# Tofu Industrial Wastewater Treatment by Electrocoagulation Method

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**ABSTRACT**

Tofu waste liquid contains high levels of organic impurities, such as protein and amino acids. These organic compounds cause the tofu industrial wastewater to contain high biological oxygen demand (BOD), chemical oxygen demand (COD), pH and total suspended solid (TSS) which can pollute the environment. In general, the liquid waste from the tofu factory is discharged directly into rivers through sewers and rivers. Most of the tofu wastewater contains various kinds of pollutants which may be produced in the form of organic pollutants (foul smelling), inorganic pollutants (spicy and colored), so they are dangerous to the surrounding environment and need to be treated. One alternative to tofu liquid waste treatment is electrocoagulation. The electrocoagulation method has the potential to purify tofu wastewater and reduce the content of BOD, COD, TSS and neutralize pH without the addition of certain chemical coagulants. The purpose of this study was to obtain the characteristics and levels of pollutants contained in tofu industrial wastewater before and after processing, and to determine the effectiveness of the electrocoagulation method with various variations in voltage and reaction time. The electrocoagulation tub is attached with a cable connected to the power supply, then connected to a current source with a variable voltage (8; 10; 12 V) and a variable reaction time (30; 60; 90; 120; 150 minutes). The optimum conditions were obtained at a voltage variation of 12 volts and a reaction time of 150 minutes, with a percentage increase in pH of 72.33% to 5.98, a decrease in COD of 28.57% to 10 mg/L, a decrease in BOD5 of 46.87% to 2, 29 mg/L, and TSS from 11.47% to 21.6 mg/L.

***Keywords:*** *electrode, electrocoagulation, tofu wastewater*

## 1. INTRODUCTION

The number of developing tofu industries has a positive impact, namely being able to meet market demand, which continues to increase from time to time. However, environmental pollution will occur if the remaining liquid waste of production is not treated correctly. The results of a case study on the Characteristics of Tofu Industry Wastewater in Palembang [1], it was reported that the tofu industrial wastewater containing BOD5, COD, TSS, and oil/fat was 4583 mg/L, 7050 mg/L, 4743 mg/L, and 26 mg/L. Meanwhile, the quality standard of tofu industrial liquid waste is according to the Governor's Decree in the South Sumatra Governor Regulation No. 08/PERGUB/02/2012, the maximum levels allowed for BOD5 and TSS are 75 mg/L, and 50 mg/L, with a pH of 6.0-9.0 [2]. When compared with data on the quality standard of liquid waste for industrial activities according to the Decree of the Minister of Environment No. 5/MENLH/10/2014, the maximum levels allowed for BOD5, COD, and TSS are 150 mg/L, 300 mg/L, and 200 mg/L, as well as a pH of 6-9, so it is clear that the industrial tofu waste has exceeded quality standards required [3-5].

Liquid waste in the tofu production process comes from the soaking process, washing soybeans, washing tofu production process equipment, filtering, and pressing/printing tofu. Most of the liquid waste produced by the tofu-making industry is a thick liquid separated from the clumps of tofu called whey. In general, the liquid waste from the tofu factory is discharged directly into rivers through sewers and rivers. Most of the tofu waste contains various kinds of pollutants produced in the form of organic pollutants (foul-smelling), inorganic pollutants (foamy and colored). The government has established regulations to control water pollution for industrial waste from the tofu industry contains organic and inorganic pollutants. The wastewater cannot be disposed of directly into the river but must be treated first before being disposed of into the river so that pollution does not occur [6-9].

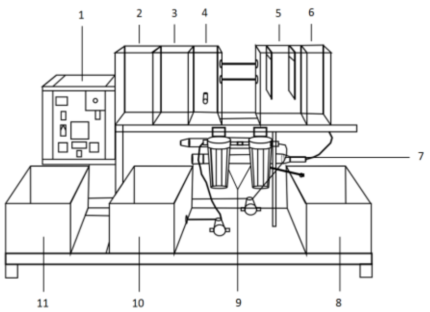
One alternative to wastewater treatment is electrocoagulation. The electrocoagulation process is an electrochemical method for water treatment where at the anode there is a release of active coagulants in the form of metal ions (usually aluminum or iron) into the solution, while at the cathode there is an electrolytic reaction in the form of the release of hydrogen gas [10-13]. The electrocoagulation process is influenced by several factors including electric current, electric voltage, contact time, temperature, pH, and conductivity. The advantages of the electrocoagulation method include that the resulting floc is the same as a regular coagulation floc, is not affected by temperature, does not need pH adjustment and does not need additional chemicals. In contrast, the drawback is that it is not able to process liquid waste with high electrolyte properties because it can cause a short circuit between the electrode and the anode rod which is easy to corrode so that it needs to be replaced periodically [14-18].

