The Influence of Applied Current Density and Agitation Speed During Electrocoagulation of Textile Wastewater

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ABSTRACT
Electrocoagulation has been noticed as a prospective technology in textile industry wastewater treatment due to its high color removal efficiency in a simple and environmental friendly method. In this study, a cylindrical EC reactor was used and equipped with a turbine agitator and Al electrodes as baffles. The EC process was conducted for 120 minutes with a flow rate of 500 mL/minute. The influence of applied current density and agitation speed was investigated. It was found that the theoretical number of ions released into the solution was increased from 49.13 to 85.97 mg/L when the current density was raised from 0.0075 to 0.0132 A/cm^2. The maximum of contaminant removal was achieved when 70 rpm of agitation speed was used at a current density of 0.0013 A/cm^2. At the mentioned agitation speed and current density, the TDS, turbidity, and COD removal were 55.6%. 98.12%, and 90.32%, respectively.

Keywords: *clean water, electrocoagulation, textile wastewater, wastewater treatment.*

1. INTRODUCTION

In the wastewater treatment field, the EC process has attracted much attention in recent years since it produces less amount of sludge, less retention time, and less chemical consumption compared to the conventional process [1, 2]. The EC process involves a complex phenomenon, both physically and chemically, that makes use of consumable electrodes to form coagulants through electrolytic oxidation of the electrodes. The electrodes, which are mostly iron (Fe) and aluminum (Al) are connected to an external DC power source [3]. The quantity of electricity pass through the electrolytic solution determines the dissolution number of metal ions from the anode to the solutions [4]. Meanwhile, hydrogen (H_2) gas bubbles are released from the cathode to lift the flocs to the top of the EC reactor.

In general, there are three stages of the process in the purification of wastewater by coagulants in the EC system: electrolytic oxidation of anodes to generate in-situ coagulants (metal oxyhydroxides) in the solution, pollutant destabilization via charge neutralization by the formed coagulants, and agglomeration of resultant particles to form flocs which bounded less water and stable [5, 6]. The concentration of metal ions released from the anode plays an important role in the EC process.

The concentration of metal ions in the solution is particularly influenced by the applied current in the electrodes. The increase of metal ions in the solution produced polynuclear aluminum complexes and aluminum hydroxide, $Al(OH)_3$, as coagulants. The reaction path is described as the following reaction equation [7]:

$$Al^{3+} \rightarrow Al(OH)_n^{(3-n)} \rightarrow Al_2(OH)_2^{4+} \rightarrow Al_{13}, complex \rightarrow Al(OH)_3$$

The electrocoagulation process can be operated in batch or continuous mode. A continuous mode is more appropriate for industrial processes than a batch mode due to the larger influent capacity. There are several previous studies using EC for textile wastewater treatment. For example, Ubale and Salkar [8] investigated the feasibility of a continuous EC process with a zigzag horizontal flow across a series of monopolar Al electrodes at a current density between 0.002 - 0.008 A/cm^2. They could remove turbidity of 97.63%, color of 87.87%, COD of 93.3%, TSS of 94.2%, and TDS of 52.13% by using a current density of 0.006 A/m2 at a detention time of 20 minutes. Rodrigues et al. [9] studied the effect of pH and applied current on color removal using Al electrodes in the EC reactor. The color removal was 98% when operated at an initial pH of 3, applied current of 3A, and the flow rate of 24 L/h.

In this study, a cylindrical EC reactor was used and equipped with six blades of turbine agitator and 6 Al as baffles. The influence of current density and agitation speed was investigated on the quality of EC system effluent at an operating time of 120 minutes.

2. MATERIAL AND METHOD

2.1. Textile Wastewater Treatment by Electrocoagulation

The EC process was conducted refer to our previous works [10, 11]. The textile wastewater was obtained from one of the textile industries in Cimahi, West Java, Indonesia. An agitator system was installed inside the EC reactor to improve the contact between coagulants and contaminants, and therefore, the separation efficiency could be enhanced. The EC reactor used six electrodes, which were arranged as four anodes and two cathodes. The EC reactor was operated in four (4) applied current density, i.e., 0.0075 A/cm^2 (8A), 0,0094 A/cm^2 (10A), 0,0113 A/cm^2 (12A), and 0,0132 A/cm^2 (14A). Besides applied current density, the agitation speed was also varied in the range of 70 until 110 rpm. The effluent of EC reactors was delivered to the sedimentation tank, which is equipped with three zigzag vertical baffles. The overall operating time of the EC system was 120 minutes at a fixed flow rate of 500 mL/min.

