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Artikel Penelitian

Application of Batch Electrocoagulation for Pollutant Removal in Tapioca Wastewater: An Environmental Engineering Approach for Sustainable Water Treatment Solutions

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ABSTRACT

Tapioca wastewater is rich in organic compounds, leading to high levels of COD (Chemical Oxygen Demand) and TSS (Total Suspended Solids). When these concentrations exceed regulatory standards, they can cause significant water pollution, which may indirectly affect human health. Therefore, it is essential to treat tapioca wastewater before discharging it into water bodies. Electrocoagulation is a promising treatment method for this purpose, as it can effectively remove contaminants through coagulation, separation, and sedimentation of fine particles using electrical energy. This study evaluated the efficiency of COD and TSS removal from tapioca wastewater using an aluminium electrode with voltage variations of 10, 20, and 30 volts. Initial concentrations of COD and TSS in the untreated wastewater were measured at 641 mg/L and 382 mg/L, respectively. Optimal removal rates were achieved at 20 volts, with reduction efficiencies of 79.5% for COD and 82.7% for TSS. Statistical analysis using ANOVA indicated a significant impact of voltage variations on COD and TSS removal efficiency, with a p-value < 0.05 and an F-value greater than the critical F-value. These findings demonstrate that electrocoagulation, particularly at an optimal voltage of 20 volts, effectively reduces the COD and TSS levels in tapioca wastewater, suggesting its potential application as an environmentally friendly solution for industrial wastewater treatment.

Keywords: Tapioca wastewater, COD, TSS, electrocoagulation, voltage

1. INTRODUCTION

Liquid waste from the tapioca starch industry is generated from the process of making tapioca starch from the washing, extraction, settling, and drying stages which reaches 4000 to 6000 liters per ton of raw material because it requires a lot of water (Djarwati, 2013). In the traditional process, the tapioca industry produces liquid waste reaching 14000 to 18000 liters per ton of cassava (Kemenperin RI), and in another study mentioned the results of liquid waste from the tapioca flour industry up to 40000 liters. Tapioca starch wastewater contains high organic matter (Suparmi, 2013). Tapioca liquid waste has a COD content of 3100-20000 mg/l and TSS (suspended solids) reaching 1500-8500 mg/l (Lilis, 2019). According to Arianti's research (2020), COD levels in tapioca liquid waste reached 12361 mg/l and TSS of 1126 mg/l. The high content of organic matter causes little dissolved oxygen so that COD levels increase. The presence of suspended solids in liquid waste also causes TSS levels to increase (Coniwanti, 2013).

In general, high COD levels also indicate a large number of both pathogenic and non-pathogenic microorganisms (Hariyanto, 2016). These pathogenic microorganisms can cause various diseases to humans such as contracting hives, and digestive tract diseases when using water sources polluted by the effluent. In addition, a high concentration of COD will make the dissolved oxygen content in the water low. Similarly, a high concentration of TSS can inhibit the entry of sunlight into the water, causing dissolved oxygen in the water to decrease. The low dissolved oxygen content in the water will result in oxygen needs for living things in the water not being met, thus disrupting the aquatic ecosystem in the water (Manahan,2012). So it is necessary to do the treatment first before being discharged into the water body.

https://doi.org/10.25077/dampak.21.1.15-22.2024 Attribution-NonCommercial-ShareAlike 4.0 International.

One other alternative method for more efficient treatment of tapioca wastewater is the electrocoagulation method (Himma, 2018). Electrocoagulation has the ability to remove contaminants in water by the process of clumping, separation and precipitation of fine particles using electrical energy and not using chemical synthetic substances (Susetyoningsih, 2008). The electrocoagulation method can remove colloidal particles and various types of pollutants in tapioca wastewater with easy operation, short time, produces less sludge than other methods, and does not require large areas of land (Daniar, 2022). The principle of electrocoagulation technology is that an electric current is applied to an electrode plate to produce ions that can act like a coagulant by binding to contaminants in wastewater.

2. MATERIAL AND METHODS

The type of research conducted is experimental, namely by analyzing samples of tapioca flour liquid waste in the laboratory with the electrocoagulation method using Aluminum (Al) electrodes to determine the removal of COD, and TSS of tapioca flour liquid waste with electrical voltage variations of 10, 20, and 30 volts. The reactor circuit sketch of the reactor circuit is presented in Figure 1.

