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The Effect of pH and Current Density on Electrocoagulation Process for Degradation of Chromium (VI) in Plating Industrial Wastewater

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Abstract. The heavy metal of chromium is one of the most common pollutants of the plating industrial wastewater. Cr (VI) is one of toxic metal that cause serious threat to human health and the environment due to its cumulative effects and non-degradability. Among the technologies for removing these pollutants, electrocoagulation can be considered as an effective method. This method has some advantages such as fewer amounts of produced sludge and high efficiency in removal of pollutants. This research intended to study effect initial pH and current density on the degree of Cr (VI) removal from wastewater of plating industry by using the electrocoagulation method. The process is done at pH values of (3-9) at current density of 0.42, 0.63, 0.83, 1.04, and 1.25 mA/cm². Synthetic chromium wastewater was prepared at the initial concentration of 50 mg L⁻¹ during 30 minutes of electrocoagulation process. After electrocoagulation treatment, concentration of Cr (VI) analysed by UV-Vis spectrophotometer. The result revealed that the best removal was achieved at pH 7 and current density of 1.25mA/cm².

1. Introduction

The wastewater generated from chemical industries contains very harmful pollutants to the environment [1]. 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 [2]. In chrome electroplating industry, Cr (VI) was one of heavy metal coating besides of nickel, and copper. Several treatment processes including physicochemical techniques are implemented for example adsorption [3], ion exchange [4], precipitation [5], membrane reserve osmosis [6] and electrocoagulation technology [7].

Electrocoagulation (EC) is a wastewater treatment technique that works through destabilizing suspended or dissolved contaminants in an aqueous medium by introducing a current into the medium and generating coagulant in situ by electrolytic oxidation of an appropriate anode material (aluminium or iron) [8]. The advantages of electrocoagulation over conventional coagulation included economic



aspects, significantly lower volume of sludge produced, better sludge quality, similar or slightly better efficiency, greater functional pH range and pH neutralization effect [7]. The most important advantage of electrocoagulation is avoiding any addition of chemical substances hence reducing the possibility of secondary pollution; the dosing of coagulant depends on the cell potential (or current density) applied [9]. Other advantages are the simple equipment, thus requiring less maintenance and easy automation of the process [10]. In addition, the formed oxygen and hydrogen bubbles increase the efficiency of the separation process through electroflotation [11].

2. Material and Methods

2.1. Material

Synthetic wastewater samples were prepared for the experiment using hexavalent chromium [Cr (VI)] solution. The solution of 50 ppm (mg/L) was prepared by dissolving 0,141g of dried potassium dichromate, $K_2Cr_2O_7$ (analytical reagent grade), in reagent water and dilute to 1 L. Electrocoagulation process using a glass reactor with 2.5 litres of volume. The electrode using aluminum with dimension of aluminum is 10×3 cm with 1 mm thickness. The clamps of the converter were connected to the electrode in series arrangement.



Figure 1. Electrocoagulation equipment of electroplating wastewater

2.2. Methods

The current density and pH was controlled during electrocoagulation process. The process is done at pH values of 3-9, current density of 0.42; 0.63; 0.83; 1.04 and 1.25 mA/cm². During electrocoagulation processes, the flocks 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 540 nm. The standard curve of absorbance was used for predict the concentration chromium after electrocoagulation process.

3. Results and Discussion

3.1. Effect of initial pH

In this experiment, the sample regulated the pH by using hydroxyl chloride solution and sodium hydroxide to pH 3-9. These ranges will give the data about how acidic pH, neutral pH and bases pH will affect the electrocoagulation efficiency in the removal of heavy metal that contain in the samples.

