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Reduction of COD and BOD Levels in Tofu Liquid Waste Processing Using the Electrocoagulation Method

Suci Amanda[1], Masthura[1*], and Ety Jumiati[2]
[1] *Physics Program, Fakultas Sains dan Teknologi, Universitas Islam Negeri Sumatera Utara, Jl. Lapangan Golf, Medan, 20353, Indonesia*
[2] *BPFK Medan Kemenkes RI, Jln. K.H. Wahid Hasyim No. 15 Kec. Medan Baru, Kota Medan, Sumatera Utara 20153, North Sumatra, Indonesia*

[*]Corresponding Author: masthura@uinsu.ac.id

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ABSTRACT
Tofu liquid waste treatment is very important because of its high organic content and can cause environmental pollution. This research uses electrocoagulation method with cylindrical aluminum electrodes to lower Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels. The variation of the treatment time used is 45, 60, and 75 minutes with a voltage of 12 volts and a distance between the electrodes of 2 cm. The test results showed that the BOD concentration decreased from 816 mg/L to 57–104 mg/L (efficiency 87–93%), while COD decreased from 2696 mg/L to 78–118 mg/L (efficiency 95–97%). In addition, the pH increased from 3.44 to 6.03–6.99 so that it is close to neutral condition. All final results meet the quality standards of liquid waste according to the Regulation of the Minister of Environment and Forestry No. 5 Year 2014, as well as aluminum content according to drinking water quality standards according to Permenkes No. 492/MENKES/PER/IV/2010. Thus, electrocoagulation using cylindrical electrodes is proven to be effective, environmentally friendly, and potentially applied to small to medium-scale tofu waste treatment.

Keywords: Cylindrical Aluminum, Electrocoagulation, Time Variation, Tofu Wastewater

ABSTRAK
Pengolahan limbah cair tahu sangat penting karena kandungan organiknya tinggi dan dapat menimbulkan pencemaran lingkungan. Penelitian ini menggunakan metode elektrokoagulasi dengan elektroda aluminium berbentuk silinder untuk menurunkan kadar *Biochemical Oxygen Demand* (BOD) dan *Chemical Oxygen Demand* (COD). Variasi waktu perlakuan yang digunakan adalah 45, 60, dan 75 menit dengan tegangan 12 volt dan jarak antar elektroda 2 cm. Hasil pengujian menunjukkan bahwa konsentrasi BOD menurun dari 816 mg/L menjadi 57–104 mg/L (efisiensi 87–93%), sedangkan COD menurun dari 2696 mg/L menjadi 78–118 mg/L (efisiensi 95–97%). Selain itu, pH meningkat dari 3,44 menjadi 6,03–6,99 sehingga mendekati kondisi netral. Seluruh hasil akhir memenuhi baku mutu limbah cair sesuai Peraturan Menteri Lingkungan Hidup dan Kehutanan No. 5 Tahun 2014, serta kadar aluminium sesuai standar kualitas air minum menurut Permenkes No. 492/MENKES/PER/IV/2010. Dengan demikian, elektrokoagulasi menggunakan elektroda silinder terbukti efektif, ramah lingkungan, dan berpotensi diterapkan pada pengolahan limbah tahu skala kecil hingga menengah.

Kata kunci: Aluminium Silinder, Elektrokoagulasi, Limbah tahu, Variasi Waktu

1. Introduction

Tofu is widely consumed in Indonesia, primarily because of its rich protein content and plan-based composition [1]. The characteristic of tofu is its texture that soft, neutral taste, and high nutritional content. until now, most of the tofu production in Indonesia still uses technology simple, which causes the efficiency of the use of raw materials and water has not yet optimum [2]. However, the tofu production process produces a large amount of liquid waste that is cloudy in color and has a pungent odor [3]. This waste is generally discharged directly into the environment without treatment, thus causing water and soil pollution [4]. Tofu liquid waste contains high concentrations of organic pollutants, shown by the values of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) [5]. This high organic content can disrupt the environmental balance, lower dissolved oxygen levels, and even cause the death of aquatic organisms [6]. Therefore, the handling of this liquid waste very important to prevent environmental pollution [7]. High BOD and COD values also indicate the presence of easily decomposed organic compounds that require a lot of oxygen in their degradation process [8]. Based on the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia N umber 5 of 2014, the maximum allowed BOD level is 150 mg/L and COD 300 mg/L. Unfortunately, laboratory test results show that the BOD and COD levels of tofu waste far exceed the limit