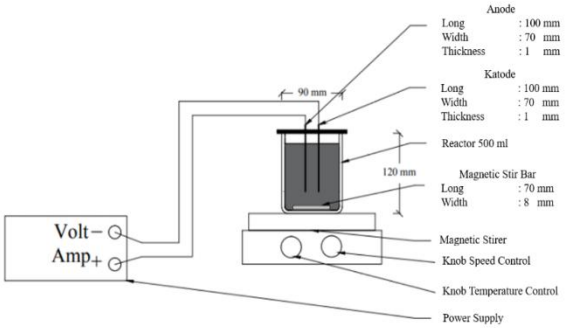


Figure 1. Electrocoagulation Circuit

The steps taken in the electrocoagulation process of tapioca liquid waste are to put a 500 ml sample into a batch reactor measuring 500 ml then the plate is attached to the power supply by varying the voltage value from 10, 20, and 30 volts with a contact time of 5 minutes. the stirring speed is set at 265 rpm with a fast state until it is continued with slow stirring to form larger flocs. the resulting floc sediment will then be tested for COD, TSS, and record the optimal voltage.

a. COD Measurement

COD measurement is carried out by spectrophotometric method, namely liquid waste samples that have been electrocoagulated for 2 ml mixed with COD reagent and then homogenized. after that turn on the COD reactor with a temperature of 150^{o}C, input a vial containing a blank solution containing distilled water heated for up to 2 hours. the blank is cooled to room temperature and inserted into the spectrophotometer to serve as a calibration. after the tool is calibrated, enter the sample into the vial to be tested on the spectrophotometer and take measurements of the COD in the sample.

b. TSS Measurement

TSS measurement was carried out according to SNI 6989.3: 2019 by gavimetry. the testing process was carried out using a petri dish containing filter paper which was oven dried for 1 hour at 150^{o}C for 1 hour and cooled in a desiccator for 15 minutes. the prepared wastewater sample was poured into a measuring cup of 50 ml then homogenized and slowly inserted into the erlenmeyer through the filter paper. then transfer the filter paper to a petri dish and dried at 150^{o}C for 1 hour and cooled in a desiccator for 15 minutes. The TSS obtained on the filter paper was then weighed and calculated with the following formula:

$$\text{TSS (mg/L)} = \frac{(W1\text{-}W0) \times 1000}{V \text{ sample}}$$

Explanation :

W0 : weight of the weighing medium containing the initial filter medium (g);

W1 : weight of weighing media containing filter media and dry residue (g);

V : volume of test sample (L);

1000 : gram to milligram conversion.

The analysis in this study was carried out in a descriptive and statistical way with the one way ANova test to determine the effect between the voltage variations used on COD and TSS levels after processing with the electrocoagulation method using the help of the IBM SPSS Statistic 25 for window program. The normality test uses Shapiro Wilk because the sample n < 30, at a significant level (α) = 0.05 (Astutik, 2011).

3. RESULT AND DISCUSION

Characteristics of tapioca liquid waste taken for the research sample physically looks cloudy, brownish in color, and there are solid deposits. After laboratory analysis, the initial characteristics of tapioca liquid waste are presented in **Table 1.**

Tabel 1. Test results of initial levels of COD and TSS parameters of tapioca liquid waste

No	Parameter	Unit	Quality Standards	Test Results
1	COD	Mg/L	300	641 ± 14,5
2	TSS	Mg/L	100	382 ± 6,4
3	pH	Mg/L	6-9	6,36

**Quality standards refer to Peraturan Menteri Lingkungan Hidup Republik Indonesia Nomor 5 tahun 2014 tentang Baku Mutu Air Limbah*

Table 1. shows that the COD and TSS levels of tapioca liquid waste before treatment with the electrocoagulation method are still far above the established quality standards. The high level of COD in tapioca liquid waste is due to the presence of organic matter from cassava, and the remaining undigested starch during the production process which then dissolves with water, causing little oxygen dissolved in tapioca liquid waste. High TSS levels are characterized by a large amount of solids suspended in liquid waste. The suspended solids come from the remaining tapioca, fiber, and starch that are not fully dissolved, as well as impurities from the raw materials that are carried into the wastewater (Rachmawati, 2015). This causes water pollution that can reduce the amount of sunlight and lower dissolved oxygen levels in the water. pH measurement is important in wastewater treatment. The right pH can affect the efficiency of treatment processes, such as particle settling, coagulation, or other chemical processes. From the measurement results, the pH shows a value that has met the established quality standard, which is from the range of 6-9.

