Hotel Wastewater Treatment by Integrating Mixing and Electrocoagulation Process

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Abstract. Hotels used a considerable amount of water and chemicals for guest rooms, pools, landscaping, laundry, gardening, and other activities, depending on hotel categories. In this research, the liquid waste of the hotel was treated by a combination of mixing and electrocoagulation process to produce clean water, which was safely discharged into the environment. The EC reactor was equipped with 6 (six) Al electrodes as baffles with a current strength of 12 A and operated in a continuous process. The agitation rate of turbine impeller was fixed at 100 rpm, while the influent flow rate into the EC reactor was maintained at 200 mL/min. The influences of differences in electrode configurations (i.e., 3 Anodes 3 Cathodes and 4 Anodes 2 Cathodes) on pH, turbidity, and BOD of the effluent were studied. Based on the experimental results, the Al electrode configuration of 4 Anodes 2 Cathodes showed better results than 3 Anodes 3 Cathodes. The decrease in BOD and turbidity were 84% and 93%, respectively. This technology can be considered as a promising green technology to treat various industrial wastewater as well as reduce the raw water pollution by the industrial waste.

Keywords: Clean water, electrocoagulation, hotel, mixing process.

1. Introduction
Hotels and resorts consume a huge amount of water during its activities, particularly for guest rooms, restaurants or kitchens, pools, landscaping, laundry, and gardening. It is estimated that the hotels require 100 to over 700 m$^3$ per day of water, depending on the category and guest capacity of the hotels [1]. Consequently, considerable amount of wastewater is generated and should be treated before being discharged into the environment. In general, the wastewater is common treated by a combination of physical, chemical, and biological processes [2, 3]. However, the conventional biological process is limited by several factors when it will scale up to a large capacity, such as high volume or detention time, a large area required, complex operating systems, inability to treat a complex and unpredictable wastewater, as well as require skilled manpower [4]. Alternative processes are required to overcome the mentioned problems.

Electrocoagulation (EC) is one of the alternative processes that has been developed to treat industrial wastewater, especially to treat textile industry wastewater with a high removal efficiency, large volume handling ability, and eco-friendly [5]. A growing research interest of EC technology is reported on other wastewater types, including olive mill wastewater [6], urban wastewater [7], restaurant wastewater [8], poultry slaughterhouse wastewater [9], and other applications [10, 11]. The basic EC unit is an electrolyte cells, which consists of a pair of electrodes, namely anode and cathode. The electrodes are connected to an externally DC power source and immersed in the solution (Figure...
Iron and aluminum are the most used metals for EC electrodes due to their availability, non-toxic, and proven to be reliable [14].

Figure 1. Schematic of the electrocoagulation process [12]

The electrochemical reactions with metal M in EC reactor are summarized as follows:

At anode:

\[ \text{M} \rightarrow \text{M}^{n+} + n \text{e}^- \]  \hspace{1cm} (1)
\[ 2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + \text{O}_2 + 4\text{e}^- \]  \hspace{1cm} (2)

At cathode:

\[ \text{M}^{(n+)} + n \text{e}^- \rightarrow \text{M} \]  \hspace{1cm} (3)
\[ 2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2\text{O} + 2\text{OH}^- \]  \hspace{1cm} (4)

The cations M\(^{n+}\) destabilize colloid particles and react with hydroxide (OH\(^-\)) ions to produce coagulant agent, M(OH)\(_n\) [15, 16]. Meanwhile, the hydrogen gas bubbles lift the pollutants to the top of the EC reactor to be collected and removed.

In this study, EC process was used to treat liquid waste from one of the hotels in Cimahi, West Java. The EC reactor was equipped with a turbine impeller to generate a mixing process in the reactor tank and accelerate the agglomeration of pollutants in solution. The influence of electrode and mixing process on the effluent quality were investigated.

2. Experimental Methods

2.1. Electrocoagulation process

The experimental set-up refers to our previous work (Figure 1) [12]. The EC reactor was cylindrical with a liquid volume of 60 L and equipped with 6 (six) electrodes that served as baffles. The feed flow rate was maintained at 200 mL/min. The electrodes were made from aluminium (Al) and then connected to a DC power supply (Atten, KPS3030DA) at an applied current of 12 A. The EC process was operated continuously with an overall operating time of 80 (eighty) minutes. Two types of electrode configurations were used, i.e., 3 Anodes 3 Cathodes (3A-3C) and 4 Anodes 2 Cathodes (4A-2C). The change of BOD, turbidity, and pH was measured after and before the EC process. The influence of mixing process was investigated by comparing it to the process without stirring. The dimension of experimental equipment is shown in Table 1.
2.2. Calculation of the theoretical production of metal ions

