current flowing into the column plate electric reactor to be greater, resulting in larger deposits as well. The more mass of sediment produced by the electrode, the decrease in the TDS value will be even greater.

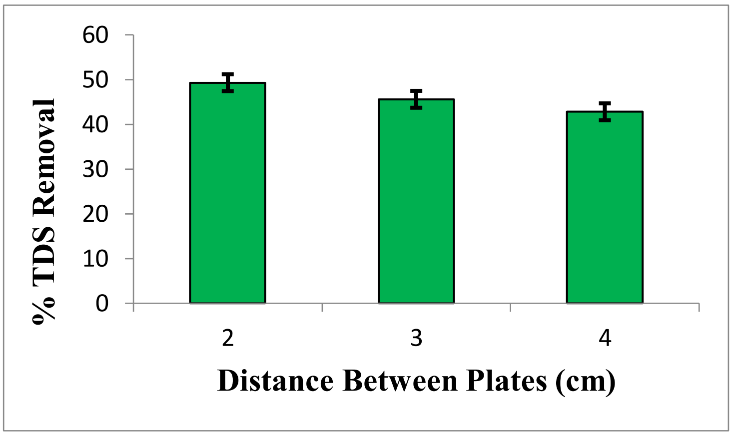

Figure 7. The effect of the distance between plates vs TDS removal

From Figure 7 it can be seen that the highest TDS reduction is in the variation of the distance between plates of 2 cm, which is 49.30% and the lowest percentage of TDS removal occurs in the variation of the distance between plates of 4 cm, which is 42.79%. Babu et al., (2007) have conducted a study using an electric column plate reactor to decompose the concentration of TDS in industrial tannery waste using aluminum electrodes and obtained the best percent removal of 70%. The results of this study are in accordance with research conducted by Saputra & Hanum (2016) which states that the greater the distance between the plates, the decrease in the TDS concentration will decrease because when the distance between the electrodes is enlarged, it causes a large current resistance so that the conductivity decreases and causes interactions between the electrode the molecules become weak.

Chemical Oxygen Demand (COD)

The initial COD concentration of the sample was 1310 mg/L so it was necessary to carry out an electrocoagulation process with the results as shown in Figure 8, 9 and 10.

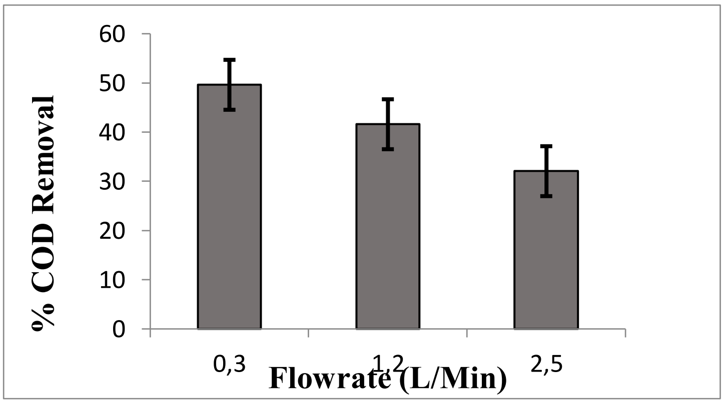

Figure 8. Effect of flowrate vs % COD removal

From Figure 8 in the plate column electric reactor, the lowest COD removal percentage is 32.06% at a flowrate of 2.5 L/min, a voltage of 26 V and a distance between plates of 3 cm. While the highest concentration decrease was obtained 49.62% at flowrate of 0.3 L/min from the initial sample of 1310 mg/L to 660 mg/L. The percentage of COD removal will increase along with the slower flowrate used (Malakootian & Yousefi, 2009)..

Kobya et al., (2016) have also conducted research using an electric reactor to treat household waste and obtained a percent allowance of 85% with a flowrate of 0.01 L/min. The percentage of removal in this study is lower than the study of Kobya et al, (2016) because the flowrate used is greater, namely 0.3 L/min.

