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Electrolysis of Metal Coating Industrial Waste Using Carbon Electrode to Reduce Metal Levels of Chromium (Cr), Zink (Zn), and Cadmium (Cd)

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ABSTRACT
The wastewater from the metal coating industry comprises hazardous and poisonous metals, necessitating the reduction of its concentration before its release into water. The typically employed chemical technique involves the addition of Poly Aluminium Chloride (PAC), which causes the hazardous element to accumulate due to the subsequent application of Poly Aluminium Chloride (PAC). Next, the metal content is measured and determined using the atomic absorption spectrophotometry. This study employed the electrolysis technique utilizing carbon electrodes. The liquid waste undergoes electrolysis with voltage changes of 8, 11, 14, and 17 volts for 2 hours. The investigation yielded the optimal voltage for minimizing the metal content. The voltage applied to the metal is 17 volts. The reduction in the concentrations of Cr, Zn, and Cd metals achieved with the optimal voltage is 63.02%, 70.02%, and 80.14%, respectively.

Keywords: Electrolysis, Heavy Metal, Metal Coating, Poly Aluminium Chloride, Wastewater

ABSTRAK
Air limbah industri pelapisan logam mengandung logam berbahaya dan beracun sehingga memerlukan pengurangan konsentrasi sebelum dibuang ke air. Teknik kimia yang biasanya digunakan melibatkan penambahan Poli Aluminium Klorida (PAC), yang menyebabkan unsur berbahaya terakumulasi akibat penerapan Poli Aluminium Klorida (PAC) selanjutnya. Selanjutnya kandungan logam diukur dan ditentukan dengan menggunakan metode spektrofotometri serapan atom. Penelitian ini menggunakan teknik elektrolisis dengan menggunakan elektroda karbon. Limbah cair tersebut mengalami elektrolisis dengan perubahan tegangan 8, 11, 14, dan 17 volt dalam kurun waktu 2 jam. Penyelidikan menghasilkan tegangan optimal untuk meminimalkan kandungan logam. Tegangan yang diberikan pada logam adalah 17 volt. Penurunan konsentrasi logam Cr, Zn, dan Cd yang dicapai pada tegangan optimal masing-masing sebesar 63,02%, 70,02%, dan 80,14%.

Kata Kunci: Elektrolisis, Limbah Cair, Logam Berat, Pelapisan Logam, Poli Aluminium Klorida

1. Introduction

Industrial wastewater is water from the production process, and industrial wastewater generally occurs due to water use in the production process. The substances contained in it vary greatly depending on the raw materials used by the industry. Not appropriately managed wastewater can harm living things and the environment [1].

Chromium (Cr), Zinc (Zn), and Cadmium (Cd) are heavy metals and are included in the group of metals that are toxic and harmful to the life of living things. These three heavy metals are also included in the parameters of PerMenLH RI No. 5 of 2014 concerning wastewater quality standards for businesses or activities of the metal coating and galvanizing industry [2]. The accumulation of these heavy metals in the body can interfere with human health. Chromium can cause damage to the body's organ systems, such as irritating the nose, lungs, stomach, and intestines. Zinc can reduce copper absorption, affect cholesterol, change lipoprotein values, and accelerate atherosclerosis onset. In contrast, cadmium can increase the risk of breast cancer, cardiovascular or lung disease, heart disease, kidney failure, gout, arthritis formation, and bone damage. Therefore, further handling or processing steps are needed in this metal plating industry liquid waste before it is discharged into the environment as effluent or reused as water to support industrial activities [3].

Various methods have been designed and applied to overcome the liquid waste problem, mainly using chemical processes through chemical reactions. Purifying liquid waste can also be done using chemical processes, such as adding Poly Aluminum Chloride (PAC). However, this process has several disadvantages, including using chemicals that can have side effects on health, high operational costs, and the purification process takes a long time [4].

In the era before and even after globalization, the use of chemicals as the main ingredient and additives in the waste treatment process must be seriously considered because the burden of environmental pollution is increasingly worrying. Chemical treatment in the processing of water-phase liquid B3 waste is usually only able to overcome waste problems with specific characteristics so that the being produced from the chemical treatment process usually still contains a small amount of heavy metals and dissolved solids so that it cannot be discharged into the environment [5].