The theoretical production of Al$^{3+}$ from the electrochemical dissolution of Al anodes was calculated using Faraday’s 2nd Law, as shown in the following equation [14]:

\[
\text{Al generated (mg/s)} = \frac{I \times M}{F} \times \text{Al}_{\text{ne}} \times 1000 \text{ mg/g}
\]

where \( I \) is the applied current in Amperes (coulomb/second), \( M \) is the molecular weight of Aluminum (26.98 g/mol), \( F \) is the Faraday constant (96,485 C/mol), and \( \text{Al}_{\text{ne}} \) is the number of electrons transferred in the electrochemical reaction (3e$^-$/Al ion). The electrochemical reaction of the Aluminum at anode during the EC process may be summarized as follows [14]:

\[
\text{Al (s)} \rightarrow \text{Al}^{3+}_{(aq)} + 3\text{e}^-
\]

2.3. Measurement of BOD, Turbidity, and pH

The BOD analysis referred to the previous work, which was determined by measuring oxygen consumed in a 5-d (5-d BOD or BOD$_5$) according to AWWA 5210-B standard method [17]. 300 mL of sample was placed in a Winkler bottle and kept it in an incubator for 5 days at 20 °C. The dissolved oxygen concentration was measured by redox titration method using thiosulfate as a titrant. Before the titration process, the analyte was added to sulfuric acid and starch indicator. The BOD value was calculated from the difference between the initial and final value of dissolved oxygen.

The turbidity was measured by turbidity meter (Turbi Check, Levibond), which used LED light source at an angle of 90° as stipulated in EN ISO 7027. Prior to the sample test, the turbidity meter was calibrated using the standard solution provided by the supplier (0.02 NTU, 20.0 NTU, 100 NTU,
3. Result and Discussions

3.1. The theoretical production of metal ions

The theoretical number of metal ions (Al$^{3+}$) generated in the EC process at a constant applied current of 12 A is presented in Figure 2. The increase of operating time enhanced the number of metal ions (Al$^{3+}$) released by the anode into the solution. The Al$^{3+}$ ions destabilized the pollutants and allowing the agglomeration of pollutants.

![Figure 3](image_url). Number of metal ions during the EC process at a constant applied current of 12 A

3.2. The influence of electrode configuration and mixing process on the pH of solution.

Figure 3 presents the influence of electrode configuration and mixing process on the change of pH during EC process. The EC process was conducted continuously for 80 minutes at a constant applied current of 12 A. Based on the experimental data results, the pH of solution was decreased from 8 to 7 after the EC process, both using electrode configuration of 3A-3C and 4A-2C. The addition of mixing process minimized the increase of pH. The mixing process improved the distribution of OH$^-$ and Al$^{3+}$ ions in the solution, and then contact to form Al(OH)$_3$ as coagulants. Therefore, the concentration of OH$^-$ ions in the solution was reduced, and consequently, the effluent of EC process coupled with mixing provided a lower pH of effluent compared to without mixing process.

![Figure 4](image_url). The influence of electrode configuration on pH of the solution after the EC process
3.3. The influence of electrode configuration and mixing process on the turbidity reduction

The influence of electrode configuration and the presence of mixing during the EC process at a constant applied current of 12 A is shown in Figure 5. Higher turbidity reduction was achieved when the EC process used 4 anodes and 2 cathodes with a mixing process. It was related to the higher amount of metal ions released to the bulk solution with the increase of anode number. The mixing process improved the distribution of metal ions and coagulants in the solution, which generated Brownian motion to enhance the destabilization of pollutants and the collision rate of flocs. The decrease of turbidity was 93.6% (from 30.6 to 1.95 mg/L) when used 4 anodes and 2 cathodes with a mixing process.

![Figure 5. The influence of electrode configuration on turbidity of the solution during the EC process.](image)

3.4. The influence of electrode configuration and mixing process on the reduction of BOD

The decrease of BOD during the EC process without and with mixing process is presented in Figure 6. The increase of anode number in the EC system improved the BOD reduction. It has been explained that the rise in anode number enhanced the concentration of metal ions (Al^{3+}) released in the solution. The metal ions destabilized or neutralized the repulsive charge of pollutants to form flocs, which can be easily separated from water by sedimentation and flotation[18].

![Figure 6. The influence of electrode configuration on BOD of the solution during the EC process.](image)
4. Conclusions
Integration of electrocoagulation and mixing process has successfully used to treat hotel wastewater. The EC reactor was equipped with 6 (six) Al electrodes as baffles with a current strength of 12 A and operated in a continuous process. The agitation rate of turbine impeller was fixed at 100 rpm, while the influent flow rate into the EC reactor was maintained at 200 mL/min. The influences of differences in electrode configurations (i.e., 3 Anodes 3 Cathodes and 4 Anodes 2 Cathodes) on pH, turbidity, and BOD of the effluent were studied. Based on the experimental results, the Al electrode configuration of 4 Anodes 2 Cathodes showed better results than 3 Anodes 3 Cathodes. The decrease in BOD and turbidity were 84% and 93%, respectively.

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