Wastewater treatment for tofu home industries in Semanan, West Jakarta using electrocoagulation method with electrode al-stainless steel

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Abstract. Tofu wastewater is dangerous for the aquatic environment because it contains high BOD, COD, and TSS, which will damage life in the river. Tofu home industries in Semanan have not used a proper wastewater treatment system, and this study was conducted to test the electrocoagulation system to reduce the levels of BOD, COD, and TSS. According to several studies, the electrocoagulation system can reduce BOD, COD, and TSS. It is hoped that this electrocoagulation system can solve environmental problems caused by tofu wastewater. From the research that has been done, namely with the stirring variable at a speed of 150 RPM and at a detention time of 10 minutes with a discharge of 0.6 liter/minute, the percentage of COD removal is 36%, the percentage of BOD removal is 27%, and the percentage of TSS removal is 51%. Then on the stirring variable at a speed of 100 RPM and at a detention time of 10 minutes with a discharge of 0.6 liter/minute, the percentage of COD removal is 32%, the percentage of BOD removal is 15%, and the percentage of TSS removal is 58%.

1. Introduction

Tofu waste is waste generated in making tofu in the form of solid and liquid waste. So far, solid waste can be reused as animal feed, but for liquid waste, the impact will result in a foul smell and discolouration of river water if it is directly disposed of without treatment [1]. In the tofu industry, the wastewater produced generally contains high organic compounds. The organic compounds are usually COD, BOD and TSS. If the industrial tofu waste is not treated correctly, it can cause water pollution, a source of disease, and a disturbing odour, so a process for handling the tofu wastewater is needed [2].

In the electrocoagulation process, active coagulants are released in the form of metal ions at the anode (usually aluminium or iron) into the solution. At the same time, an electrolysis reaction occurs in the form of the release of hydrogen ions at the cathode, the process of releasing active coagulants and the release of hydrogen ions in the electrocoagulation process is influenced by several things, including; electric current, voltage, contact time, temperature, pH and conductivity [3]. So it is hoped that the process of releasing active coagulants and hydrogen ions can reduce the pollutant content of COD, BOD, and TSS. The electrocoagulation process is eco-friendly cause it saves chemical use, energy-saving, low operating cost, and saving space in use [4].
2. Methodology

2.1. Time and location
This research was conducted from March 2021 to August 2021, and this research was carried out in the Environmental Laboratory of the Department of Environmental Engineering, Universitas Trisakti, West Jakarta and the testing and analysis of research results was carried out at the Environmental Laboratory of the Department of Environmental Engineering, Universitas Trisakti. Wastewater samples were taken from the sewerage outlet of the Semanan tofu industrial complex, to be precise, the tofu factory owned by Mr. Haji Cahyo, West Jakarta. The reason for choosing the location was because the location specifically produces tofu, so it is hoped that the wastewater content will not be mixed with other wastewater so that the results obtained are representative.

2.2. Research stages
The treatment system used is continuous electrocoagulation with aluminium-stainless steel electrodes, and the preliminary research is oxidation. The following is a chart that explains the stages of the research.

![Figure 1. Stage of preliminary research.](image1)

![Figure 2. Stage of the primary research.](image2)

2.3. A sampling of tofu wastewater
Sampling was carried out at the Semanan tofu factory, where the sampling point was at the tofu wastewater disposal outlet at the Haji Cahyo tofu factory located in the Semanan Tofu Tempe Indonesia Cooperative Area (KOPTI), West Jakarta.

2.4. Characteristic identification of tofu wastewater
In the Table 1, some pollutant parameters will be tested and compared with DKI Jakarta Governor Regulation No. 69 of 2013 and Minister of Environment Regulation No. 5 of 2014.
Table 1. Regulation of tofu wastewater.

| Test Parameters | Standard (mg/L) |
|-----------------|----------------|
|                 | PerGub DKI No.69 of 2013 (mg/L) | Perrin LH No. 5 of 2014 (mg/L) |
| COD             | 75              | 150          |
| BOD₃            | 100             | 300          |
| TSS             | 100             | 200          |
| Nitrate         | 10              | 20           |

2.5. Preliminary research

Preliminary research conducted is to test the process of oxidation and stirring of tofu wastewater samples.