A. COD Removal Efficiency of Tapioca Liquid Waste after Electrocoagulation Process

COD measurement was carried out to determine the amount of oxygen needed to chemically oxidize organic and inorganic materials contained in wastewater. From the measurement of the initial COD level, the results obtained reached 641 mg/l. After the electrocoagulation process using voltage variations, it can be seen that COD levels are reduced. The removal of COD levels with voltage variations can be seen from the graph in **Figure 2.**

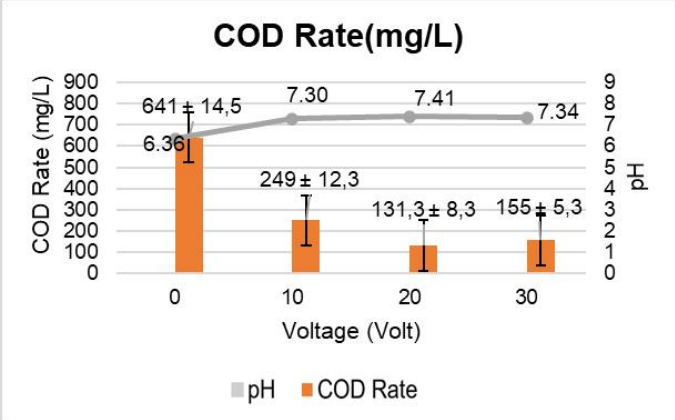


Figure 2. Measurement of COD and pH

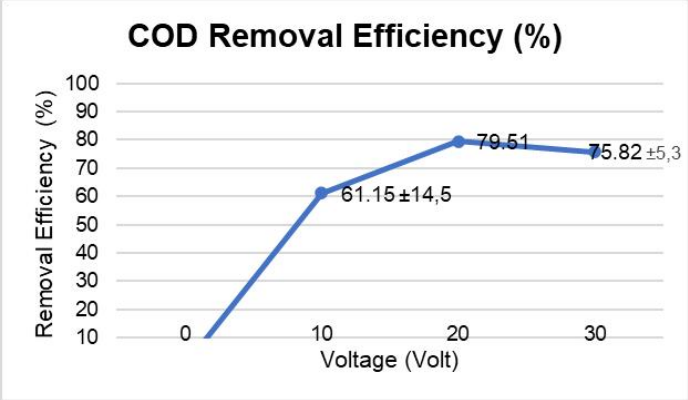


Figure 3. COD elimination efficiency

Based on **Figure 2**, it can be seen that the variation of applied voltageaffects the removal of COD levels of tapioca liquid waste. From **Figure 3** it can be seen that the percentage of removal of COD levels of tapioca liquid waste obtained reached 79.51%. In the treatment of 10 volt voltage variation, the percentage of removal from the initial level was 61.15%. Then the percentage of removal increased at a voltage variation of 20 volts which reached

79.51%, but at a voltage variation of 30 volts the percentage decreased to 75.82%. The highest percentage of COD removal occurred in the 20-volt variation. The reduction of COD content of tapioca liquid waste from the initial level and the increase in the percentage of removal after the electrocoagulation process are influenced by, the electric current flowing, the pH of the wastewater, the applied voltage and the electrodes used(Can, 2014). When the electric current increases, the formation of ions at the anode and cathode will also increase (Cerqueira,2012). From the electric current and voltage applied, it causes a reaction from the aluminum electrode used, at the anode a reaction will occur:

$$Al_{(s)} \qquad Al^{3+}_{(aq)} + 3e^-$$

Katode **:**

$$2H_2O_{(l)} + 2e^- \qquad H_2(g) + 2OH^-_{(aq)}$$

The result of the anode and cathode reaction is**:**

$$Al_{(s)} + 3H_2O_{(l)}{}^- \qquad Al(OH)_{3(s)} + 3/2H_{2(g)}$$

In the reaction that occurs, it will form the aluminum hydroxide compound $Al(OH)_3$ which acts like a coagulant because it helps clumping in the precipitation of dissolved and colloidal particles in wastewater. $Al(OH)_3$ will make colloidal particles formed in water unstable so that they lose charge and then form flocs (Aminoto, 2019). lon hydroxide (OH^-) formed will also react with dispersed particles or solutes in wastewater and help the floc clumping process. While the reduction reaction at the cathode will produce H_2 gas which functions to lift the floc to the surface, assisted by the number of hydroxide ions which causes the energy for the formation of hydrogen and oxygen gas to be lower so that gas bubbles will be produced which improve the flotation process (Bharath,2018). The existence of the given electrical voltage causes more aluminum hydroxide and bubbles (gas) to form. When the voltage strength is high, the speed of aluminum hydroxide formation increases so that it reduces more contaminants in tapioca liquid waste, as evidenced by increasing the voltage from 10 volts to 20 volts, the percentage of removal increases, but after increasing it to 30 volts the percentage of removal decreases slightly. This is because a large voltage does not always provide optimum results, if the voltage is higher, the time required for precipitation should be longer (Ahsan et al, 2015). A voltage that is too high causes floc instability so that the electrode experiences saturation and then the floc falls to settle and reacts again at the anode-cathode, causing the removal percentage to decrease (Amelia et al, 2019).

B. TSS Removal Efficiency of Tapioca Liquid Waste after Electrocoagulation Process

TSS measurement is carried out to determine the amount of suspended solids or undissolved solids in liquid waste. The measurement results of the initial TSS level of tapioca liquid waste are 382 mg/l. So that further processing is carried out with the electrocoagulation method After obtaining the results of measuring TSS levels from the voltage variations used, TSS levels drop from the initial levels. The elimination of TSS levels is presented in **Figure 4**.

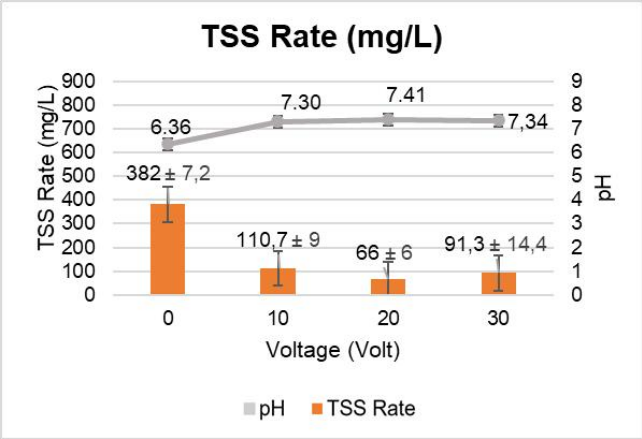


Figure 4. Measurement of TSS and pH

Based on **Figure 4**. it can be seen that variations in voltage can affect the removal of TSS levels from tapioca liquid waste. The highest removal of TSS levels occurred in the 20 volt variation. pH in TSS measurements is the same as the pH value in COD measurements because the effluent samples tested are the same. pH of wastewater after being treated with electrocoagulation is in a neutral condition (Liu, 2010). After knowing the results of TSS level removal, then the percentage of removal is calculated. The percentage of TSS level removal is presented in **Figure 5**.

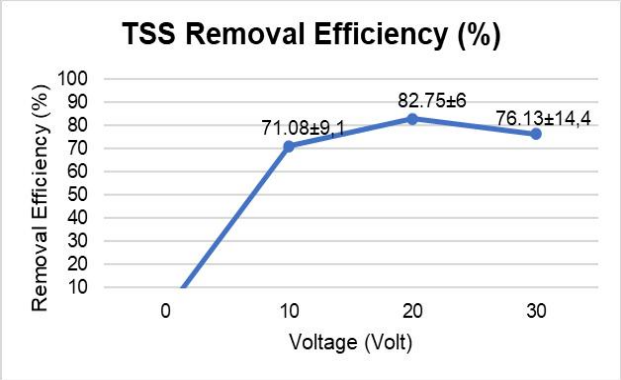


Figure 5 . TSS elimination efficiency

Based on Figure 4.6, it can be seen that the percentage of removal of TSS levels of tapioca liquid waste obtained reached 82.72%. In the 10 volt voltage variation treatment, the percentage of removal from the initial level was 71.08%. Then experienced an increase in the percentage of removal at a voltage variation of 20 volts which reached 82.7%, but in the 30 volt voltage variation the percentage decreased to 76.09%. The highest percentage of removal of TSS levels occurred in the 20 volt variation. TSS levels can decrease due to the electrocoagulation process carried out using aluminum electrodes forming Al (OH) 3 compounds which help form flocs to bind suspended particles in wastewater (Sahu, 2014). The use of too high a voltage causes heating around the electrode and wastewater, resulting in increased temperature. The increase in temperature can reduce the solubility of precipitated particles and make it more difficult to separate so that when the voltage is increased to the highest voltage of 30 volts the results are less optimal than when treated with 20 volts 9 (Al-Ansari, 2020).