One of the alternatives that is starting to be researched a lot is electrocoagulation, which is a method of waste treatment with a direct electric current to produce coagulant ions directly from the electrode [9]. The advantages of this electrocoagulation method include the equipment structure which is simple, easy to operate, and does not require additional chemical coagulant, so it does not cause further neutralization problems [10]. This method can reduce the content of pollutants without the addition of external chemicals. When a current is given, the aluminum electrode releases Al^{3+} ions that react with water to form an $Al(OH)_3$ flock that is able to bind colloidal particles in the waste [11]. The effectiveness of electrocoagulation is influenced by various factors, including voltage, type and shape of electrodes, distance between electrodes, reaction time, and initial pH of waste [12]. From these factors, process time plays a very important role because it is directly related to the number of ions released. Several previous studies reported that the use of cylindrical electrodes is more efficient than plate electrodes because they have a larger surface area. However, there are still challenges such as the formation of scale on the electrode surface and the need to replace the electrode periodically [13].

However, challenges in this technology remain, such as scale formation on the electrode surface and the need for periodic electrode replacement [14]. Therefore, further research is needed related to optimization of time parameters and electrode shape to improve process efficiency. The aim of this study is to assess how effective the electrocoagulation method is when using aluminum electrodes with a cylindrical design electrode in lowering BOD and COD concentrations in tofu wastewater, with treatment durations of 45, 60, and 75 minutes. The findings are expected to offer an alternative solution for treating tofu industrial effluent in a manner that is efficient, cost-effective, and environmentally sustainable.

2. Method

2.1. Tools and Materials

This research was conducted at the Basic Physics Laboratory of the State Islamic University of North Sumatra and the Environmental Health and Disease Control Engineering Center (BTKLPP) Medan. A sample of tofu liquid waste was obtained from one of the household industries at Pasar V Helvetia, Deli Serdang Regency, North Sumatra.

The electrode used is a cylindrical aluminum with a length of 10 cm, a diameter of 19 mm, and a thickness of 0.2 mm, consisting of two types, namely perforated and non-perforated electrodes. Supporting equipment used include 1000 mL beaker glass as a reactor, DC power supply with 12 volts voltage, multimeter, cable and alligator clamp, stopwatch, and filter paper to separate the coagulation results.

2.2. Research procedures

The tofu liquid waste sample is put into a beaker with a capacity of 1000 mL, then two cylindrical aluminum electrodes are installed parallel with a distance of 2 cm. The electrode is connected to a direct current (DC) source with a constant voltage of 12 volts. The treatment is carried out with a time variation of 45, 60, and 75 minutes. After the electrocoagulation process is completed, the sample is filtered using filter paper, then tested for Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) parameters according to the standard method. The test results are compared to the quality standards of liquid waste according to the Regulation of the Minister of Environment and Forestry No. 5 Year 2014 to assess the effectiveness of electrocoagulation methods.