![Figure 3. Sketch of oxidation and stirrer reactor.](image)

![Figure 4. The operation condition of oxidations.](image)

In Figure 3 and Figure 4, the process that occurs is that oxygen will enter the wastewater to increase the oxygen level in the wastewater, then the function of stirring is for mixed the oxygen with the wastewater so that will make maximum distribution of oxygen.

2.6. The primary research of electrocoagulation

The reactor used has a stainless-steel anode that also serves as a stirring rod and uses aluminium as a cathode placed on the base of the reactor. The residence time is setting 20 minutes with a flow rate of 0.3 L/min, a residence time of 10 minutes with a flow rate of 0.6 L/min, and a residence time of 30 seconds with a flow rate of 11 L/min. As well as setting the rotation speed of the stirrer set at 150 rpm, 100 rpm and 50 rpm, and with fixed voltage electricity sourced from 12V 65Ah battery capacity. The following is contained in the Table 2 the variation of the research variables carried out.

Table 2. Variable variation of research.

| Rotation Speed (rpm) | Detention Time | Flow Rate (L/Minutes) | Inlet | Outlet |
|----------------------|----------------|-----------------------|-------|--------|
| 150                  | 20 Minutes     | 0.3                   | A     | I      |
|                      | 10 Minutes     | 0.6                   |       | II     |
|                      | 30 Second      | 11                    |       | III    |
|                      | 20 Minutes     | 0.3                   | B     | IV     |
|                      | 10 Minutes     | 0.6                   |       | V      |
|                      | 30 Second      | 11                    |       | VI     |
|                      | 20 Minutes     | 0.3                   |       | I      |
|                      | 10 Minutes     | 0.6                   |       | II     |
|                      | 30 Second      | 11                    |       | III    |
| 100                  | 20 Minutes     | 0.3                   | C     | IV     |
|                      | 10 Minutes     | 0.6                   |       | V      |
|                      | 30 Second      | 11                    |       | VI     |
| 50                   | 20 Minutes     | 0.3                   |       | I      |
|                      | 10 Minutes     | 0.6                   |       | II     |
|                      | 30 Second      | 11                    |       | III    |
A reactor of electrocoagulation was used during the study, as shown in Figure 5 below.

![Electrocoagulation reactor](image)

**Figure 5.** Electrocoagulation reactor.

2.7. Laboratory analysis
A sampling of tofu wastewater was carried out at the wastewater outlet of the tofu industry. The pollutant parameters that will be tested in this study are COD, BOD, TSS and Nitrate. The results of the analysis of the electrocoagulation process will be compared with the Governor's regulation No. 69 of 2013 concerning Wastewater Quality Standards for Activities and/or Businesses and compared with the Regulation of the Minister of the Environment No. 5 of 2014 concerning Wastewater Quality Standards. There is an analytical method used to measure the parameters studied in Table 3.

| Parameter | Methods | Analysis Methods |
|-----------|---------|------------------|
| COD       | Closed Refluks with titrimetric | SNI 6998.2:2009 |
| BOD       | Winkler | SNI 6989.72:2009 |
| TSS       | Gravimetric | SNI 6989.3:2004 |
| Nitrate   | Spektrofotometri | SNI 6989.9:2004 |

2.8. Equation and mathematics
To get the efficiency of reducing the pollutant content, the calculation is carried out with the following formula:

\[
\text{Efficiency} = \frac{a-b}{a} \times 100\%
\]

Description:
- a: value of sample concentration before electrocoagulation
- b: the value of sample concentration after electrocoagulation