## 2. RESEARCH METHODS

This research was conducted to determine the effect of variations on the content and quality of tofu industrial wastewater. The variations used in this research are time and voltage variations. The parameters observed in this experiment were the content of tofu industrial wastewater for each result of this variation.

This study uses time and voltage variations, which aaimsto see the parameters of changes tn the content contained in tofu industrial wastewater in the form of TSS, pH, BOD5, ,and COD from the variations used. The electrode used is aluminum. The time used in the electrocoagulation process varies, namely for (30, 60, 90, 120, 150) minutes, the voltage used varies, namely (8, 10, 12) volts, and with a constant electrode distance of 2 cm, so for each variation, there are 5 the resulting sample.

The schematic of the electrocoagulation device (electrocoagulator) can be seen in Figure 1.




Annotation:

1. *Control Panel*
2. *Carbon Active Filter*
3. *Silica Filter*
4. Reservoir 1
5. Electrocoagulator
6. *Polypropylene* Sponge Filter
7. *Reverse Osmosis* (RO)
8. *Final Reservoir*
9. Cartridge Filter
10. Reservoir 2
11. Feed Reservoir

**Figure** 1 Electrocoagulator scheme

## 3. RESULTS AND DISCUSSION

### *3.1. Initial characterization of tofu wastewater*

The sample used was liquid tofu waste by processing using the electrocoagulation method. Tofu liquid waste samples were taken from the filtering process during the tofu making process.

The results of the tofu industrial wastewater research included analysis of pH, COD levels, BOD5 levels, and TSS levels before and after the electrocoagulation process. The results of the initial analysis of tofu liquid waste can be seen in Table 1.

Table 1. Results of the initial characterization of tofu wastewater

| No. | Parameters | Results |
|---|---|---|
| 1 | pH | 3,47 |
| 2 | COD (mg/L) | 1400 |
| 3 | BOD5 (mg/L) | 431 |
| 4 | TSS (mg/L) | 244 |

### *3.2. Effect of voltage and reaction time on pH*

The pH value shows the acid-base balance in water. Low pH or acidic waste that is harmful to the environment, because it is corrosive, while a pH that is too high or alkaline is also not good for the environment.

From the research that has been done, the obtained pH value data is presented in Figure 2.

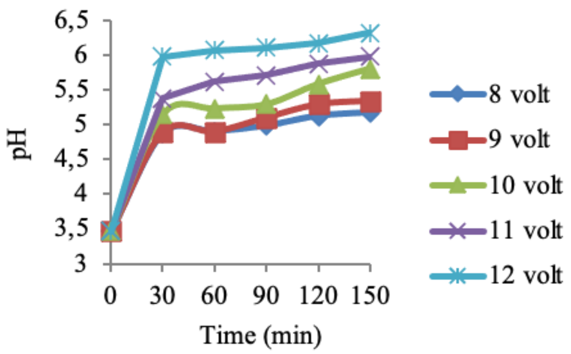



**Figure 2** Effect of voltage and reaction time on pH

From the analysis of pH levels in Figure 2, it is known that the voltage and reaction time also affect pH. Before the research, the initial pH of the waste was 3.47. The low pH value was happened because liquid tofu waste contained high levels of organic matter such as protein and amino acids. From these data, the optimal variable is at 150 minutes with an electrode distance of 2 cm and a voltage of 12 Volt with a pH value of 6.32, so that the pH value obtained from the research results is 82.13%.