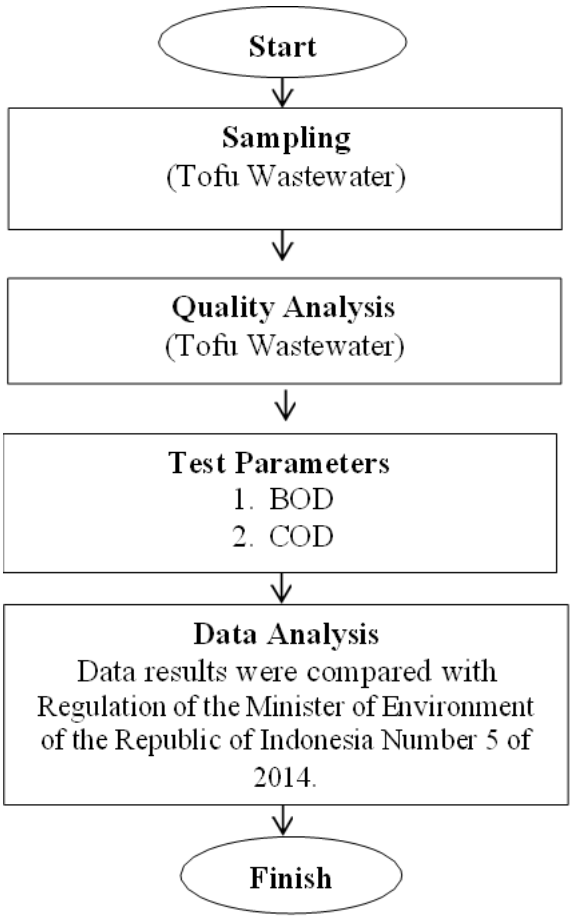

Figure 1. Flowchart of tofu liquid waste testing before electrocoagulation process.

The next stage after electrocoagulation is to evaluate tofu liquid waste samples to see changes in their quality. The waste used came from one of the tofu industries on Jalan Pasar V Helvetia, Deli Serdang Regency, North Sumatra, and was collected in a 1000 mL beaker glass. A spacing of 2 cm was maintained between two cylindrical aluminum electrodes, which were mounted securely on a stand connected to the power source. The electrodes were then connected to a direct current (DC) power source using cables and alligator clips. The voltage used in the process was set at 12 volts, while the treatment duration was varied to 45, 60, and 75 minutes. After treatment, the effluent that had gone through the electrocoagulation process was filtered and tested again for BOD and COD parameters. The findings were then compared to national wastewater discharge standards as outlined in Indonesian environmental regulation (Ministerial Decree No. 5/2014), in order to determine the most effective treatment duration.