3. Results and discussion
By the planned research stages, the initial stage after sampling is to check the characteristics of the tofu wastewater. There are in Table 4 regarding some of the characteristics of the pollutant obtained, namely as follows:

| Test Parameters | Tofu Wastewater (mg/L) | Standard (mg/L) | Description |
|-----------------|------------------------|-----------------|-------------|
|                 |                        | PerGub DKI No.69 of 2013 | PerMen LH No. 5 of 2014 | |
| COD             | 6120                   | 75              | 150         | Does Not Qualify |
Testing the characteristics of wastewater is used to determine how much pollutant content is in the wastewater and how much removal efficiency is obtained from the electrocoagulation process. Table 5 shows the % removal of COD (chemical oxygen demand) obtained from the electrocoagulation process.

### Table 5. Result of COD analysis.

| Rotation Speed (rpm) | COD (Mg/L) | %Efficiency | Standard PerGub DKI No.69 of 2013 | Standard PerMen LH No. 5 of 2014 | Description |
|----------------------|------------|-------------|-----------------------------------|-----------------------------------|-------------|
| **150 rpm**          | 6120       | 20%         | 150 mg/L                          | 150 mg/L                          | Does Not Qualify |
| Inlet                | 4896       | 20%         |                                   |                                   | Does Not Qualify |
| 30 Second            | 3916.8     | 36%         |                                   |                                   | Does Not Qualify |
| 10 Minutes           | 4406       | 28%         |                                   |                                   | Does Not Qualify |
| Inlet                | 6854.4     | 29%         |                                   |                                   | Does Not Qualify |
| 30 Second            | 4896       | 29%         |                                   |                                   | Does Not Qualify |
| 10 Minutes           | 4651.2     | 32%         |                                   |                                   | Does Not Qualify |
| 20 Minutes           | 4896       | 29%         |                                   |                                   | Does Not Qualify |
| Inlet                | 5280       | 20%         |                                   |                                   | Does Not Qualify |
| 30 Second            | 4224       | 20%         |                                   |                                   | Does Not Qualify |
| 10 Minutes           | 4012       | 24%         |                                   |                                   | Does Not Qualify |
| 20 Minutes           | 4224       | 20%         |                                   |                                   | Does Not Qualify |
| **100 rpm**          | 6280       | 20%         |                                   |                                   | Does Not Qualify |
| Inlet                | 4896       | 20%         |                                   |                                   | Does Not Qualify |
| 30 Second            | 4651.2     | 24%         |                                   |                                   | Does Not Qualify |
| 10 Minutes           | 4012       | 24%         |                                   |                                   | Does Not Qualify |
| 20 Minutes           | 4224       | 24%         |                                   |                                   | Does Not Qualify |
| **50 rpm**           | 5280       | 20%         |                                   |                                   | Does Not Qualify |
| Inlet                | 4896       | 20%         |                                   |                                   | Does Not Qualify |
| 30 Second            | 4224       | 20%         |                                   |                                   | Does Not Qualify |
| 10 Minutes           | 4012       | 24%         |                                   |                                   | Does Not Qualify |
| 20 Minutes           | 4224       | 24%         |                                   |                                   | Does Not Qualify |
| **150 rpm + Garam**  | 5280       | 44%         |                                   |                                   | Does Not Qualify |

In Table 5, it can be seen that the most optimum COD reduction condition is at a rotation speed of 150 rpm with a residence time of 10 minutes where the flow rate is 0.6 L/minute. The rotational speed at 150 rpm is said to be optimum for reducing COD levels because mixing Al\(^{3+}\) ions as a coagulant will work well, as well as a residence time that is too fast and too long can cause the failure of mixing of cations and anions produced by the electrode, a long residence time as well. It causes deposits on the electrodes to reduce the ability of the electrodes to be able to produce the required ions. The non-fulfilment of the quality standard criteria for tofu wastewater after the electrocoagulation process is caused by factors that affect the efficiency of electrocoagulation. Such as the electric current flowing in the wastewater and the electric voltage during the electrocoagulation process [5]. Addition of salt at a salt concentration of 1 g/L to increase the efficiency of removal, the salt content affects the amount of electrical conductivity in the water, with the addition of the salt to the most optimum variable, namely the stirring speed of 150 rpm with a detention time of 10 minutes. Set aside the COD content of 44\%. There are results of the BOD allowance analysis with the same variation of variables, which are shown in Table 6.