2.2. Calculation of dissolved ion number

The dissolved ion number was calculated using Faraday's 2nd law, as follows:

$$w = {I \,.\, t \,.\, M_{electrode}} / {n \,.\, F \,.\, V} \quad (1)$$

Where w is the number of dissolved metal ions from the anode (g.cm^{-2}.L^{-1}), I is current density (A.cm^{-2}), t is operating time (second), $M_{electrode}$ is the molecular weight of electrode (g/mole), n is the number of electrons transferred (e$^-$/mole), F is a Faraday constant (96,485.33 Coulomb/mole), and V is the treated solution volume (Liter). The Al electrode has a molecular weight of 26.98 g/mole, while the number of electrons relates to the following electrochemical reaction:

$$Al_{(s)} \rightarrow Al^{3+}_{(Aq)} + 3e^- \quad (2)$$

2.3. Measurement of TDS, Turbidity, and COD

The measuring of TDS, Turbidity, and COD was referred to in our previous works [11, 12]. The TDS of the solution was measured using a TDS meter (TDS-3, HM Digital) which was previously calibrated with a 1382 ppm solution at room temperature. Meanwhile, the turbidity was measured by using a turbidity meter (Lovibond 266030 TB 211 IR) which was calibrated using the standard solutions at 0.02 NTU, 20.0 NTU, 100 NTU, dan 800 NTU. The COD analysis was determined using closed reflux spectrophotometry according to SNI 6989.2:2009 standard method [13].

3. RESULTS AND DISCUSSIONS

3.1. The Number of Dissolved Ions During the EC Process

The average Al^{3+} ions released to the solution during the EC process were showed in **Table 1** based on the current density of the EC process and the contact area of the anode with the solution.

Table 1. The theoretical number of ions released during the EC process

Code	Current density (A/cm^2)	Theoretical number of ions released (mg/L)
4A-2C 8A	0.0075	49.13
4A-2C 10A	0.0094	61.41
4A-2C 12A	0.0113	73.69
4A-2C 14A	0.0132	85.97

The increase of current density raised the number of ions released from the anodes due to electrolytic oxidation. The released ions react with hydroxyl ions (OH^-) in the solution to form coagulants.

3.2. The influence of applied current density on the quality of EC effluent.

The influences of various current densities on the quality of EC effluent were shown in **Figure 1** to **Figure 3** which was measured in terms of TDS, turbidity, and COD. The maximum efficiency of contaminant removal was achieved when a current density of 0.0132 A/cm^2 (Code: 4A-2C 14A) was used in the EC process. The maximum TDS removal was 57%, i.e., from 2381 to 1024 mg/L (**Figure 1**). The increase of current density raised the number of ions released in the wastewater from anodes, and consequently, the TDS removal was improved. A similar result was achieved for turbidity and COD removal. More than 97% turbidity removal could be achieved at the overall operating current density (**Figure 2**). Meanwhile, the maximum COD removal was 91.5% (from 321 to 5.45 NTU). The current density of 0.0113 A/cm^2 (Code: 4A-2C 12A) could also be chosen for waste treatment using EC, with the separation efficiency of TDS, turbidity, and COD of 56%, 98%, and 92%, respectively.

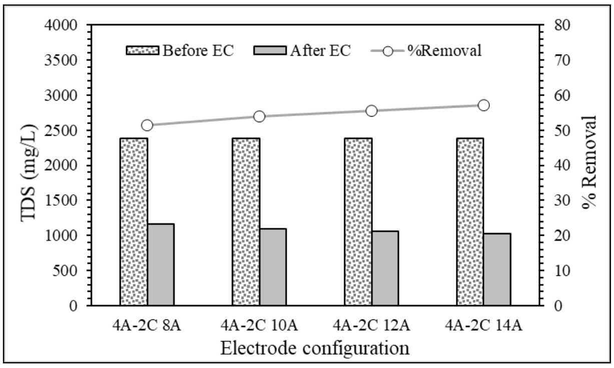

Figure 1 The influence of applied current density on TDS removal at a fixed agitation speed of 70 rpm

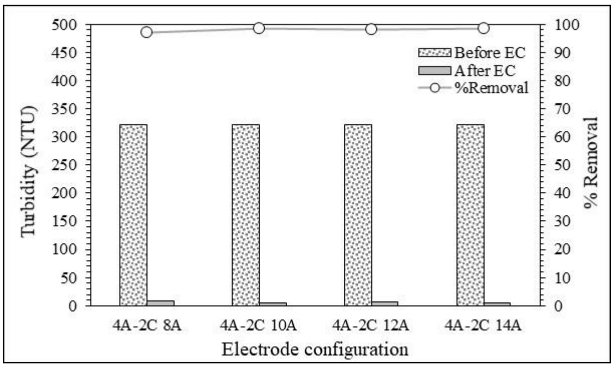

Figure 2 The influence of applied current density on the turbidity removal at an agitation speed of 70 rpm.

