Optimization of NaCl concentration and electrocoagulation processing time to reduce the level of chromium heavy metal solutions

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Abstract. The process of reduction of Cr from the wastewater of the metal coating industry can be carried out by electrocoagulation process. The purpose of this research was to reduce the levels of Cr in solutions, containing Cr as a preliminary study for the determination of NaCl levels added as electrolyte media and the determination of optimal electrocoagulation processing time. This research was laboratory experiments with a continuous electrocoagulation process using iron electrodes, with variations in addition of NaCl and processing time. Determination of Cr in solutions was carried out before and after electrocoagulation using an Atomic Absorption Spectrophotometer (AAS). Two-way ANOVA was used to analyze the result and showed that the significance value of the variation of NaCl concentration and processing time are decrease concentration of heavy metal Cr in solutions was 0.001 (p <0.05). These results indicate that there is a significant difference in the concentration of Cr which is significant in terms of variations in NaCl concentration and variations in electrocoagulation processing time. Based on these results, it can be concluded that the continuous system electrocoagulation process with the addition of 1.20 % w/v a time of 60 minutes gave the most optimum reduction of Cr.

1. Introduction
Electroplating industry wastewater have an impact on the environment, including soil fertility and water quality. The electroplating industry produced heavy metal waste through the metal coating process, if thrown into environment it will cause water pollution. Chromium (Cr) is one of the heavy metals produced by the electroplating industry process. It is highly toxic, carcinogenic, and mutagenic. It needs to be reduced before discharge into environment.

Various techniques have been carried out to reduce heavy metals include biosorption [1], adsorption [2], chemical precipitation [3], electrodialysis [4], and electrocoagulation [5], [6]. In this study, the electrocoagulation method was used to reduce the Cr in the electroplating industry. The electrocoagulation has many benefits compared to other methods, including (i) simple and easy
operation; (ii) does not require large amounts of chemicals; and (iii) small amount of sediment is formed [7].

Electrocoagulation is a process that consists of making metallic hydroxide assemblages in a solution or liquid waste by breaking electrons from soluble anodes, usually made of iron metal, aluminum metal or a combination of both [8]. Electrocoagulation process with ferrous metal anode, iron dissolution process occurs, initially iron $\text{Fe}^{2+}$ or $\text{Fe}^{3+}$ cations will be formed, which will then react with water to form $\text{Fe(OH)}_{2}$ or $\text{Fe(OH)}_{3}$ [9], [10]. The formed metal hydroxide has high adsorption ability and binding power to pollutants, including the heavy metals contained there in which then metal hydroxides and bound pollutants will settle.

This research studied the effect of the addition of NaCl as an electrolyte media and the effect of electrocoagulation processing time which aims to reduce the levels of Cr in artificial solutions containing Cr. Furthermore, the results of this research can be applied to electrocoagulation processing in liquid waste produced by wastewater from the electroplating industry.

2. Methods

2.1. Apparatus

Apparatus used in this research contains of tools and materials as follows.

2.2. Tools

Atomic Absorption Spectrophotometer (AAS), DC Power Supply, A set of electrocoagulation devices consists of: Sample place vessel, Stop faucet, Flow Meter, Electrocoagulation vessel, Iron electrode.

2.3. Materials

Cr solution (artificial), standard solution of Cr, NaCl, aquades.

2.4. Electrocoagulation process

In the experiment of decreasing Cr level by electrocoagulation continuous system was carried out at variation of sample solution flow rate 0.6 Liter Per Minute (LPM) and variation of processing time 15, 30, 45, 60 and 75 minutes and variations in addition of NaCl concentration (0.40; 0.80; 1.20; 1.60)% w/v with the following procedure.

- The solution of Cr artificial heavy metal samples which have been added to the variation of NaCl levels, with concentrations (0.40; 0.80; 1.20; 1.60)% w/v separately, each of which is inserted into the sample vessel.
- Fe electrodes connected to DC Power Supply with a voltage of 12 Volt.
- The faucet is opened so that the sample from the sample vessel flows into an electrocoagulation vessel with a sample solution flow rate of 0.6 LPM to the flow hole limit.
- DC Power Supply is turned on so that the electrocoagulation process lasts until the process deadline is 15, 30, 45, 60 and 75 minutes starting from DC Power Supply is turned on.
- The results of the solution from the electrocoagulation process contained in the storage vessel at 15, 30, 45, 60 and 75 minutes from the electrocoagulation process determined the level of Cr metal with AAS.