The pH value in the electrocoagulation process is caused because at the aluminum electrode cathode, a reduction reaction occurs, wherein the reduction reaction process produce $H^+$ ions and $OH^-$ ions which form water. Voltage significantly affects the pH in electrocoagulation where if the voltage is added, the more $H^+$ and $OH^-$ ions are formed at the cathode electrode, so that if more water is formed, the initial pH is gets more acid and vice versa if the initial pH value is alkaline, then with the reduction reaction process that occurs at the cathode which produces water, the pH will become neutral [19].

Aluminum is the most widely used electrode, where in the electrocoagulation process an anodic dissolution process occurs, the reactions of which [19] are as follows:

$$Al \rightarrow Al^{3+} + 3e \quad (1)$$

The formation of oxygen also occurs at the anode, the reaction is as follows:

$$4\,OH^- \rightarrow O_2 + 2H_2O + 4e \quad (2)$$

In addition, a reaction at the cathode poles simultaneously occurs, namely the formation of hydrogen gas. The reaction that occurs at the cathode depends on the pH of the treated water. Under neutral or basic conditions, gases occur by reaction:

$$2H_2O + 2e \rightarrow 2OH^- + H_2 \quad (3)$$

Whereas in acidic conditions, the reaction for the formation of hydrogen gas is as follows:

$$2H^+ + 2e \rightarrow H_2 \quad (4)$$

So, it can be concluded that the electrocoagulation method can neutralize the pH of wastewater and the processing results obtained almost meet the quality standards set by South Sumatera Governor Regulation No. 8 of 2012 and Indonesian Minister of Environment Regulation No. 5 of 2014, so it is safe to dispose of in the environment.

### *3.3. Effect of Voltage and Reaction Time on COD Level*

Chemical Oxygen Demand (COD) is the amount of oxygen needed to oxidize organic substances in liquid waste by utilizing potassium dichromate oxidizer as a source of oxygen. The COD figure is a measure of water pollution by organic substances, which can naturally be oxidized through biological processes and can cause reduced dissolved oxygen in the water.

Based on the theory that has been explained, it can be concluded that the higher the voltage and the smaller the electrode distance, the more optimal the decrease in COD levels is. This is due to the electric voltage that circulates the electric current, thereby accelerating the electrocoagulation reaction.

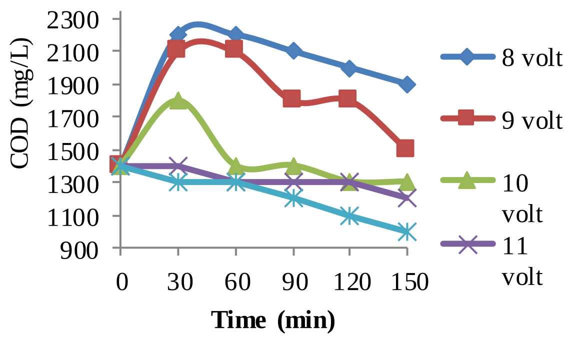



**Figure** 3 Effect of voltage and time on decreasing COD levels

Figure 3 shows a relatively stable decrease in COD levels. The highest COD value was in the sample with a voltage of 8 volts and 30 minutes of 2200 mg/L, so there was an increase of 57.14%. While the lowest COD value in the sample with a voltage of 12 volts and a time of 150 minutes. The high level of COD indicates that there are organic pollutants in a high enough amount. This can cause the dissolved oxygen content in the water to be low. This factor can cause animals and plants in the water to be threatened with death and unable to thrive.

The decrease in COD levels is due to the floc formed by the organic compound ion binds to the coagulant ion, which is positive. The molecules in the tofu liquid waste form into flocks, the colloid particles in the waste bind other particles or compounds in the waste. For example ,colloid $Al(OH)_3$ is positively charged because its surface binds to $H^+$ ions. The working principle that occurs in the formation of flocculated particles is adsorbed, positively charged coagulants absorb negative ions in waste such as organic compounds and form floc which helps the COD reduction process.

The processing is not following the quality standards set by the Governor of South Sumatra No. 8/2012 and Indonesian Minister of Environment Regulation No.5 because the higher the level, it indicates that these substances are still in an unnatural and dangerous amount if circulated directly into the free environment.

