

# The Influence of Applied Current Strength and Electrode Configuration in Laundry Wastewater Treatment by Electrocoagulation

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**Abstract.** Wastewaters generated by domestic laundry processes contained a considerable amount of mineral oils, heavy metals, and other toxic chemicals that can damage the aquatic ecosystems if discarded without treatment. In this paper, the domestic laundry wastewater was treated by electrocoagulation (EC) process. EC reactor was cylindrical with a volume of 70 L and operated continuously at a fixed flow rate of 500 mL/min. The influence of current strengths and aluminum (Al) electrode configurations on EC performances were investigated. It was found that the Al electrode configuration of 3 anodes 1 cathode, which were operated at a current strength of 6 A, provided preferable results compared to the other configurations. The reductions of COD, surfactant, TDS, and turbidity were 80.76%, 27.11%, 17.66%, and 74.12%, respectively.

## 1. Introduction

A significant amount of domestic laundry processes has been released and changed the natural water characteristics due to its highly toxic chemical content. In general, the laundry effluents have a wide range of COD value, which is between 400 to 20000 mg/L, depending on the type and concentration of the cleaning item used [1]. As the main component in the laundry in detergents, ionic surfactants contribute to short term changes in river ecosystem and harmful to human health. Therefore, many environmental and public health regulatory authorities have stringent the concentration of surfactant in effluent treatment wastewater before being discharged into the environment [2].

Several technologies have been proposed to treat the laundry wastewater, including coagulation, flocculation, adsorption, chemical oxidation, electrocoagulation [3]. Among these technologies, electrocoagulation (EC) has considered as an alternative to conventional coagulation and flocculation due to its green precipitation process with high removal efficiency. EC technology eliminates the use of chemicals, which generates hazardous sludge. Further research has been focused on process development in the EC process.

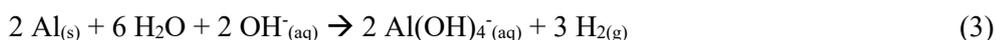
The EC technology combines coagulation, flotation, and electrochemical process in one unit [4, 5]. The EC unit contains electrodes, namely anode and cathode, to generate coagulants and hydrogen gas bubbles to eliminate contaminants in wastewater [6]. Electrodes used in the EC unit are commonly made from aluminum (Al) or iron (Fe). When the current is applied to the anodes, ions ( $Al^{3+}$  or  $Fe^{2+}$ ) are released from the plate and dispersed into the bulk solution. The released ions destabilize the particulate suspension and form small flocs due to the decrease of electrostatic interparticle repulsion



[7]. In cathode, the water dissociates into hydroxyl ions ( $\text{OH}^-$ ) and hydronium ( $\text{H}_3\text{O}^+$  or  $\text{H}^+$ ) ions, which produces hydrogen gas (bubbles) to lift the flocs to the top of the EC reactor and then removed by a skimmer [8]. Simultaneously, cations ( $\text{Al}^{3+}$ ) react with  $\text{OH}^-$  ions to produce different species, such as  $\text{Al}(\text{OH})^{2+}$ ,  $\text{Al}_2(\text{OH})_2^{4+}$ ,  $\text{Al}(\text{OH})_3$ , and charged hydroxo cationic complexes [9, 10]. The electrochemical reactions during the EC process have been mentioned in literature [11]. If the electrodes are aluminum-based, the reactions in EC process are as follows:



When the pH of solution is high, both cathode and anode is attacked by  $\text{OH}^-$  ion. The reaction is:



Applied current is one of the critical variables in the EC process. The applied current relates to the anode dissolution rate, hydrogen gas bubble production at cathode, and development of flocs by coagulation process in the EC reactor [7]. The increase of applied current enhances the coagulant dosage, which directly impacts the removal efficiency [12]. Besides the corrosion phenomenon in anodes, an oxidation layer is formed on the cathodes simultaneously. As a result, it decreases the pollutant removal efficiency [13]. On the other hand, very high applied current gives negative effect on the EC process. The overdosing of metal ions concentration in the bulk solution may reverse the charge of the colloids, which also reduces the coagulation efficiency [14].

Electrode configuration in the EC unit also affects the electrocoagulation performance. A higher potential difference is needed for the current to flow. The same or different types of electrodes can be used in the EC process. In a parallel configuration, the applied current is distributed between the electrodes, which is proportional to the individual resistance of the cells [15]. Bipolar and monopolar configurations have been proposed. Khaled [16] was found that bipolar configuration provided higher cadmium removal efficiency (92%) and power consumption ( $4.15 \text{ kW.h/m}^3$ ) compared to the monopolar electrode (87% and  $1.2 \text{ kW.h/m}^3$ ). Due to lower energy consumption, thus, the monopolar configuration becomes the main choice in the EC process.

In this research, the EC process was used for Tempe industrial waste treatment. 4 (four) aluminum-based electrodes are used, which are arranged with different configurations and applied current. The influence of operating parameters on EC performances was investigated.