3. Results and Discussion

The research results are presented in the Table 1 as follows

Table 1. Decrease of Cr level with NaCl concentration and processing time variation
Based on these data, a two-way ANOVA was carried out. The use of two-way ANOVA was carried out because the decrease in the concentration of Cr was influenced by NaCl concentration (0; 0.40; 0.80; 1.20; 1.60) % w/v and processing time electocoagulation (0 minutes; 15; 30; 45; 60; 75) minutes. The requirements that must be fulfilled in the two-way ANOVA test are the significance values of the interaction between variations in NaCl concentration and electrocoagulation processing time of less than 0.05 (p < 0.05). The calculation results can be seen in the Table 2.

**Table 2. Two-way ANOVA analysis**

| Source               | Type III Sum of | df | Mean Square  | F      | Sig. |
|----------------------|-----------------|----|--------------|--------|------|
| Corrected Model      | 1343.247        | 29 | 46.319       | 5182.242 | .001 |
| Intercept            | 6442.914        | 1  | 6442.914     | 720845.267 | .001 |
| NaCl                 | 560.241         | 4  | 140.060      | 15670.211 | .001 |
| Time                 | 567.208         | 5  | 113.442      | 12692.048 | .001 |
| NaCl * Time          | 215.799         | 20 | 10.790       | 1207.197  | .001 |
| Error                | .536            | 60 | .009         |        |      |
| Total                | 7786.698        | 90 |              |        |      |
| Corrected Total      | 1343.784        | 89 |              |        |      |

a. R Squared = 1.000 (Adjusted R Squared = .999)

Based on Table 2, it can be seen that the significance value of the two-way ANOVA test variations in NaCl concentration and electrocoagulation processing time on the concentration of Cr in solutions is 0.001 (p < 0.05), so it can be concluded that there are significant differences in Cr concentrations in terms of variations in NaCl concentration and electrocoagulation processing time. Furthermore, to find out the difference between each variation of NaCl concentration and electrocoagulation processing time, a post-Hoc test was carried out using the Tukey test. The test criteria are if the difference in the average of two values is compared (mean difference) is significant (p < 0.05), it can be concluded that there are significant differences.

Based on the Tukey test, it can be seen that each variation of NaCl concentration and electrocoagulation time differed significantly from each other (significance 0.001). In addition, Tukey's advanced test showed that the interaction between variations of NaCl concentration of 1.20% w/v and electrocoagulation processing time for 60 minutes with variations of NaCl 1.20% w/v concentration and electrocoagulation processing time for 75 minutes had the greatest role in reducing Cr concentration in solution artificially. However, the two interactions did not differ significantly, so that the optimal variation of NaCl concentration and electrocoagulation processing time used by the decrease in Cr concentration was NaCl concentration of 1.20% w/v and processing time was 60 minutes. 60 minutes electrocoagulation processing time was chosen because the time used for electrocoagulation was shorter than 75 minutes.
The decrease in Cr concentration at variations in NaCl concentration and electrocoagulation processing time can be seen in the following figure.

\[ \text{Figure 1. Graphic of Cr concentration at variation of NaCl concentration and electrocoagulation processing time} \]

The addition of NaCl to wastewater causes an improvement in the conductivity of the solution [11]. The more NaCl is added, the higher the conductivity of electricity or the resistance to the type of solution. Furthermore, if the solution type resistance decreases, then the electric current that flows becomes increasingly large. The longer the electrocoagulation processing time, the better the pollution parameters. According to Faraday Law [12], the longer the processing time, the more coagulants will be formed. The more coagulants formed, the better the decrease in pollution parameters.

4. Conclusion
The results showed that the addition of NaCl concentration and the timing of certain electrocoagulation processes affected the optimization of the decrease in Cr heavy metals in solutions containing Cr. The addition of optimal NaCl concentration is 1.20 % w/v and the optimal processing time is 60 minutes.

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