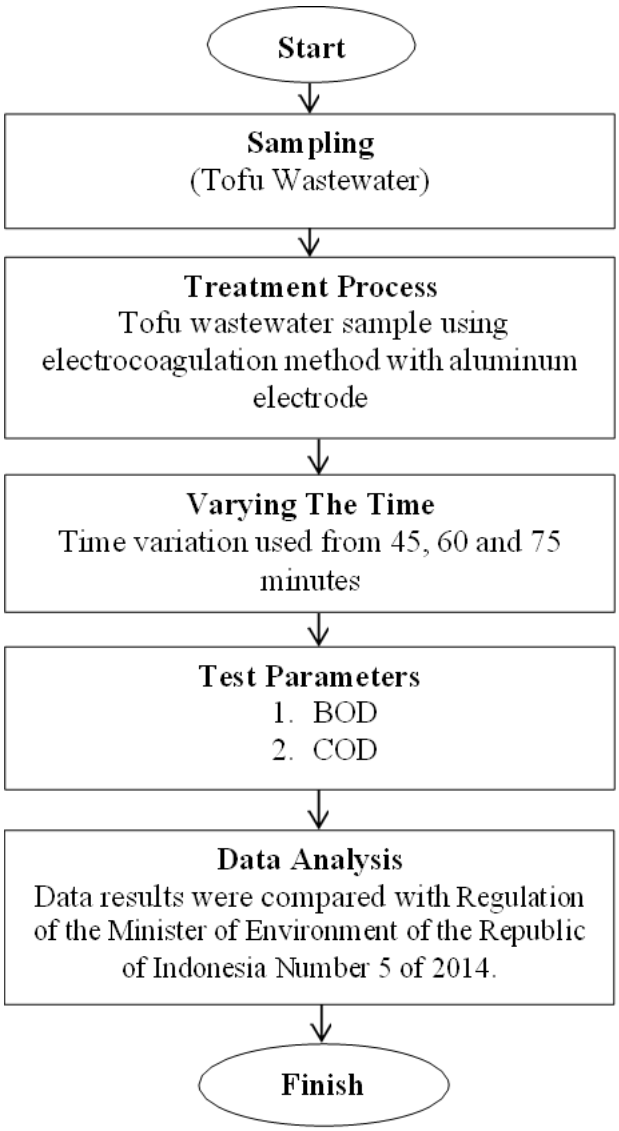

Figure 2. Flowchart of research and testing of tofu wastewater with electrocoagulation method.

For the electrocoagulation process equipment circuit can be seen in the Figure 3.

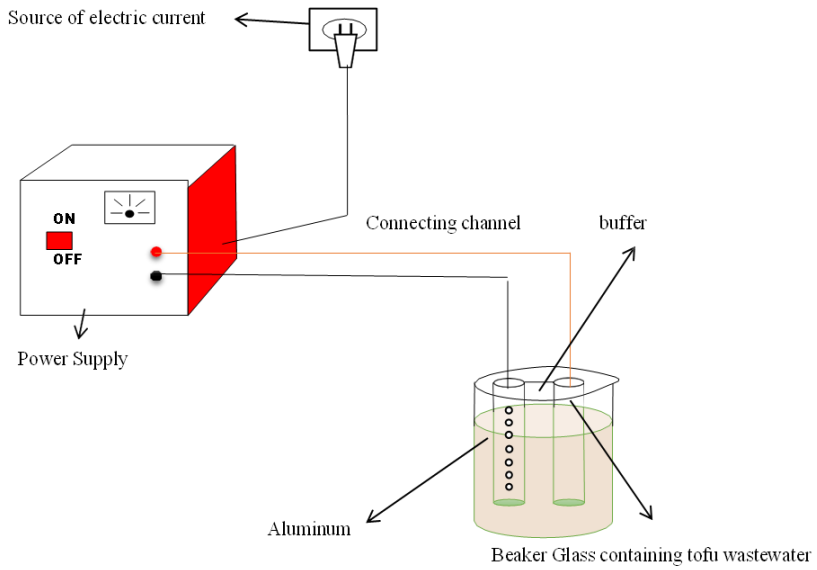

Figure 3. Range of research tools.

3. Result and Discussion

This study employed an experimental approach using tofu wastewater as the research object. Prior to treatment, the wastewater samples were analyzed to determine the pollutant levels. The parameters examined included BOD and COD, which were later evaluated against the standard limits specified in the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 concerning wastewater quality standards.

3.1. Quality of Tofu Wastewater Before Electrocoagulation

Before the undergoing electrocoagulation treatment, the tofu wastewater samples were tested for BOD and COD levels. Table 1 shows the initial analytical results.

Table 1. Display the values obtained from the underrated samples.

Parameters	Result	Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014
BOD	816 mg/L	150 mg/L
COD	2696 mg/L	300 mg/L

Table 1 reveals that both BOD and COD concentration iin the raw tofu wastewater samples prior to treatment significantly exceeded the permissible limits. These findings imply that the wastewater does not fulfill the required environmental standards and may lead to environmental contamination if discharged without adequate treatment measures. According to the test results based on Regulation No. 5 of 2014, the tofu wastewater had a BOD concentration of 816 mg/L, COD of 2696 mg/L, and a pH of 3.44. The concentration of heavy metals in the tofu wastewater was also examined. Compared to the regulatory limits for tofu wastewater set by the same regulation BOD of 150 mg/L and COD of 300 mg/L the results clearly show that the wastewater fails to comply with the established quality standards.

3.2. Quality of Tofu Wastewater After Electrocoagulation

The electrocoagulation process was carried out by applying a direct electric current to cylindrical aluminum electrodes immersed in the wastewater sample. The objective was to reduce pollutant levels through the formation of flocs produced by aluminum ions released from the electrodes. In this study, the treatment duration was varied at 45 minutes, 60 minutes, and 75 minutes, using a constant voltage of 12 volts.