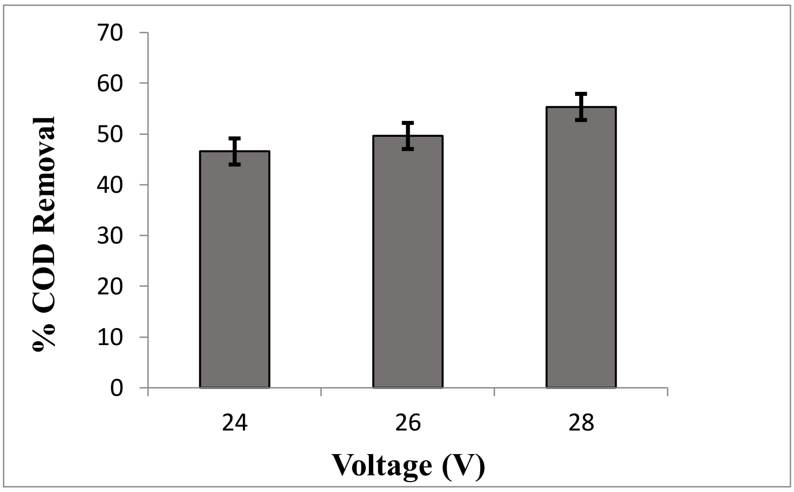

Figure 9. The effect of voltage vs % COD removal

Figure 9 shows the highest COD removal percentage at 28 V with a flowrate of 0.3 L/min and a distance between plates of 3 cm, which is 55.34% and the lowest concentration decrease at a voltage of 24 V with a flowrate of 0.3 L/min. min and the distance between plates is 3 cm, which is 46.56%. Efficiency increases with increasing voltage due to the presence of an electric voltage that carries an electric current thus accelerating the electrocoagulation reaction.

The increasing value of electric voltage causes a greater decrease in COD concentration. This is because the higher the value of the electrical voltage used, the amount of oxidized aluminum increases so that the pollutants in the wastewater are set aside more and more (Takdastan et al, 2015). The experiment of Setianingrum et al., (2017) on dye waste, the COD reduction reached 87% at 60 minutes at a voltage of 15 volts and the distance between the electrodes was 2 cm. The decrease in COD was due to organic pollutants being oxidized and partially flocculated so that they separated from the water. The higher the applied voltage, the lower the COD.

Based on the equation from Faraday's Law regarding electrode consumption, the number of dissolved electrodes is directly proportional to the value of the electric current in the electrocoagulation system. When viewed from Ohm's law, the electric current is directly proportional to the voltage. Therefore, the higher the value of the electric voltage used, the decrease in COD concentration after going through the electrocoagulation process will be even greater. In addition, the electric voltage applied to the electrocoagulation process determines the amount of coagulant dose and the formation of bubbles which greatly affect the agitation of wastewater and mass transfer at the electrodes (Farhadi et al., 2012). Wahyulis et al., (2014) have conducted research using a plate column electric reactor to degrade chromium waste in water using a voltage of 8 volts and obtained the best removal percentage of 98.82%. Sayuti and Azoddein et al., (2015) also carried out the degradation of POME waste using a plate column electric reactor and obtained the best COD removal percentage of 99.25% using a voltage of 100 Volts.

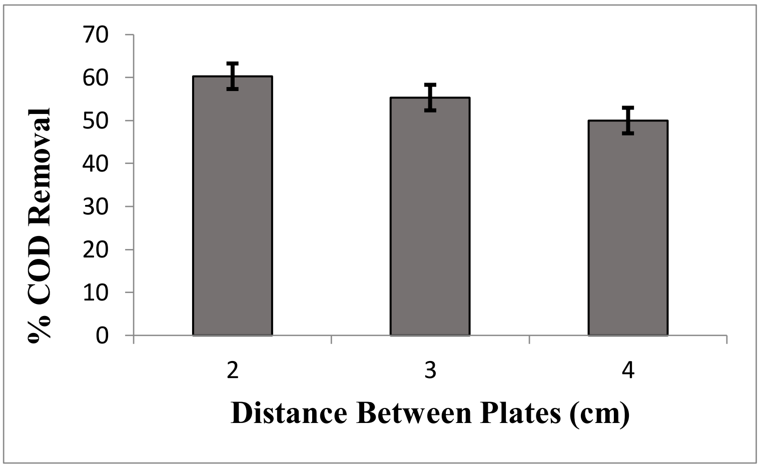

Figure 10. The effect of the distance between plates vs % COD removal

From Figure 10, the results of the processing of the electric reactor show that the highest decrease in COD concentration occurs at a variation of the distance between plates of 2 cm by 60.31%. Meanwhile, the lowest decrease in COD concentration occurred at a variation of the distance between plates of 4 cm, namely 50%.

COD reduction efficiency in the electrolysis process, depends on the concentration of ion production, electrode material, and reaction time. The distance between the electrodes has an impact on the speed of electron transfer between the anode that receives electrons and the cathode as the site of the reduction process. A decrease in processing efficiency occurs when the distance between the electrodes is enlarged which causes a large current resistance so that the conductivity decreases. The interaction between the molecules becomes weak when the distance between the electrodes is more than 1 cm. However, if the distance between the electrodes is too close it will cause the amount of coagulant to increase so that the system is disrupted due to a short circuit between the electrodes (Saputra and Hanum, 2016).

CONCLUSION

The voltage positively influences the system performance, while the distance between the electrodes and flowrate negatively influenced the removal of TSS, TDS, and COD. The optimum conditions obtained in this study were at a flowrate of 0.3 L/min, a voltage of 28 V, a distance between plates of 2 cm with the percent removal of TSS, TDS, COD, respectively 49.30; 49.40; 60 and 30%.

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