Another alternative that can be used for this wastewater treatment process is the electrolysis process. The electrolysis technique has several advantages: simple equipment, easy operation, and short reaction time. Electrolysis can dispose of various types of pollutants in water, namely suspended particles, heavy metals, colors in dyes, and different hazardous substances [6].

Various studies have been carried out on the electrolysis method. Hutagalung (2018) has used this electrolysis method by comparing the use of aluminum electrodes with the use of Poly Aluminum Chloride (PAC) to reduce metal levels of Chromium (Cr), Zinc (Zn), and Cadmium (Cd) in metal coating liquid waste. There is also a variation of time used to reduce metal levels of Chromium (Cr), Zinc (Zn), and Cadmium (Cd) obtained the optimum time in electrolysis for 90 minutes. This study aimed to determine the effective and efficient processing of banana stem waste as an antibacterial filter on masks and determine the effectiveness and antibacterial activity of the mask filters produced [7].

Based on this description, the researcher is interested in researching the application of the use of electrolysis using carbon electrodes to reduce the levels of Chromium (Cr), Zinc (Zn), and Cadmium (Cd) by electrolysis by varying the voltage in the liquid waste of the metal plating industry.

2. Materials and Methods

2.1. Equipment

Atomic Absorption Spectrophotometer, Power Supply Adaptor, Carbon Electrode, Distilled Water Bottle, Rubber Ball, Beaker Cup, Measuring Cup, Hot Plate, Filter Paper, Whatman No. 42 Filter Paper, Measuring Flask, Matt Pipette, Analytical balance Glass Funnel, Universal Indicator, Tube clamp, pH Meter, Glass stirring rod, Crocodile tongs.

2.2. Materials

Distilled water, HNO_3, NaOH, Cr^{6+}, Zn^{2+}, Cd^{2+}, Universal pH indicator, Metal Plating Industry in Medan Johor District, Medan, North Sumatra.

2.3. Research Procedures

2.3.1. Sampling

Effluent samples were taken from the catch basin (depth = ± 2.5; capacity ± 3000 L) on the surface and at a depth of ± 50 cm with a distance of ± 30 cm from the edge of the catch basin with the time of taking the sample in the morning, afternoon and evening. Then, the sample is mixed in a container to make it homogeneous. For one stage of the process, 20 liters of wastewater samples were taken. Then, it was put into a tightly closed container, and the sample was preserved with the addition of $HNO3_{(p)}$ until pH = 3. The money samples taken are wastewater without adding Poly Aluminum Chloride (PAC) and waste addition of Poly Aluminum Chloride (PAC).

2.3.2. Determination of Zn, Cd, and Cr Levels in Metal Plating Industry Liquid Waste Before Addition of Poly Aluminum Chloride (PAC)

a. Sample Preparation

A total of 100 mL of liquid waste from the metal plating industry without the addition of PAC was filtered using ordinary filter paper; then, the filtrate was put into a 250 mL beaker, added 5 mL of HNO_3, heated on a hotplate until the volume of the solution became ± 15 mL, added 50 mL of distilled water, put into a 100 mL volumetric flask through Whatmann No. 42 filter paper, diluted with distilled water to the limit line, homogenized.

a. Determination of Zn, Cd, and Cr Levels in Samples

The prepared sample solutions were analyzed quantitatively by measuring their absorbance using an Atomic Absorption Spectrophotometer for Cr at specific λ = 357.9 nm, Zn at specific λ = 213.9 nm, and Cd at specific λ = 228.8 nm.

2.3.3. Determination of Zn, Cr, and Cd Levels in liquid waste after the addition of poly aluminum chloride

a. Sample Preparation

A total of 100 mL of liquid waste from the metal plating industry without the addition of PAC was filtered using ordinary filter paper; then, the filtrate was put into a 250 mL beaker, added 5 mL of HNO_3, heated on a hotplate until the volume of the solution became ± 15 mL, added 50 mL of distilled water, put into a 100 mL volumetric flask through Whatmann No. 42 filter paper, diluted with distilled water to the limit line, homogenized.

b. Determination of Zn, Cr, and Cd Levels in the Sample

The prepared sample solution was analyzed quantitatively by measuring its absorbance using an Atomic Absorption Spectrophotometer for Cr at specific λ = 357.9 nm, Zn at specific λ = 213.9 nm, and cd at specific λ = 228.8 nm.