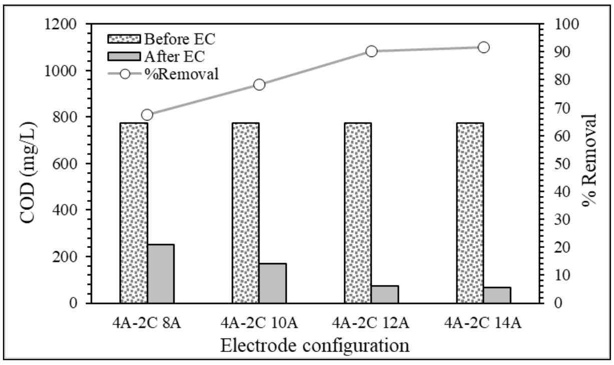

Figure 3 The influence of applied current on COD removal at an agitation speed of 70 rpm.

3.3. The influence of agitation speed on the quality of EC effluent.

The influences of agitation speeds on the quality of EC effluent are presented in **Figure 4** to **Figure 6**. The current density was fixed at 0.0013 A/cm^2. In overall processes, the contaminant removal was decreased with the increase of agitation speed, particularly above 70 rpm. The high agitation speed contributed to a higher shear rate near the interface of flocs. Therefore, irreversible floc breakage occurred, and it was unable to re-grow. The maximum of contaminant removal was achieved when 70 rpm of agitation speed was used. At the mentioned agitation speed, the TDS, turbidity, and COD removal were 55.6%, 98.12%, and 90.32%, respectively.

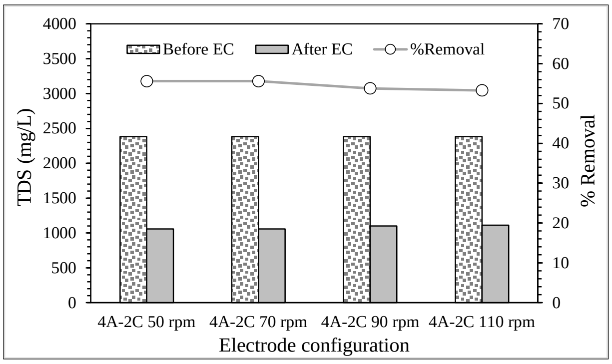

Figure 4 The influence of agitation speed on TDS removal at a fixed current density of 0.0113 A/cm^2

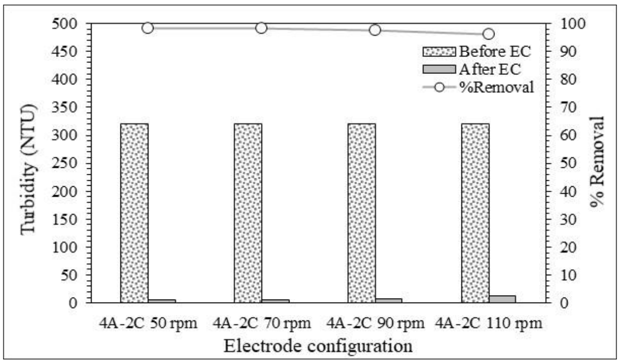

Figure 5 The influence of agitation speed on turbidity removal at a fixed current density of 0.0113 A/cm^2

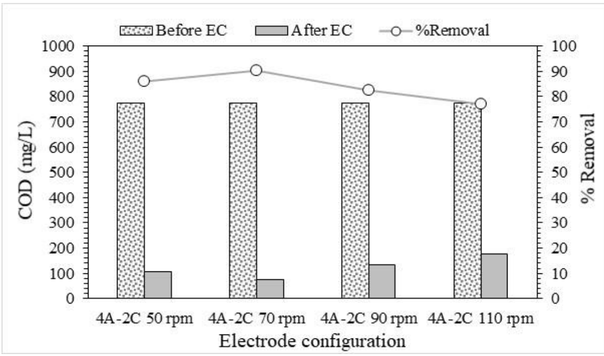

Figure 6 The influence of agitation speed on COD removal at a fixed current density of 0.0113 A/cm^2

4. CONCLUSION

A cylindrical EC reactor equipped with a turbine agitator was used to treat textile wastewater. The influences of applied current density and agitation speed on TDS, turbidity, and COD removal were investigated. It was found that the theoretical number of ions released into the solution was increased from 49.13 to 85.97 mg/L when the current density was raised from 0.0075 to 0.0132 A/cm^2. The maximum of contaminant removal was achieved when 70 rpm of agitation speed was used at a current density of 0.0013 A/cm^2. At the mentioned agitation speed and current density, the TDS, turbidity, and COD removal were 55.6%. 98.12%, and 90.32%, respectively.

ACKNOWLEDGMENT

This research was supported by the Ministry of Education, Culture, Research, and Technology / National Research and Innovation Agency Republic of Indonesia through a program entitled: “Research Funding in Higher Education 2021”, with Contract No.: 164/SP2H/LT/DRPM/2021 dated 18th March 2021.

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