### *3.4. Effect of voltage and reaction time on levels of BOD5*

Biological Oxygen Demand (BOD) is the amount of oxygen needed by bacteria to break down residual substances in industrial waste. The higher the level, it means that bacteria need much oxygen. If the BOD level in the waste is still high, but the flow is still carried out into the river, then this make the water biota die because the oxygen intake in the river is fully absorbed by the bacteria that exist to dissolve organic materials.

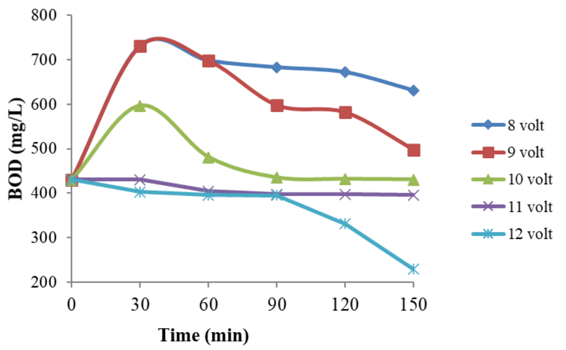



**Figure 4** Effect of voltage and reaction time on levels of $BOD_5$

From Figure 4 it can be seen that the processing that has been carried out has decreased from the initial $BOD_5$ level of 431 mg/L to 229 mg/L. Meanwhile, in some treatments there were still those that experienced an increase in $BOD_5$ levels to 431-732 mg/L. This is due to the effect of the voltage on the metal ionization process at the anode electrode as a determinant of the reaction rate and in the electrocoagulation process to reduce the BOD concentration, where at the anode electrode the aluminum metal oxidation process occurs, resulting in $Al^{3+}$ ions which act as a coagulant, the greater the added voltage. In the electrocoagulation process, the greater the chemical energy produced, where the chemical energy produced is the $Al^{3+}$ ion at the anode electrode which acts as a coagulant, so if the voltage is added the coagulant will be even more, if more coagulants are formed, then more also pollutants that will be bound into floc-floc which will settle, so that the waste becomes clearer than before, so the organic compounds that are left in the liquid waste become more easily degraded by microorganisms [20].

The decrease in BOD levels in this study was only 46.87%. In this processing, the BOD level has not reached the quality standard set by the Governor of South Sumatra No. 8 of 2012, namely with a maximum of 75 mg/L and Indonesian Minister of Environment Regulation No. 5 of 2014 with a maximum of 150 mg/L. The decrease in $BOD_5$ levels is not too significant due to the boundary between waste treatment and testing of $BOD_5$ levels or sample storage time, because based on SNI 6989.72:2009 the samples obtained should not be left for more than 2 hours or if more than 2 hours are stored in a cooler with a temperature under 4 °C.

### *3.5. Effect of voltage and reaction time on TSS*

Suspended solids are all solids (sand, mud, and clay) or particles suspended in water and can be in the form of living (biotic) components such as phytoplankton, zooplankton, bacteria, fungi, or inanimate components (abiotic) such as detritus and inorganic particles. The suspended solid is a place for heterogeneous chemical reactions to take place, and it functions as the earliest sediment-forming material and can hinder the ability to produce organic substances in a waters. The penetration of sunlight to the surface and deeper parts is not effective because it is blocked by suspended solids, so photosynthesis does not take place completely. The distribution of suspended solids in the sea is influenced, among other things, by inputs from land through river flows, or from air and displacement due to sediment resuspension due to erosion [20].

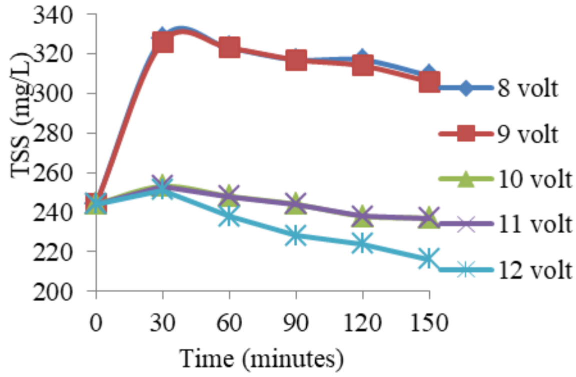



**Figure 5** Effect of stress and reaction time on decreasing TSS levels

Based on Figure 5, it is known that the highest decrease in TSS levels is 216 mg/L at a voltage of 12 volts for 150 minutes. The decrease in TSS levels was only 11.47% and it had not reached the acceptable quality standards. Meanwhile, in some treatments, there were still those who experienced an increase in TSS levels to 244-328 mg/L. This is due to the possibility that during the filtering process of the electrocoagulation results, there are flocks involved. So that for the determination of TSS levels, the waste sample after electrolysis needs to be deposited for a long time to separate suspended solids from water.