2.3.4. Liquid Waste Electrolysis Process Before Addition of Poly Aluminum Chloride (PAC)

Before the electrolysis process is carried out, the sample solution is tested to determine whether or not the sample solution is an electrolyte solution, whether the electrolyte solution can conduct electric current, and whether or not the emergence of gas bubbles in the solution.

2.3.4.1 Electrolysis of Liquid Waste with Carbon cathode and Anode

a. Electrolysis Process and Sample Preparation

As much as 500 mL of metal plating industry wastewater without the addition of PAC was put into a 1000 mL beaker, measured pH if pH ≤ 7 added NaOH 1 N and paired electrolysis circuit with Carbon electrodes, dipped both electrodes into the sample connected to a DC current source with a current strength of 1 and a voltage of 8 V. The electrolysis process was carried out for 2 hours then filtered then the filtrate was put into a 100 mL beaker, added 5 mL of $HNO3_{(p)}$, heated on a hotplate until the volume of the solution became ± 15 mL, the electrolysis process was carried out for 2 hours then filtered then the filtrate was put into a 100 mL beaker, added 5 mL of $HNO3_{(p)}$, heated on a hotplate until the volume of the solution became ± 15 mL, added 50 mL of distilled water, put into a measuring flask through Whatman filter paper no. 42, diluted with distilled water. 42, diluted with distilled water to the limit, homogenized.

c. Determination of Zn, Cr, and Cd Levels in Samples

The prepared sample solution was analyzed quantitatively by measuring its absorbance using an Atomic Absorption Spectrophotometer for Cr at specific λ = 357.9 nm, Zn at specific λ = 213.9 nm, and Cd at specific λ = 228.8 nm.

2.3.4.2 Electrolysis of Liquid Waste with Voltage Variations

d. Electrolysis Process and Sample Preparation

A total of 500 mL of metal plating industry wastewater without the addition of PAC was put into a 1000 mL beaker, measured pH if pH ≤ 7, added NaOH 1 N and paired electrolysis circuit with Carbon electrodes, dipped both electrodes into the sample connected to a DC current source with a current strength of 1 A and a voltage of 8 V, the electrolysis process was carried out for 2 hours and then allowed to stand, after being allowed to stand then filtered then the filtrate was put into a 100 mL beaker, added 5 mL, added 50 mL of distilled water, put into a measuring flask through Whatman filter paper no. 42, diluted with distilled water.

42, diluted with distilled water until the limit line homogenized. The same was done for 11, 14, and 17 voltage variations.

e. Determination of Zn, Cr, and Cd Levels in Samples

The prepared sample solution was analyzed quantitatively by measuring its absorbance using an Atomic Absorption Spectrophotometer for Cr at specific λ = 357.9 nm, Zn at specific λ = 213.9 nm, and Cd at specific λ = 228.8 nm.

3. Results and Discussion

The treatment of metal plating industry wastewater by electrolysis has reduced heavy metal levels such as chromium, zinc, and cadmium. The basic principle of electrolysis is the decomposition of electrolytes by an electric current with two kinds of electrodes, namely: electrode (+) or anode that undergoes an oxidation process and at the same time serves as a coagulant and electrode (-) or cathode that undergoes a reduction process and at the same time serves as a place of deposition of electrodes. In addition, in this study, the electrolysis process was carried out with voltage variations of 8, 11, 14, and 17 volts to determine the optimum voltage in the electrolysis process of the metal plating industry's liquid waste.

Research has been carried out using electrolysis with voltage variations of 8, 11, 14, and 17 volts. The electrode chosen for the electrolysis process is a carbon electrode because this carbon electrode is an inert electrode with a high electrode potential (Eo) and is quickly reduced.

