The influence of electrode type on electrocoagulation process for removal of chromium (VI) metal in plating industrial wastewater

IOP Conf. Series: Journal of Physics: Conf. Series **1025** (2018) 012126 doi:10.1088/1742-6596/1025/1/012126

The influence of electrode type on electrocoagulation process for removal of chromium (VI) metal in plating industrial wastewater

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Abstract. Chromium (VI) is one of the major metallic pollutants in plating industrial wastewater. Cr(VI) is one of toxic metal that cause serious threat to human health and the environment because its non-biodegradable. Among the technologies for removing these pollutants, electrocoagulation can be considered as an effective method. This method have some advantages such as less amount of produced sludge and high efficiency in removal of pollutants.This research intended to study the effects of type of electrode on the degree of Cr(VI) removal from wastewater of plating industry using electrocoagulation method. This laboratory research conducted with 3 types of electrode (aluminum, stainless and combination of both electrode). Synthetic chromium wastewater was prepared at the initial concentration of 100 mg L^{-1}. The process was conducted at pH 3. The electricity current was setting at 3 Ampere. The variable of time of electrocoagulation at 1 and 2 hours. After performing the process on electrochemical cells, samples analyzed by the UV-Vis spectrophotometer regarding amount of Cr(VI) metals. The results showed that aluminium was the best performance electrode at variable of 2 hours with 26% of reduction of Cr(VI)metal content in plating industrial waste water.

Keywords: type of electrode, electrocoagulation, chromium metal, plating industry

1. Introduction

Chromium waste Cr(VI) is a type of heavy metal that is harmful to humans as well as to the environment. Cr(VI) is also more easily absorbed in the human body, especially the digestive tract in humans [1]. In chrome electroplating industry, Cr(VI) was one of heavy metal coating besides of nickel, and copper. There have been many attempts to reduce chrome waste which one of them is with electrocoagulation technology. Electrocoagulation utilizes ion exchange at the anode to trigger oxidation-reduction reactions on chrome and plate waste to form flocs which can then be physically treated to purify of them. Electrocoagulation is an effective and quick method for treating water or wastewater containing dissolved salts or toxic metal compounds. The ion exchange mechanism by anode plates is used in electrocoagulation, there was no chemical added to the water to cause coagulation, and the volume of produced sludge is less compared to most other common treatment methods [2].

Pollutants in raw waters and wastewaters are typically colloidal particles, which are not easily removed with typical filtration sedimentation or flotation due to their stability in water. These particles have special properties due to their small size and large total surface area [3]. Crittenden [4] and Bratby [5] research conducted mechanisms which can destabilise colloidal particles in water are compression of electrical double layer, adsorption destabilisation, inter-particle bridging, precipitation and enmeshment mechanism.

The advantages of electrocoagulation over conventional coagulation included economic aspects (relatively low investment, maintenance, energy, and treatment costs), significantly lower volume of sludge produced, better sludge quality (lower water content, much larger and more stable flocs with better settlability), similar or slightly better efficiency, avoidance of chemical additions, ease of automation, simple equipment and compact size of electrocoagulation systems (allowing decentralized treatment), greater functional pH range and pH neutralization effect, and the presence of electroflotation [6].

2. Material and Methods

2.1. Material

The reactor using copolymer tank material with 40 litres of volume. The electrode using stainless steel, aluminum, and combination of both plates. The electrode dimension is 30 × 10 cm with 1 mm thickness. Reactor and plates was constructed, then put on 1000 l/h aquatic pump. Power converter to convert AC to DC could be set at 0-6 amperes and 60 volts. The clamps of the converter were connected to the electrode in series arrangement.

The actual wastewater was obtained from UD Sinar Padi electroplating home industry and located at Juwana Pati, Center of Java, Indonesia. Simulated of wastewater with 100 mg L^{-1} of Cr (VI) solution was prepared using $K_2Cr_2O_7$ analytical-gradeMerck chemicals and dissolved in demineralized water. The pH was not controlled during electrocoagulation, but the initial pH was recorded.