### Table 6. Result of BOD analysis.

| Rotation Speed (Rpm) | BOD (Mg/L) | %Efficiency | Standard PerGub DKI No.69/2013 | Standard PerMen LH No. 5/2014 | Description |
|----------------------|------------|-------------|---------------------------------|---------------------------------|-------------|
| **150 rpm**          | 4898       |             |                                 |                                 | Does Not Qualify |
Based on Table 6, the most extensive BOD removal was 27% at 150 Rpm stirring with a detention time of 10 minutes. It can be seen that there is an interaction between the variation of residence time and the speed of stirring rotation on the decrease in BOD levels in tofu wastewater treated with electrocoagulation. At speeds of 150 rpm and 100 rpm with variations of residence time, the most optimum is at 10 minutes with a stirring rotation speed of 150 rpm with the results of the removal efficiency of 27% and 15%. In reducing BOD levels, variations in residence time and variations in the speed of stirring rotation have a strong influence on decreasing BOD levels. In Table 7, the results of the analysis of Total Suspended Solid (TSS) are obtained.

Table 6. Results of BOD analysis.

| Rotation Speed (Rpm) | BOD (Mg/L) | % Efficiency | Standard | Description |
|----------------------|------------|--------------|----------|-------------|
| 30 Second            | 4080       | 17%          | 100 mg/L | Does Not Qualify |
| 10 Minutes           | 3600       | 27%          | 300 mg/L | Does Not Qualify |
| 20 Minutes           | 3740       | 24%          |          | Does Not Qualify |
| Inlet                | 6120       |              |          | Does Not Qualify |
| 100 rpm              | 30 Second  | 5680         | 7%       | Does Not Qualify |
|                      | 10 Minutes | 5200         | 15%      | Does Not Qualify |
|                      | 20 Minutes | 5460         | 11%      | Does Not Qualify |

Based on Table 6, the most extensive BOD removal was 27% at 150 Rpm stirring with a detention time of 10 minutes. It can be seen that there is an interaction between the variation of residence time and the speed of stirring rotation on the decrease in BOD levels in tofu wastewater treated with electrocoagulation. At speeds of 150 rpm and 100 rpm with variations of residence time, the most optimum is at 10 minutes with a stirring rotation speed of 150 rpm with the results of the removal efficiency of 27% and 15%. In reducing BOD levels, variations in residence time and variations in the speed of stirring rotation have a strong influence on decreasing BOD levels. In Table 7, the results of the analysis of Total Suspended Solid (TSS) are obtained.

Table 7. Results of TSS analysis.

| Rotation Speed (Rpm) | TSS (Mg/L) | % Efficiency | Standard | Description |
|----------------------|------------|--------------|----------|-------------|
| 150 Rpm              | Inlet      | 570          |          | Does Not Qualify |
|                      | 30 Second  | 277          | 51%      | Does Not Qualify |
|                      | 10 Minutes | 236          | 59%      | Does Not Qualify |
|                      | 20 Minutes | 257          | 55%      | Does Not Qualify |
|                      | Inlet      | 378          |          | Does Not Qualify |
| 100 Rpm              | 30 Second  | 196          | 48%      | Does Not Qualify |
|                      | 10 Minutes | 159          | 58%      | Does Not Qualify |
|                      | 20 Minutes | 257          | 32%      | Does Not Qualify |
|                      | Inlet      | 366          |          | Does Not Qualify |
| 50 Rpm               | 30 Second  | 268          | 27%      | Does Not Qualify |
|                      | 10 Minutes | 167          | 54%      | Does Not Qualify |
|                      | 20 Minutes | 236          | 36%      | Does Not Qualify |
| 150 Rpm + Garam      | Inlet      | 366          |          | Does Not Qualify |
|                      | 10 Minutes | 135          | 63%      | Does Not Qualify |