## 2. Experimental Methods

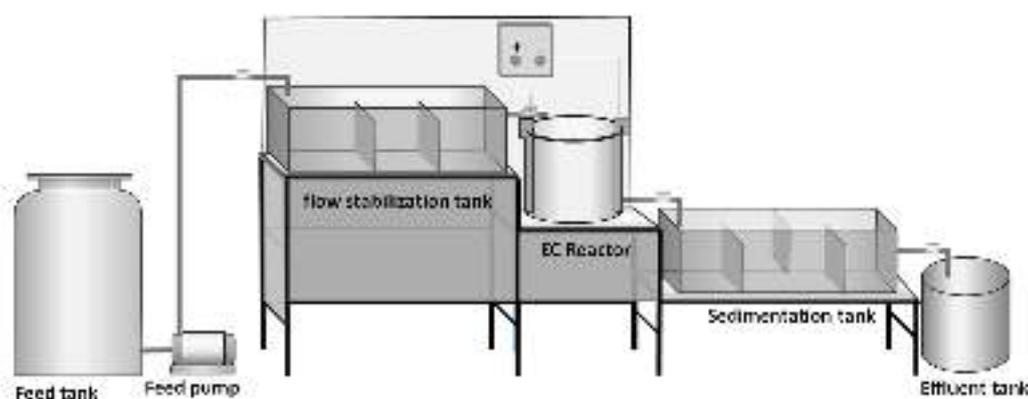
### 2.1. Electrocoagulation process

The experimental set-up refers to our previous work, however, it operates without agitation process (**Figure 1**) [8]. The liquid sample was obtained from one of the domestic laundries in Cimahi - West Java. The EC reactor was cylindrical with a liquid volume of 60 L and equipped with electrodes that served as baffles. The feed flow rate was maintained at 500 mL/min. 4 (four) Aluminum electrodes were used with different configurations (1 anode 3 cathodes (1A-3C), 2 anodes 2 cathodes (2A-2C), and 3 anodes 1 cathode (3A-1C)). The electrodes were connected to a DC power supply (Atten, KPS3030DA) and operated at currents of 4 and 6 A. The laundry wastewater was treated by EC process for 1 (one) hour. The change of surfactant concentration, COD, and turbidity was measured after and before the EC process.

### 2.2. Measurement of Surfactant and Turbidity

The surfactant concentration in feed wastewater and effluent was measured by MABS (Methylene Blue Alkyl Sulfonate) method [17]. 50 mL of sample was placed in separating funnel. The sample was titrated by 0.1 M sodium hydroxide (NaOH) with the addition of phenolphthalein indicator until the pink color appeared in the solution. Then, the solution was titrated by 1 N sulfuric acid ( $\text{H}_2\text{SO}_4$ ) until the pink color was disappeared. 10 mL of chloroform ( $\text{CHCl}_3$ ) and 25 mL of methylene blue reagent was added to the solution, then shaken for 30 seconds. To prevent the formation of emulsion, 10 mL

isopropyl alcohol ( $C_3H_8O$ ) to the solution. After a few minutes, 2 (two) layer of solution was formed, i.e.  $CHCl_3$  and water. The  $CHCl_3$  layer was separated from water by open the valve of separating channel, and then placed in another separating funnel. The remain  $CHCl_3$  in water was extracted by adding 10 mL of  $CHCl_3$ . The whole  $CHCl_3$  was chemically washed by 30 mL of phosphate solution. The  $CHCl_3$  solution analyzed using a UV-Vis spectrophotometer at a wavelength of 652 nm. Meanwhile, the turbidity of sample was measured by turbidity meter (Turbi Check, Levibond), which used LED light source at an angle of  $90^\circ$  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, dan 800 NTU (polymer)).



**Figure 1.** Experimental set-up of electrocoagulation process

### 2.3. Analysis of Chemical Oxygen Demand (COD)

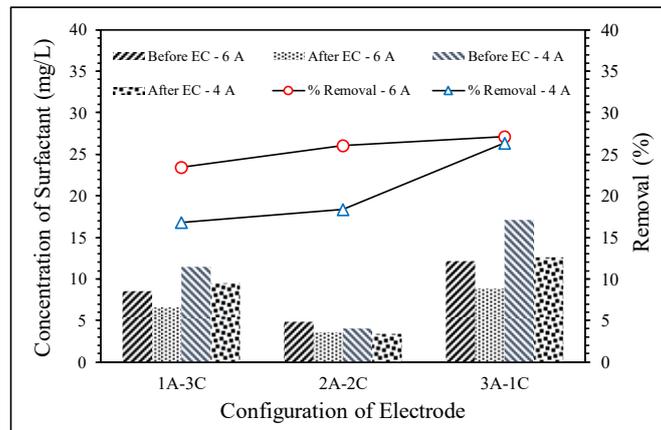
The COD analysis referred to our previous work [8]. The COD of feed wastewater and effluent were determined using closed reflux spectrophotometry according to SNI 6989.2:2009 standard method. The sample was oxidized by  $Cr_2O_7^{2-}$  in closed reflux to produce  $Cr^{3+}$ . The amount of oxidant demand was expressed in oxygen equivalents ( $O_2$  mg/L), which is measured by UV-Vis spectrophotometry. The  $Cr_2O_7^{2-}$  was measured at a wavelength of 400 nm, while the  $Cr^{3+}$  was at 600 nm.