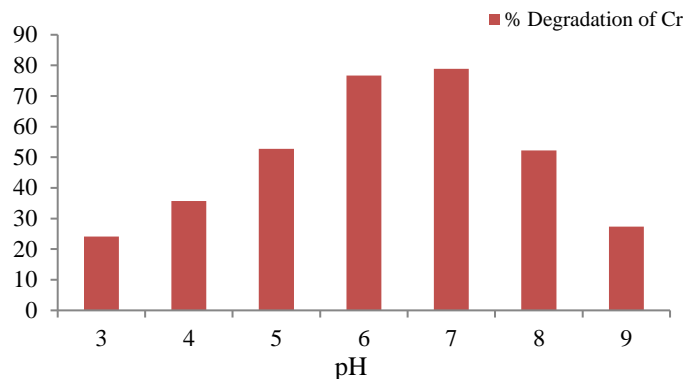


Figure 2. Influence of initial pH on the degradation of chrome

The highest reduction of chromium occurs at pH 7 with an efficiency of 78.93% by using DC current 2.5 Ampere. pH has a considerable effect on the efficiency of the electrocoagulation process. The change of pH during the process dependent on the anode material and the initial pH value of the treated solution. The increase of pH at initial pH lower than 7 is ascribed to the hydrogen evolution and the generation of OH⁻ ions at the cathodes (Viket *et al.*, 1984). During alkaline medium (pH>8), the final pH electrocoagulation process does not change significantly, because the generated OH⁻ ions at the cathodes are consumed by the generated Fe³⁺ ions at the anode forming the needed Al(OH)₃flocs. Furthermore, OH⁻ ions can also partially combine with Cr³⁺ ions to form the insoluble hydroxide precipitate Cr(OH)₃. The aluminium hydroxide (Al(OH)₃) is amphoteric. Hence, the formation of the Al(OH)₃flocs is significantly affected by the pH. Within a pH range of 4-9, aluminium hydroxides with positive charge (e.g. Al(OH)₂⁺, Al(OH)₂⁺, Al₂(OH)₂⁴⁺, Al(OH)₃, Al₁₃(OH)₃₂⁷⁺) and high adsorption capacity are formed. As soon as the pH exceeds the value of 9, the dominant aluminium form is tetrahydroxyaluminate ion (Al(OH)₄⁻) which, however, dissolves and does not form flocks [12]. In acidic medium, the presence of high hydrogen ion concentration the hexavalent chromium ions were only reduced to Tetravalent Chromium (Cr⁶⁺) ions and could not be precipitated.

When using iron electrodes, the final pH increases and is always higher than the initial pH. But when using aluminium electrodes, in initial pH greater than 7, the final pH decreases and at a pH of 7 and lower, pH increases and it is similar to the results reported by the Kabdashi I, et al. This situation shows that pH changes during the electrochemical process. Due to the production of hydroxide ions during the process of reduction of water molecules at the cathode electrode, pH usually increases. In alkaline conditions, Al(OH)₄⁻ complex is the key to reduce pH. Hydrogen bubbles produced at the cathode at neutral pH are small and thin, but they can be used to create an area to connect liquid, gas, and solid, and accumulate small neutral and colloidal particles. However, different balances occur at aluminium electrodes between hydroxide that depend on the pH and buffering properties of the waste. The highest efficiency was calculated in both electrodes at neutral pH (6 - 7), the pH of synthetic effluent [14].

3.2. Effect of Current Density

Current density is important parameter in electrocoagulation processes which determine the size and growth of the flocks, bubble production rate and coagulation dosage rate [15]. Applied current density (ACD) directly affects coagulant dosage as well as mass transfer near the electrodes. The current density was varied from 0.42 mA/cm² to 1.25 mA/cm² to assess its effect on the performance efficiency of electrocoagulation. According to Kumarasinghe *et al.*, when current is applied to the system by a power supply, metallic ions are dissolved from anode and transferred to the bulk [16].

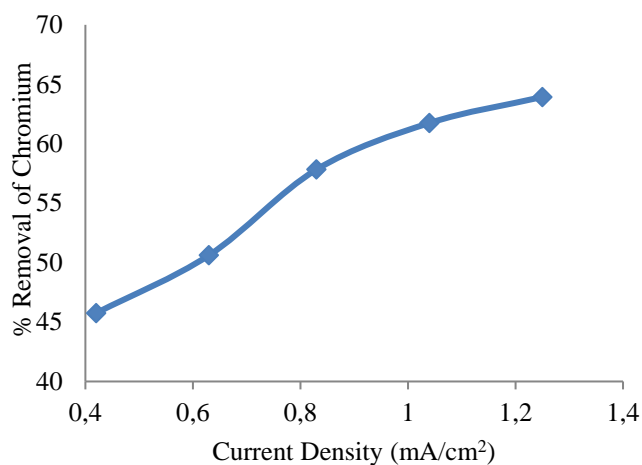


Figure 3. Influence of current density on the degradation of Cr(VI)

The effect of current density on removal percentages of Cr(VI) is illustrated in Fig. 3. With the increase of current density from 0.42 mA/cm² to 1.25 mA/cm² removal efficiency also increases. This is due to the higher amount of ions produced on the electrodes promoting destabilization of the pollutant molecules. From Fig. 3 it is found that, turbidity removal percentage maintains a plateau from current density 1.04 to 1.25 mA/m². Total chromium maximum occurs at 1.25 mA/cm² with an efficiency of 63.73% by using DC current 2.5 Amphere. With an increase in the current density, the anode dissolution rate increase. This leads to an increase in the number of metal hydroxide flocks resulting in the increase in pollutant removal efficiency. An increase in current density above the optimum current density does not result in an increase in the pollutant removal efficiency as sufficient number of metal hydroxide flocks are available for the sedimentation of the pollutant [10]. Current density gives significant effect on removal efficiency of Cr(VI) during electrocoagulation process. At the high current density promoted the generation of hydroxide ion (OH)⁻. This finding was contributed by high formation of Al(OH)₃ and hydrogen gas bubbles generation at high current density accordance to Faraday's law. High formation of Al(OH)₃ allowed more nitrate absorbed on their surface which increase the removal efficiency.

4. Conclusion

The result showed that the optimum removal efficiency was 63.73% at pH 7 and current density of 1.25 mA/cm mA/cm². pH and current density is a significant factor in electrocoagulation process. However, there is still a possibility to increase wastewater reduction by examining several other variables. Electrocoagulation was approved as an effective method for the reduction of chemical in electroplating wastewater. In this treatment, the effect of electrocoagulation on the removal efficiency of Cr(VI) to be dependent on the amount of ion release by electrode for the higher current densities, because higher amount of metal ion generated and leading to higher treatment efficiency.

Acknowledgments

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