2.2. Methods

The power of converter was set at 3 Ampere and initial condition adjusted at pH 3. During electrocoagulation process, the flocs formed during electrolysis which can then be physically removed from the reactor using filtration.

The samples of wastewater were analyzed by the UV-Vis spectrophotometer (Merck Spectroquant Pharo 300) for regarding amount of chromium metals. The absorbance was read at around 360 nm. The standard curve of absorbance was used for predict the concentration chromium after electrocoagulation process.

3. Results and Discussion

The initial stage of the analysis is to determine the exact wavelength for the sample measurement. Initially the synthetic wastewater samples tested the wavelength and obtained the optimum wavelength at 361 nm. Then the chrome wastewater was tested by the same method which results in several wavelengths but the optimum peak of the wavelength is 362 nm. This proves that synthetic wastewater and chrome waste can be matched in experiments at optimum wavelengths of 361 nm.

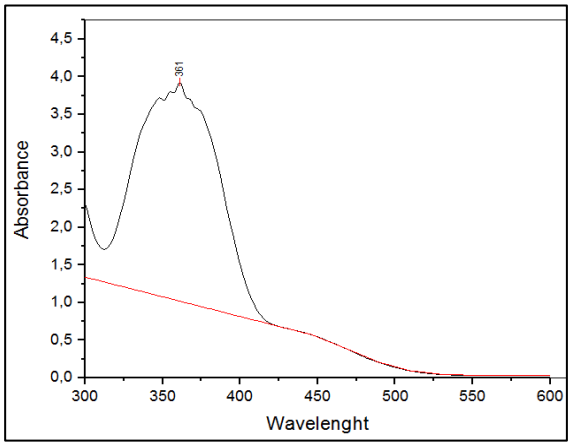

Figure 1. Synthetic wastewater wavelenght

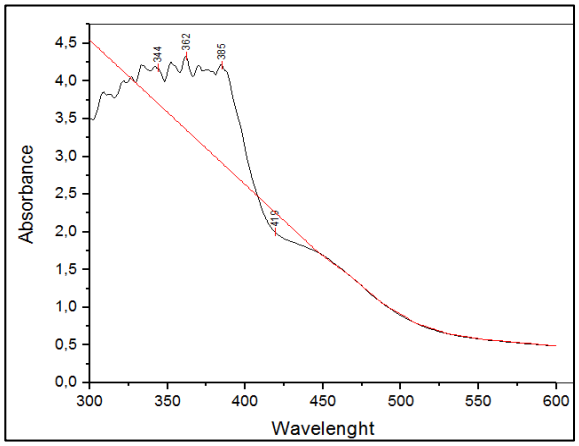

Figure 2. Home industry wastewater wavelenght

The optimum wavelength was used for prepared the standard curve of the absorbance wastewater. The resulting of linier equation is $y = 0{,}0309x + 0{,}052$ (y=absorbance and x = concentration of wastewater).The reduction of chromium wastewater at different electrodes shows at Figure 3.

For this research, the stainless steel plate was used because it is easy to find due to the rest waste of the home industry materials, stainless steel contains around 70% iron (SS304). Aluminum is used because it is a cheap and easy available.The results shows that during 1 hour electrocoagulation, the reduction of Cr(VI) metals was increase until above 15%. The highest of chromium reduction was 18% using type of stainless steel electrode. For aluminium electrode, the reduction of Cr(VI) metals was increase with increasing of electrocoagulation time. Meanwhile, the chromium reduction was decrease during 2 hours of electrocoagulation process for stainless electrode and combination of stainless-aluminum.

