Slaughterhouse Wastewater Treatment by Electrocoagulation Process

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Abstract. Slaughterhouse wastewater contains a high concentration of colloids, organic compounds, and suspended solids, which cannot be directly discharged to the environment. In this research, the electrocoagulation process was used to treat slaughterhouse wastewater. The pH of the solution was neutralized by adding Ca(OH)_2. The influence of current density (933 mA/dm^2 and 1400 mA/dm^2) and electrode configuration (3 anodes 3 (three) cathodes and 4 (four) anodes 2 (two) cathodes) was investigated. The experimental results showed that the treated wastewater at a current density of 1400 mA/dm^2 produced a lower contaminant concentration than the current density of 933 mA/dm^2. The current density of 1400 mA/dm^2 and electrode configuration of 4 anodes-2 cathodes reduced BOD by 56.4%, TDS by 20.25%, and TSS by 99.47%.

1. Introduction
The slaughterhouse wastewater contains a high concentration of biodegradable organic compounds (such as proteins and blood), colloidal (such as fat, oil, and grease), suspended solids (such as grit, manure, and undigested feeds), nitrogen, phosphorus, and pathogenic bacteria [1]. These contaminants lead to a high value of BOD, COD, and turbidity, which must be treated before being discharged into the environment [2]. Coagulation/flocculation [3-5], trickling filtration [6], and biological process [7-9] are standard techniques used for wastewater treatment. Among these technologies, biological treatment, either anaerobic or aerobic treatment [7, 10, 11], has been widely chosen due to its high removal efficiency to remove the biological contaminants in slaughterhouse wastewater. Some parameters, such as long hydraulic retention time, the high energy requirement for aeration, large area, and high concentration of sludge produced during the process, become a problem in extensive scale application of biological processes [12].

Electrocoagulation (EC) has recently been used as an alternative process for slaughterhouse wastewater treatment [13, 14]. The EC is an electrochemical process, which combines coagulation, adsorption, precipitation, and flotation in a one-stage procedure. This process involves two electrodes, namely anode, and cathode, which are arranged in pairs. When a direct current is applied to the electrodes, soluble metal cations are released from the anode, neutralizing the stable charge on the subsequent pollutants and destabilizing the contaminants to form flocs. Meanwhile, hydrogen gas and hydroxyl ions are released from the cathode. The hydrogen gas lifts the pollutants to the top of the solution. Then, they are collected and removed by a skimmer. The EC process’s chemical reactions have been explained in kinds of literature [15, 16]. When using aluminum (Al) as an anode, Al^{3+} ions are released from the anode. Besides destabilizing the charge of pollutants, the Al^{3+} reacts with hydroxyl (OH)\(^{-}\) ion to form coagulants, Al(OH)\(_3\), and enlarge the agglomeration of flocs.
Several studies have been conducted using the EC process to treat slaughterhouse wastewater, mostly carried out in a batch mode. Cruz et al. [17] compared three types of electrodes, namely pure aluminum (Al), pure iron (Fe), and a combination of Al and Fe. They found that the Al electrode provided higher COD removal, up to 97%, compared to other electrodes. Paulista et al. [18] used aluminum and graphite electrode for poultry slaughterhouse treatment. High-efficiency removal of COD was achieved when the coagulant load was more than 51 mg/L, and the gas load was more than 60 NmL/L. The COD removal was up to 85%, while the turbidity removal was up to 99%. Kobyta et al. [13] used Al and Fe electrodes for treating poultry slaughterhouse waste with COD of 26,000 – 29,000 mg/L. Around 93% removal of COD was reached in 25 minutes of EC process when the applied current density was 150 A/m². It was estimated that the total operating cost of the slaughterhouse wastewater treatment by EC process was varied from 0.015 US$/kg COD removed (Fe electrode) to 0.027 US$/kg COD removed (Al electrode) or 0.4 US$/m³ (Fe electrode) to 0.7 US$/m³ (Al electrode) [19]. Potrich et al. [20] also compared Al and Fe electrodes’ performances in EC reactor to remove total nitrogen and phosphorus in poultry slaughterhouse wastewater. The EC process was conducted in batch-mode. The optimum result was achieved at 20 minutes by using Al electrode at operating treatment conditions of 30 mA/cm² current density and initial pH of 8. The lowest cost was 3.89 US$/m³. In this study, the slaughterhouse wastewater was treated using a continuous EC process. The EC reactor was equipped with a turbine impeller and six Al electrodes as baffles. The influence of electrode configurations and applied current densities was investigated.

2. Material and Methods

The experimental set-up and method were referred to in our previous work [21, 22]. A cylindrical EC reactor was used with a diameter of 25 cm and a height of 30 cm. Six Al electrodes were used as baffles, which had length, width, and thickness of 33 cm, 4 cm, and 3 mm, respectively. These electrodes were connected to a DC power supply to provide a current density of 933 mA/dm² (10A) and 1400 mA/dm² (15 A). The EC reactor’s mixing process was conducted using a turbine impeller at a stirring rate of 100 rpm.

Meanwhile, the feed flow rate was maintained at 233.3 mL/min. The experimental apparatus used in this research is shown in Figure 1. The wastewater was obtained from one of the cattle slaughterhouse industries in Cimahi, West Java, Indonesia. The influent’s pH was adjusted to 7 (neutral) by adding Ca(OH)₂. The concentration of TDS, turbidity, pH, and COD of the effluent was measured after 120 EC process minutes. The analysis methods refer to our previous research [21, 23].

