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Influence of Electrode Surface Area and Processing Time on *Chemical Oxygen Demand* (COD) and *Total Suspended Solid* (TSS) Reduction in Tofu Wastewater Using Electrocoagulation

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ABSTRACT

Electrocoagulation is a wastewater treatment process that uses electrochemical working principles to remove contaminants in solutions or wastewater. Where at the anode (negative current) metal ions are released into solution, while at the cathode (positive current) an electrochemical reaction occurs, namely the release of H_2 (hydrogen) gas. Factors that influence the electrocoagulation process include electrode type, current strength, electrode cross-sectional area, process time, voltage, stirring, distance between electrodes, and acidity level (pH). The objective of this research is to investigate the effect of the surface area of the electrode and processing time on the COD and TSS of tofu wastewater. In this research, tofu industry liquid waste was processed using the electrocoagulation method using fixed variables including, Fe-Fe type electrodes, 4 electrodes, acidity level at 4, tofu liquid waste temperature at 25° C, distance between electrodes 2 cm, electrode thickness 2 mm, test sample of 4 liters and current strength of 13 V. The changing variables used are electrode cross-sectional area (70 cm² and 60 cm²) and processing time (30, 45, 60, 75, 90 minutes). In this study, the best conditions for reducing COD and TSS levels were obtained with a cross-sectional area of 70 cm² and a process time of 60 minutes for reducing COD levels and 30 minutes for reducing TSS levels. With a reduction in COD levels of 690.66 mg/L and a reduction in TSS levels of 181.25 mg/L. The results of reducing COD levels do not meet the tofu industry wastewater quality standard of 300 mg/L, and the results of reducing TSS levels meet the tofu industry wastewater quality standard of 200 mg/L.

Keywords: electrocoagulation, tofu industry liquid waste, COD, TSS, wastewater

1. INTRODUCTION

Tofu is a food made from soybeans and has a very high protein content [1]. The content found in tofu includes 68 grams of calories, 7.8 grams of protein, 4.6 grams of fat, 1.6 grams of carbohydrates, 12.4 grams of calcium, and 6.3 grams of phosphorus [2]. The tofu industry in Indonesia is growing very rapidly, with one of the tofu industries located in Banyumas Regency, Central Java, situated in the village of Kalikidang. The tofu industry in Kalikidang Village, Sokaraja, Banyumas, Central Java, Indonesia consists of 78 home-scale producers. However, attention to the disposal of tofu wastewater is lacking [3]. It is known that out of the total tofu producers, only 37 have wastewater treatment facilities. That means 52% of producers do not have waste treatment facilities.

In this study, the processing of tofu industry liquid waste located in Kalikidang Village will be carried out using the electrocoagulation method with parameters for reducing COD and TSS levels. The tofu liquid waste samples were taken from one of the producers located in Kalikidang Village. Whereas in one day, it can produce 25 kg of tofu and generate 500 liters of tofu wastewater per day. The disposal of production waste is carried out without any prior treatment and is dumped into the water channels (ditches) of residential areas, which can pollute the ecosystem and the environment.

The electrocoagulation method is a continuous coagulation process using metal electrodes and passing an electric current through the process of electrolysis/electrochemistry, specifically the disruption of electrolyte decomposition [4].

Previous research has shown that the electrocoagulation method can reduce COD levels by 78.7% and TSS by 88% [5].

2. MATERIALS AND METHODS

2.1 Materials

Liquid waste from the tofu industry, iron plate (coagulant), organic-free water, $K_2Cr_2O_7$, H_2SO_4, $HgSO_4$, Ag_2SO_4, filter paper with 0.50 mm porosity (Sigma Aldrich)

2.2 Experimental procedure

This research was conducted to determine the effect of electrode cross-sectional area and processing time on the reduction of COD and TSS levels in tofu industry liquid waste using the electrocoagulation waste treatment method. This research was conducted at the Basic Chemical Engineering Instructional Laboratory of Muhammadiyah University Purwokerto with wastewater samples from the tofu industry in Kalikidang Village, Sokaraja, Banyumas Regency, Central Java.

The electrocoagulation process was carried out using Fe-Fe type electrode plates, with variations in electrode cross-sectional area of 70 cm² and 60 cm², and processing times of 30, 45, 60, 75, and 90 minutes. The initial characteristics of the waste were analyzed before treatment according to the wastewater quality standards for the tofu industry as per the Minister of Environment Regulation No. 5 of 2014. After the electrocoagulation process, the COD and TSS content were analyzed as processing parameters.