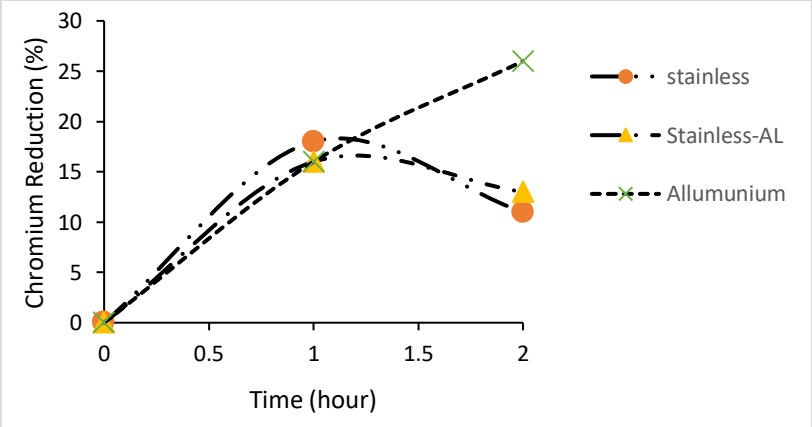

Figure 3. Reduction of chromium wastewater at different electrodes.

The highest chromium reduction efficiency was 26% with aluminium electrode for 2 hours of electrocoagulation. For this process, the pH was adjusted at acidic condition (pH 3). The reaction during electrocoagulation process can be explained as follows:

$M_{(s)} \rightarrow M^{+}_{(aq)} + ne^{-}$ (1)

$2H_2O_{(l)} \rightarrow 4H^{+}_{(aq)} + O_2 + 4e^{-}$ (2)

- At Cathode

$M^{+}_{(aq)} + ne^{-} \rightarrow M_{(s)}$ (3)

$2H_2O + 2e^{+} \rightarrow H_{2(g)} + 2OH^{-}$ (4)

- Reduction of Cr

$$7H_2O + Cr_2O_7^{2-} + 6e^- \rightarrow Cr^{3+} + 14OH^- \quad (5)$$

Noted: (M = metal stainless or aluminum)

Where the metal is erode from the anode, then forming iron hydroxide/aluminum hydroxide [7] [8]. The first step is the formation of coagulant from the anode (stainless and aluminum) which dissolves causing contaminants and particulates of suspension to be coagulated (chromium) as well as break down the emulsion. The aggregate is then formed from the flocculation or adsorption on the metal hydroxide floc. pH becomes an important parameter and the optimum reduction efficiency is also found in acidic pH [9].

Aluminum and iron hydrolysis products then destabilize pollutants present in the solution, allowing agglomeration and further separation from the solution by settling or flotation. Destabilization is achieved mainly by means of two distinct mechanisms, *i.e.* 1) charge neutralization of negatively charged colloids by cationic hydrolysis products; and 2) "sweep flocculation", where impurities are trapped and removed in the amorphous hydroxide precipitate produced [10].

Based on research conducted by Kashefi [9], the efficiency of stainless anode- cathode electrodes and aluminum anode-cathode electrodes is better than the system efficiency of stainless anode-aluminum cathode and aluminum anode-stainless cathode[9]. In fact, the electrodes of stainless anode-stainless cathode will increase the iron ions and hydroxide produced in the anode and cathode.Therefore, the electrocoagulation process with the help with application of stainless plate electrodes. The removal efficiency of heavy metals in wastewater influence of different conditions such as potential difference, acidity, reaction time, the distance between electrodes, and type of selected electrodes [9].

4. Conclusion

Chromium removal from home industrial waste water was carried out using electrocoagulation. The results showed that the optimized removal eficiency 26% was achieved using alumunium electrodes. It can be destabilize pollutants present in the solution, allowing agglomeration and further separation from the solution by settling or flotation. However, there is still a possibility to increase waste reduction by examining several other variables. For further study there are many variables that we have not traced like initial concentration, voltage &electricity current variation, pH, and density might be increase reduction of chromium wastewater.

Acknowledment

We would like to thank the Directorate General of Higher Education, Ministry of National Education through HILINK Grant-2018. We also thank for UD. Sinar Padi, industrial of electroplating at Pati Center Java, Indonesia for an object of this research.

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