![Figure 1. Experimental set-up: (1) feed tank, (2) feed pump, (3) stabilizer tank, (4) EC reactor equipped with a turbine impeller and baffles, (5) sedimentation tank, (6) effluent tank, and (7) control panel.](image-url)
3. Result and Discussion

3.1. The influence of operating parameters on TDS, turbidity, and pH of the slaughterhouse wastewater

Figure 2 shows the influence of operating parameters on effluent qualities, including TDS, turbidity, and pH of the solution. It shows that higher TDS removal was achieved when four anodes and two cathodes (4A-2C) were used in the EC reactor compared to three anodes and three cathodes (3A-3C) configuration. When the current density was increased from 933 mA/dm$^2$ (10A) to 1400 mA/dm$^2$ (15A) the TDS concentration was reduced by 11.81% (from 2370 to 2090 mg/L) when using 3A-3C configuration. The TDS reduction was improved to 17.72% when using the 4A-2C configuration at a current density of 933 mA/dm$^2$ and 20.25% at a current density of 1400 mA/dm$^2$ (Figure 2A). In this research, more than 98% reduction in turbidity can be achieved in the whole experiments. It has been reported that the amount of applied current was related to the coagulant dose produced by the anode [24]. The increase of applied current density enhanced the amount of ion Al$^{3+}$ released from the anode. The Al$^{3+}$ ions form complex compounds that act as coagulants to destabilize the contaminants, allowing contaminants to agglomerate and form flocs. The amount of Al$^{3+}$ ions can be enhanced by increasing the number of anodes or increasing the applied current density value. Besides, the reaction of Al$^{3+}$ with hydroxide ions (OH$^-$) in solution resulted in Al(OH)$_3$, which was able to adsorb contaminants and form larger flocks, then settled to the bottom of the EC reactor. The Al$^{3+}$ ions and Al(OH)$_3$ were easier to destabilize colloids and particulates than ionic contaminants, and therefore, higher removal in turbidity was resulted compared to TDS.

![Figure 2](image_url)

**Figure 2.** The influence of operating parameters on reducing: (a) TDS, (b) turbidity, and (c) pH of slaughterhouse wastewater.
Figure 2c shows the change in pH of the solution during the EC process, where the influent’s initial pH was adjusted to 7. In general, the solution’s pH will be raised during the EC process due to OH- ions in the cathode. The electrode configuration of 4A-2C showed a more significant change in pH compared to 3A-3C. The lowest change in pH (i.e., 2.63%) has occurred at the electrode configuration of 4A-2C and a current density of 933 mA/dm$^2$. It was suggested that the OH- ions in the solution was mostly reacted to Al$^{3+}$ ions to form Al(OH)$_3$. Therefore, the concentration of OH- was low, and the pH of the solution was slightly changed. The increase in current density led to a more significant change in pH. As the charge density increased to 1400 mA/dm$^2$, many OH- ions were produced. Consequently, the pH of the solution was changed by 7.79% (from 7.6 to 8.2). Several research studies have been conducted and reported that the slaughterhouse wastewater treatment using the EC process was optimum when the treatment process was completed at pH 3.

3.2. The influence of operating parameters on the decrease in BOD by the EC system

The influence of the configuration of electrodes and current density on BOD removal is presented in Figure 3. There was no significant change in BOD removal by increasing the number of anodes in the EC reactor. In both electrode configurations, i.e. 3A-3C and 4A-2C, the BOD removal was by 37.97% (from 710.60 to 440.80 mg/L) and 39.38% (from 710.60 to 430.80), respectively. However, BOD removal was improved to 56% by increasing the current density. It has been mentioned that the current per area of electrodes in the EC reactor was proportional to the number of metal ions or coagulant produced from the electrodes. As the current density increased, a larger amount of coagulant was produced to destabilize the wastewater contaminants. The increase of current density reduced the bubble size of H$_2$ gas in the cathode, which enhanced the bubble densities to upward the contaminants to the top of the EC reactor. The smaller size of bubbles improved particle attachment’s surface area, and thus higher separation efficiency could be achieved [25]. However, the percentage of BOD reduction was still below 60%. Therefore, further experimental by varying the current density and other operating parameters are still required to improve the BOD removal.

![Figure 3](image-url)
4. Conclusion

In this research, a continuous electrocoagulation (EC) process is used to treat cattle slaughterhouse wastewater that contains a high concentration of colloids, organic compounds, and suspended solids. The cylindrical EC reactor is designed to combine mixing and electrocoagulation in a one-stage process and is conducted using a six-blade turbine impeller. Six Al electrodes are used as baffles to generate turbulence during the EC process. The pH of the solution is neutralized by adding Ca(OH)₂.

The influence of current density (933 mA/dm² and 1400 mA/dm²) and electrode configuration (3 anodes 3 (three) cathodes and 4 (four) anodes 2 (two) cathodes) is investigated. The experimental results showed that the treated wastewater at a current density of 80 mA/cm² produced a lower contaminant concentration than the current density of 50 mA/cm². The current density of 80 mA/cm² and electrode configuration of 4 anodes-2 cathodes reduced BOD by 56.4%, TDS by 20.25%, and TSS by 99.47%.

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