2.3 Methods of analysis

2.3.1 Analysis of COD (*Chemical Oxygen Demand)*

COD analysis is performed using spectrophotometry. The test sample placed in the culture tube is then added with digestion solution and sulfuric acid reagent solution. The culture tube is closed and gently shaken until homogeneous. The reflux process was carried out using a COD reactor at a hot temperature of 150℃ for 2 hours. After cooling to room temperature, the suspension is allowed to settle, and the part to be measured is ensured to be completely clear. The samples were then measured using a spectrophotometer with a wavelength of 600nm for samples with COD values of 100 – 900 mg/L and 420 nm for samples with COD values of ≤ 90 mg/L. The absorption reading results are entered into linear regression. The COD value (Mg O_2/L) is the result of reading the concentration of the test sample from the calibration curve with calculations according to equation (1).

$$COD\ (Mg\ O2/l) = C \times f \tag{1}$$

where: C = the COD value of the test sample (mg/l); f = the dilution factor [6].

2.3.2 Analysis of TSS (Total Suspended Solid)

The TSS (Total Suspended Solid) test is conducted using the gravimetric method. A filter paper with a pore size of 0.50 mm is placed in a porcelain dish and rinsed with distilled water. Then the filter paper is dried at a temperature of 103-105℃ for 10 minutes before weighing. A total of 10 mL of the sample is filtered using filter paper. The used filter paper is then dried in an oven at 103-105℃ for 1 hour before weighing. TSS (mg/L) is calculated using equation (2).

$$TSS\ (mg/L) = ((A-B)\times 1000)/(Volume\ of\ test\ sample\ (mL)) \tag{2}$$

where: A = weight of filter paper + dry residue (mg); B = weight of filter paper (mg) [7].

3. RESULTS AND DISCUSSION

3.1 The Effect of Electrode Cross-Sectional Area on the Reduction of COD and TSS Levels

The results of the analysis show that the cross-sectional area of the electrode affects the reduction of COD and TSS levels. This is because the larger the cross-sectional area of the electrode used, the greater the electrostatic attraction of the electrode when reducing and oxidizing metal ions in the solution, which can reduce the COD level [8]. Additionally, the reduction in TSS is caused by the production of metal ions (Fe^{3+}) as destabilizing agents at the anode through electrochemical reactions [9]. Metal ions (Fe^{3+}) will bind with colloidal and fine suspended particles, forming larger clumps that easily settle. If the operational electrode cross-sectional area is reduced, the dose of metal ions will decrease and will not be sufficient to destabilize all colloidal and fine suspended particles, resulting in no significant reduction in TSS levels [10].

Table 1. The effect of electrode cross-sectional area and processing time on the reduction of COD

Cross-sectional Area of Electrode	Process Time (minute)					
	0	30	45	60	75	90
70 cm^2	7337.33	5254	1547.33	690.66	784	1380.67
60 cm^2	7337.33	6470.66	3637.33	1424	1520.67	1624

Tabel 2. The effect of electrode cross-sectional area and processing time on the reduction of TSS

Cross-sectional Area of Electrode	Process Time (minute)					
	0	30	45	60	75	90
70 cm^2	234	181.25	130.45	101	79	58
60 cm^2	234	183	144.5	122.25	86.5	70.75

From Tables 1 and Table 2, the best results from the influence of electrode cross-sectional area on the reduction of COD and TSS levels were obtained at an electrode cross-sectional area of 70 cm^2 with a processing time of 60 minutes, resulting in a COD reduction value of 690.66 mg/L and a TSS reduction value of 181.25 mg/L. The research findings in this study are consistent, where the reduction of COD in tofu industry wastewater using the electrocoagulation method with an electrode cross-sectional area of 99 cm^2 and a voltage of 13 volts can reduce COD levels by 78% [11]. In another study, a reduction in TSS levels was achieved using the electrocoagulation method with textile wastewater samples, a voltage of 12 volts, and 4 electrodes, which can reduce TSS levels by 85% [12].

3.2 The Influence of Process Time on the Reduction of COD and TSS Levels

The results of the analysis show that the processing time has an effect on the reduction of COD and TSS levels. In the case of COD reduction, it occurs when the processing time is extended, making the electrocoagulation process more effective and affecting the ion solution oxidized by the cathode, causing organic compounds to accumulate and form flocs [13]. Additionally, the reduction in TSS levels is due to the contact duration with the electrode being proportional to the amount of charge flowing during the electrocoagulation process, and this tendency is based on the impact of flocculant production. Thus, it can reduce the TSS levels [14].