The test results of the tofu wastewater samples after treatment under different time variations are shown in Table 2.

Table 2. Tofu wastewater sample data after electrocoagulation.

Parameter	Result			Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014
	45 minutes	60 minutes	75 minutes	
BOD	104 mg/L	85 mg/L	57 mg/L	150 mg/L
COD	118 mg/L	102 mg/L	78 mg/L	300 mg/L

Table 2 clearly shows a decrease in BOD and COD concentrations as the treatment time increases. The most significant reduction occurred at 75 minutes, where BOD dropped to 57 mg/L and COD to 78 mg/L, both well below the maximum limits specified by the regulation.

Based on Table 2, the BOD concentration decreased significantly following electrocoagulation. The BOD value decreased from the initial 816 mg/L to 104 mg/L after 45 minutes, 85 mg/L after 60 minutes, and 57 mg/L after 75 minutes. The decrease in BOD indicates that the electrocoagulation process effectively removed organic matter. Longer treatment time allows more Al^{3+} ions to be released from the electrodes, forming $Al(OH)_3$ flocs that bind and settle suspended organic particles. All BOD values after treatment met the required environmental standard of 150 mg/L.

A similar trend was observed for COD. As shown in Table 2, the COD value decreased from 2696 mg/L to 118 mg/L at 45 minutes, 102 mg/L at 60 minutes, and 78 mg/L at 75 minutes. This significant reduction demonstrates the effective removal of high molecular weight organic compounds through

flocculation and sedimentation. The final COD concentrations were well below the maximum limit of 300 mg/L, confirming the effectiveness of the electrocoagulation process in purifying tofu wastewater.

These findings are consistent with those reported by Subuharni et al. (2023) [15], the effectiveness of the electrocoagulation method in reducing BOD and COD levels in tofu liquid waste. In their research, electrocoagulation with aluminum electrodes succeeded in lowering the best BOD in 50 minutes is 3.9 mg/L and the best COD in 50 minutes is 10.2 mg/L. The main difference with this study lies in the shape of the electrode used. Subuharni et al. (2023) use a plate-shaped electrode, while this study uses a cylindrical electrode that has a larger surface area. This is suspected to be one of the factors causing the increase in the efficiency of pollutant reduction, especially at a 75-minute contact time which results in higher efficiency. The higher removal efficiency obtained in the present research is likely due to the use of cylindrical electrodes, which provide a larger effective surface area and enhance the interaction between coagulant ions and pollutants. This increased surface contact accelerates floc formation and improves treatment performance.

Based on the laboratory analysis, electrocoagulation with cylindrical aluminum electrodes proved highly effective in reducing BOD and COD concentrations in tofu wastewater. The optimal treatment time was observed at 75 minutes, achieving the lowest pollutant values that fully complied with national wastewater quality standards. These results indicate that the method offers a simple, environmentally friendly, and potentially scalable solution for tofu wastewater treatment, especially for small to medium-sized tofu industries.

3. Conclusion

Electrocoagulation using cylindrical aluminum electrodes proved effective in reducing organic pollutant levels in tofu wastewater. The BOD concentration decreased from 816 mg/L to 104 mg/L, 85 mg/L, and 57 mg/L at treatment durations of 45, 60, and 75 minutes, respectively. Meanwhile, the COD concentration decreased from 2696 mg/L to 118 mg/L, 102 mg/L, and 78 mg/L for the same treatment durations. All final values met the wastewater quality standards set by the Regulation of the Minister of Environment and Forestry No. 5 of 2014. The 75-minute treatment duration produced the optimal reduction in pollutant levels. These results indicate that the electrocoagulation method is suitable, efficient, and environmentally friendly, and it has strong potential for application in small- to medium-scale tofu wastewater treatment systems.

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