During the wastewater filtration process after the electrocoagulation process, it is possible that the floc contained in the wastewater is still filtered out, so that the percentage of removal obtained is not too large (Doe, 2021). pH in wastewater also has an influence on TSS content, so that an optimal pH in wastewater can help precipitate particles well and reduce TSS content in wastewater (S.Huang et al, 2019). Based on the measurement results, the TSS level obtained from the 10-volt voltage variation is slightly higher than the quality standard, but when using the 20-volt and 30-volt voltage variations, the TSS level is below the specified quality standard.

C. Statistical Analysis of the Effect of Voltage Variations on the Removal of COD and TSS Levels of Tapioca Liquid Waste

A series of ANOVA tests were conducted using a significance assumption of 0.05. Significance of 0.05 was chosen because the assumed confidence level is 95% and the hypothesis taken has an error rate of 5%. This is based on things that allow limitations to occur when conducting research, so that the accuracy of the results obtained is not too strict. The ANOVA test begins by conducting a normality test and homogeneity test first to determine whether the research data is normally distributed or not, the decision-making analysis for the normality test is carried out using the Shapiro-Wilk test because the amount of research data is less than 30. From the results of the significance of all data in the normality and homogeneity tests, it shows the Sig> 0.05 value. At a significance level of 0.05 if the p-value is greater than 0.05, it can be concluded that the data follows a normal distribution and is acceptable (Hendriarianti, 2011). The data from the normality test and homogeneity test can be seen in **Table 6.** and **Table 7**.

Table 2. Normality test results

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Variasi Tegangan	Statistic	df	Sig.	Statistic	df	Sig.
Measurement of COD	0 Volt	0.194	3	.	0.996	3	0.886
	10 Volt	0.325	3	.	0.876	3	0.312
	20 Volt	0.292	3	.	0.923	3	0.463
	30 Volt	0.314	3	.	0.893	3	0.363
Measurement of TSS	0 Volt	0.276	3	.	0.942	3	0.537
	10 Volt	0.196	3	.	0.996	3	0.878
	20 Volt	0.175	3	.	1.000	3	1.000
	30 Volt	0.361	3	.	0.807	3	0.132

Table 3. Homogeneity Test Results

		Levene Statistic	Df1	Df2	Sig.
Measurement COD	Based on Mean	0.971	3	8	0.453
	Based on Median	0.401	3	8	0.756
	Based on Median and with adjusted df	0.401	3	6.083	0.758
	Based on trimmed mean	0.923	3	8	0.463
Measurement TSS	Based on Mean	1.678	3	8	0.248
	Based on Median	0.211	3	8	0.886
	Based on Median and with adjusted df	0.211	3	3.567	0.884
	Based on trimmed mean	1.494	3	8	0.288

Based on the results obtained in the Test of Homogeneity of Variances, the probability value or significance is more than 0.05, so the assumption that the three voltage variations are the same (homogeneous) and can be accepted. After that, the ANOVA statistical analysis results will appear from the distribution of the research data. In the ANOVA (Analysis of Variance) test, the main objective is to compare the means of three or more different groups. The ANOVA test results are presented in **Table 4**.

Table 4. Anova Test Results

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Measurement COD	Between Groups	504646.250	3	168215.417	1464.866	.000
	Within Groups	918.667	8	114.833		
	Total	505564.917	11			
Measurement TSS	Between Groups	195731.667	3	65243.889	689.196	.000
	Within Groups	757.333	8	94.667		
	Total	196489.000	11			

From the results of the ANOVA statistical test conducted, it can be seen that the probablitias or significant value shows 0.000, which means that the Sig value is <0.05 or in decision making, H0 is rejected. There are two hypotheses in making decisions on this statistical test, namely H1 and H0. H1 means that there is a significant effect on the voltage variation used on the removal of COD and TSS levels, while H0 means that there is no significant effect on the voltage variation used on the removal of COD and TSS levels. Because H0 is rejected, it means that H1 is accepted (A. Field, 2013). In addition, it is shown by the value of F count and F table. F count is the F value of the analysis calculation results that will be compared with the F table value, while F table is the comparison value, so it must show the value of F count > F table. The calculated F value from Figure 4.9 for COD is 1464.8 and TSS is 689.1 while the F table used is 3.10. So from the ANOVA test it can be concluded that there is a significant influence between the voltage variations given to the removal of COD and TSS levels of tapioca liquid waste by the electrocoagulation method.