Electrocoagulation treatment based on Table 7 has proven successful in reducing TSS levels in tofu wastewater, with the best % removal at a stirring speed of 150 Rpm with a residence time of 10 minutes with a % removal value of 59%, reducing TSS with an initial value of 570 mg/L to 277 mg/L, this result still exceeds the specified quality standard. However, it can be concluded that electrocoagulation can reduce the TSS content in tofu wastewater. However, in the variation of stirring of 100 Rpm and residence time of 10 minutes, although the % removal of TSS is more minor, it is 58%. This variation can reduce TSS levels not to exceed the quality standard of Minister of Environment Regulation No.
The main form of nitrogen in natural waters is Nitrate. Besides that, Nitrate acts as the primary nutrient in the photosynthesis process of autotrophic organisms in the waters. It makes the nitrate content in the waters monitored not excessive and triggered algae blooms. To reduce the nitrate concentration in tofu wastewater, statistically, it can be seen that the nitrate concentration decreased after being given electrocoagulation treatment. As shown in Table 8, the results of the analysis of tofu wastewater, the nitrate concentration met the quality standards of DKI Jakarta Governor Regulation No. 69/2013 and Minister of Environment Regulation No. 5/2014 both before and after electrocoagulation.

| Rotation Speed | Nitrate (Mg/L) | % Efficiency | Standard | Description |
|---------------|---------------|--------------|----------|-------------|
| 150 rpm | 4 | 43% | PerGub DKI No. 69/2013 | Qualified |
| | 2.29 | 45% | PerMen LH No. 5/2014 | Qualified |
| | 1.784 | 55% | | Qualified |
| | 2.253 | 44% | | Qualified |
| | 1.265 | 37% | | Qualified |
| 100 rpm | 0.798 | 43% | | Qualified |
| | 0.789 | 38% | | Qualified |
| | 0.726 | 43% | | Qualified |
| | 0.592 | 37% | | Qualified |
| 50 rpm | 0.527 | 11% | | Qualified |
| | 0.328 | 45% | | Qualified |
| | 0.472 | 20% | | Qualified |
| 150 rpm + Garam | 0.592 | 58% | 10 mg/L | Qualified |
| | 0.246 | 58% | 20 mg/L | Qualified |

Based on Table 8, the optimum condition for decreasing the nitrate concentration was at a stirring speed of 150 Rpm with a residence time of 10 minutes, with a % removal of 55%, in this case, the stirring speed had a more vital interaction in reducing the nitrate concentration compared to the residence time interaction. It depends on the amount of \( \text{H}_2 \) gas formed during the electrocoagulation process. The \( \text{H}_2 \) gas formed is strongly influenced by the formation of \( \text{Al}^{3+} \) from the aluminium anode. Organic matter can conduct electricity better, so the result of the % allowance is 58%, where this result is the most optimum result among other variables. Salt is an alternative that can increase the % removal of pollutant parameters because, at a low cost, it can get more optimum results [6].

4. Conclusion

Based on the research conducted, it can be concluded that electrocoagulation with Al-St as an electrode can reduce the pollutant content of COD, BOD, TSS and Nitrate in tofu wastewater even though its efficiency is low and does not meet quality standards, except Nitrate. The optimum variation to reduce COD, BOD, TSS, and Nitrate is at an emotional cycle of 150 Rpm and a residence time of 10 minutes. It is necessary to add salt because the 150 Rpm variable with a residence time of 10 minutes added salt at a concentration of 1gr/L can get a higher removal result for COD by 44%, in TSS by 63%, and in Nitrate by 58%.

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