## 3. Result and Discussions

### 3.1. The influence of operating parameters on surfactant removal efficiency.

The influence of applied current and electrodes configuration on surfactant removal during the EC process is presented in **Figure 2**. Higher surfactant removal efficiency (27.11%) was achieved when the EC process was conducted by applying current of 6A compared to 4A. The increase of applied current enhanced the release of metal ions from anode as well as gas bubbles from the cathode. Consequently, the concentration of coagulants formed in wastewater was increased, which adsorbed more surfactant on the coagulant surface. Therefore, the next experimental was focused on the applied current of 6A.

In addition, the increase of removal efficiency was achieved by the increase of anode number in the EC system. It was related to the higher amount of metal ions released to the bulk solution with the increase of anode number. However, the surfactant removal efficiency in this research was still below 30%. Therefore, further research is required to investigate the optimum applied current for surfactant removal.

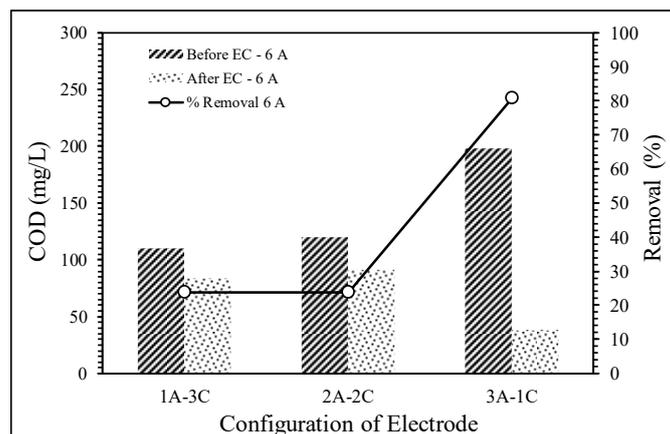


**Figure 2.** The influence of applied current on surfactant removal at different electrode configuration

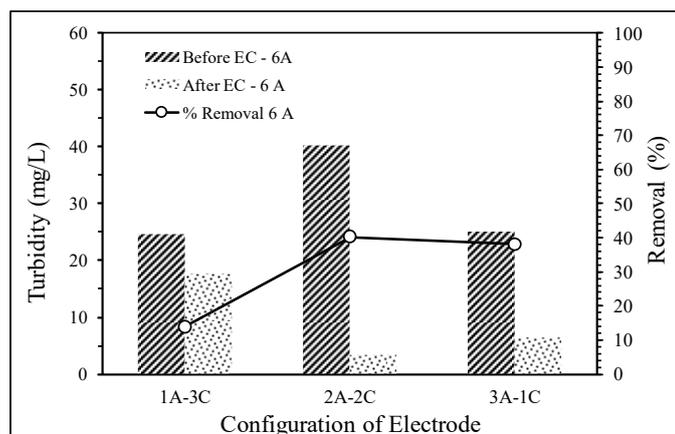
3.2. *The influence of operating parameters on COD and turbidity removal efficiency.*

**Figure 3** presents the COD removal efficiency of laundry wastewater treatment by EC at fixed applied current of 6A. As explained previously that the increase of anode numbers in the EC system enhanced the metal ions concentration released to the bulk of solution. As a result, the concentration of coagulant formed due to the reaction of  $Al^{3+}$  and  $OH^-$  ions was increased, which improved the COD removal efficiency. The highest COD removal was achieved when the electrode configuration of 3 anodes and 1 cathode (3A-1C).

The same trend was achieved in turbidity removal, as shown in **Figure 4**. Higher concentration metal ions with the increase of anode number improved the turbidity removal in EC system. A slight decrease in turbidity occurred when 3 anodes were used in the EC system. It can be attributed to the slight change in colloidal charge due to the increase of metal ion numbers in the bulk solution. Further research is needed to investigate the influence of higher number of anode on the EC performance, particularly in turbidity removal.



**Figure 3.** The influence of operating parameters on COD removal at different electrode configuration



**Figure 4.** The influence of operating parameters on turbidity removal at different electrode configuration

#### 4. Conclusions

The influence of current strengths and aluminum (Al) electrode configurations on electrocoagulation (EC) performances during laundry wastewater treatment were investigated. The EC process operates at a fixed flow rate of 500 mL/min. The Al electrode configuration of 2 anodes 3 cathodes, which are operated at a current strength of 6 A, provides preferable results compared to the other configurations. The reductions of COD, surfactant, TDS, and turbidity were 80.76%, 27.11%, 17.66%, and 74.12%, respectively. Further research is needed to investigate the optimum applied current for surfactant removal.

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