To determine the significant differences between the three variations used, further analysis was carried out with the BNT (Least Significant Difference) test using the Post Hoc Test LSD (Least Significant Difference) on SPSS. BNT test results are presented in **Table 5**.

Multiple Comparisons

Dependent Variable	(I)Voltage Variation	(J) Voltage Variation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Measurement	0 Volt	10 Volt	8.750	392.000	.000	371.82	412.18

COD		20 Volt	8.750	509.667	.000	489.49	529.84
		30 Volt	8.750	486.000	.000	465.82	506.18
	10 Volt	0 Volt	8.750	-392.000	.000	-412.18	-371.82
		20 Volt	8.750	117.667	.000	97.49	137.84
		30 Volt	8.750	94.000	.000	73.82	114.18
	20 Volt	0 Volt	8.750	-509.667	.000	-529.84	-489.49
		10 Volt	8.750	-117.667	.000	-137.84	-97.49
		30 Volt	8.750	-23.667	.027	-43.84	-3.49
	30 Volt	0 Volt	8.750	-486.000	.000	-506.18	-465.82
		10 Volt	8.750	-94.000	.000	-114.18	-73.82
		20 Volt	8.750	23.667	.027	3.49	43.84
Measurement TSS	0 Volt	10 Volt	7.944	271.333	.000	253.01	289.65
		20 Volt	7.944	316.000	.000	297.68	334.32
		30 Volt	7.944	290.667	.000	272.35	308.99
	10 Volt	0 Volt	7.944	-271.333	.000	-289.65	-253.01
		20 Volt	7.944	44.667	.000	26.35	62.99
		30 Volt	7.944	19.333	.041	1.01	37.65
	20 Volt	0 Volt	7.944	-316.000	.000	-334.32	-297.68
		10 Volt	7.944	44.667	.000	-62.99	-26.35
		30 Volt	7.944	-25.333	.013	-43.65	-7.01
	30 Volt	0 Volt	7.944	-290.667	.000	-308.99	-272.35
		10 Volt	7.944	-19.333	.041	-37.65	-1.01
		20 Volt	7.944	25.333	.013	7.01	43.65

From the results of the BNT test, if the resulting significance value is less than 0.05, it means that there is a significant difference or significantly different between voltage variations. For the results of COD levels, it can be seen that the significance value that is more than 0.05 is in the voltage variation of 20 volts with a voltage of 30 volts, meaning that the voltage variation of 20 volts with 30 volts on COD levels is not significantly different or significant. As for the results of TSS levels, the significance value that shows more than 0.05 is in the voltage variation of 10 volts with 30 volts, and 20 volts with 30 volts, which means that there is no significant difference between these variations on TSS levels. It can be concluded that in addition to the comparison of the variations mentioned, the comparison of other variations shows significant differences.

4. CONCLUSION

Based on the analysis carried out regarding the removal of COD and TSS levels in the liquid waste of the tapioca flour industry using the electrocoagulation method. The initial characteristics of tapioca flour wastewater before processing with electrocoagulation are brownish murky in color, and there are solid deposits. From the results of laboratory analysis, the initial COD level of tapioca liquid waste is 641 mg/l, and for TSS levels is 382 mg/l, which means it still exceeds the quality standards. The efficiency of removal of COD levels after the electrocoagulation process with a voltage variation of 10 volts is 61.15%, when the voltage of 20 volts is 79.5% and at a voltage variation of 30 volts is 75.8%. As for the percentage of removal of TSS levels when the voltage variation of 10 volts is 71%, the voltage variation of 20 volts reaches 82.7% and at a voltage variation of 30 volts is 76%. With the optimum voltage variation at 20 volts. ANOVA test results show a significant value <0.05 or in decision making, H0 is rejected and the value of F count> F table, meaning that there is a significant influence between voltage variations on the removal of COD and TSS levels of tapioca liquid waste.

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