The TSS analysis results show that the excess TSS concentration value is indicated by the color of turbid wastewater. This can prevent sunlight from entering the wastewater which is undergoing processing, thus obstructing the photosynthesis process and reducing oxygen levels in the water. If there is only a little oxygen and aerobic bacteria die quickly because the oxygen supply is low and anaerobic bacteria begin to grow. Anaerobic bacteria decompose and use the oxygen stored in the molecules that are being destroyed. The results of the activity of anaerobic bacteria can form hydrogen sulfide ($H_2S$), a gas that smells bad and is dangerous, and several other products.

In this processing, TSS levels have not reached the quality standards set by the Governor of South Sumatra No. 8 of 2012, namely with a maximum of 50 mg/L and Indonesian Minister of Environment Regulation No. 5 of 2014 with a maximum of 200 mg/L. Given the high potential for water pollution due to the tofu-making industrial liquid waste, a strategy to control water pollution is needed by treating the liquid waste before it is discharged into the environment as one of the environmental sanitation efforts.

### *3.6. The effectiveness of the electrocoagulation method in treating tofu wastewater*

Electrocoagulation was able to reduce pollutant levels, namely COD, BOD5, TSS, and the pH of tofu industrial wastewater, the optimum conditions were obtained at a voltage variation of 12 volts and a reaction time of 150 minutes, with an increase in pH of 72.33% to 5.98, a decrease in COD of 28.57% to 10 mg/L, 46.87% decrease in BOD5 to 2.29 mg/L, and 11.47% TSS to 21.6 mg/L.

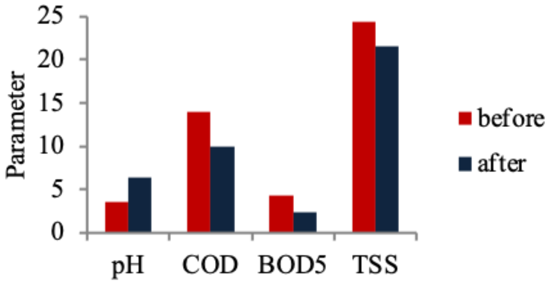



**Figure 6** Effectiveness before and after processing using the electrocoagulation method

## 4. CONCLUSION

The results of the analysis of tofu industrial wastewater before processing had a pH value of 3.47, COD levels of 14 mg/L, BOD5 levels of 431 mg/L, and TSS levels of 244 mg/L, while the levels of tofu industrial wastewater after processing had a value pH levels 6.32, COD levels 1000 mg/L, BOD5 levels 229 mg/L, and TSS levels 216 mg/L. The pH level obtained had reached the quality standard, while COD, BOD5, and TSS were not in accordance with the quality standards stipulated in Pergub No. 8 of 2012 and Permen LHK Hidup RI No. 5 of 2014 concerning the quality standard of liquid waste for the food product industry from raw materials for soybeans (tofu).

The electrocoagulation method was able to reduce the levels of COD, BOD5, TSS, and pH of tofu industrial wastewater. The optimum conditions were obtained at a voltage variation of 12 volts and a reaction time of 150 minutes, with an increase in pH of 82.13% to 6.32, a decrease in COD of 28, 57% to 1000 mg/L, the decrease in $BOD_5$ was 46.87% to 229 mg/L, and TSS was 11.47% to 216 mg/L.

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## AUTHORS' CONTRIBUTIONS

All of the authors are involved in the process of designing the equipment and analysis tofu wastewater. The first and corresponding author contribution is responsible for data processing and manuscript writing. The second author is responsible for equipment design and data processing. The third author is responsible for analysis sample electroplating wastewater. The fourth author is responsible for funding arrangement.

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