From Figure 1 and Figure 2, the best results from the influence of processing time on the reduction of COD and TSS levels are at a processing time of 60 minutes, which yields the best COD reduction value of 690.66 mg/L (70 cm^2 electrode) and a COD level of 1424 mg/L (60 cm^2 electrode), as well as at a processing time of 30 minutes, which yields the best TSS reduction value of 181.25 mg/L (70 cm^2 electrode) and a TSS level of 183 mg/L (60 cm^2 electrode). The research results obtained are consistent with previous studies, where the reduction of COD levels in tofu wastewater using the electrocoagulation method with a processing time of 30 minutes and a voltage variation of 20 V can reduce COD levels by 21% [15]. Additionally, previous research showed that the best TSS reduction level obtained was 91% [16].

4. CONCLUSION

The conclusions drawn from the study on the effect of electrode cross-sectional area and processing time on the reduction of COD and TSS levels in tofu industry wastewater using the laboratory-scale electrocoagulation method with a wastewater sample capacity of 4 liters, voltage of 13 volts, and using Fe-Fe electrodes are as follows:

1. The electrode cross-sectional area and processing time that resulted in the best COD reduction value were at an electrode cross-sectional area of 70 cm^2 and a processing time of 60 minutes, with a COD reduction value of 690.66 mg/L.
2. The electrode cross-sectional area and processing time that resulted in the best TSS reduction value were at an electrode cross-sectional area of 70 cm^2 and a processing time of 30 minutes, with a TSS reduction value of 181.25 mg/L.

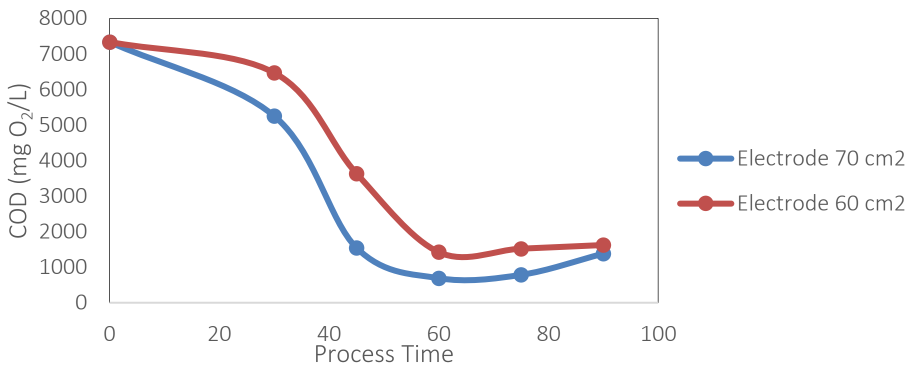

Figure 1. Graph of the relationship between electrode cross-sectional area and processing time on COD reduction

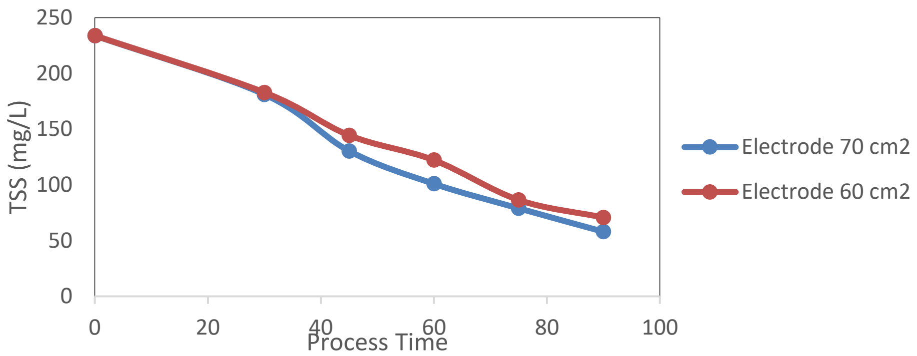

Figure 2. Graph of the relationship between electrode cross-sectional area and processing time on TSS reduction

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CONFLICT OF INTEREST

No potential conflict of interest was reported by the author(s).

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Dani Faizal: Data curation, Formal analysis, Investigation, Writing an original draft.

Anila Wirantika: Investigation, Writing-edited-review

Neni Damajanti: Conceptualization, Methodology, Investigation, Formal analysis, Writing-edited-review, Supervision.

All authors have read and agreed to the published version of the manuscript.

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