Electrolysis with carbon anode (C) and carbon cathode (C). The carbon electrode is inert, so that the following reaction occurs at the anode:

Reaction electrolytic Zn

$2ZnSO_4 \longrightarrow 2Zn^{2+} + 2SO_4^{2-}$

Cathode (Reduce): $Zn^{2+} + 2e \longrightarrow 2Zn$

Anode (Oxide) : $2H_2O \quad 4H^+ + 4e + O_2$

$2ZnSO_4 + 2H_2O \longrightarrow 2Zn + 4H^+ + O_2$

Reaction electrolytic Cd

$2CdSO_4 \longrightarrow 2Cd^{2+} + 2SO4^{2-}$

Cathode (Reduce) : $2Cd^{2+} + 2e \longrightarrow 2Cd$

Anode (Oxide) : $2H_2O \longrightarrow 4H^+ + 4e + O_2$

$2CdSO_4 + 2H_2O \longrightarrow 2Cd + 4H^+ + O_2$

Reaction electrolytic Cr

$K_2Cr_2O_7 \longrightarrow 2K^+ + Cr_2O_7^{2-}$

Cathode (Reduce) : $2Cr^{2+} + 2e \longrightarrow Cr$

Anode (Oxide) : $2H_2O \quad 4H^+ + 4e + O2$

$K_2Cr_2O_7 + 2H_2O \longrightarrow 2Cr + 4H^+ + O_2$

The research results show a comparison of the percentage reduction in chromium, zinc, and cadmium levels by adding poly aluminum chloride (PAC) and the electrolysis method against voltage variations, such as links, which can be displayed in Figure 1.

The two graphs above show the relationship between the percentage reduction of Cr, Zn, and Cd metal levels and the method used in reducing these metals. The graphs show that the percentage reduction in metal levels is much greater when the electrolysis method is used compared to the PAC addition method. It can be concluded that using carbon electrodes as anodes in the electrolysis method effectively reduces heavy metal levels, such as Cr, Zn, and Cd, in electroplating industry wastewater. This is because the presence of electric current in the electrolysis process can cause metal ions contained in the solution to be reduced. In addition, increasing the electrolysis voltage can also form $Al(OH)_3$ with an increasing amount, which has high adsorption power and can act as a coagulant that can attract colloids in the form of metal ions or other particles and form flocs which will separate from the solution so that it is easy to separate.

To determine the optimum voltage in electrolysis carried out at potential and controlled electric current with voltage variations of 8, 11, 14, and 17 volts. From the research that has been done obtaining changes in metal concentration against electrolysis voltage as in the link in Figure 3.

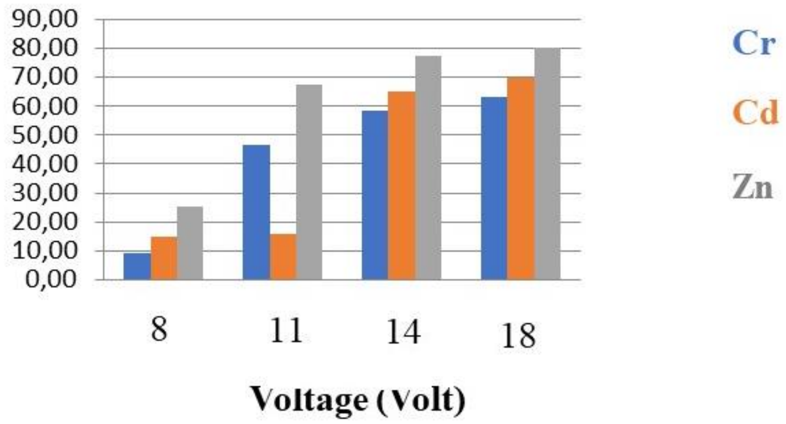

Figure 1. Percentage decreasing of metal levels against PAC

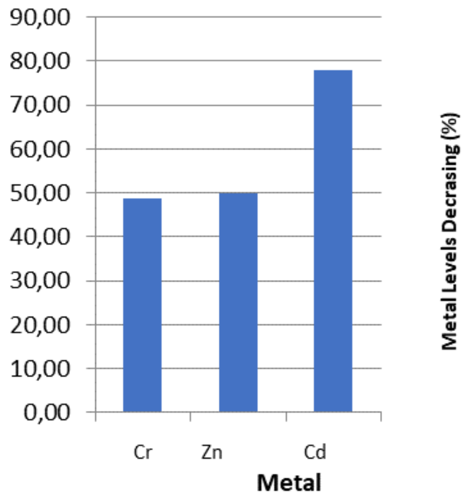

Figure 2. Percentage of metal levels decreasing

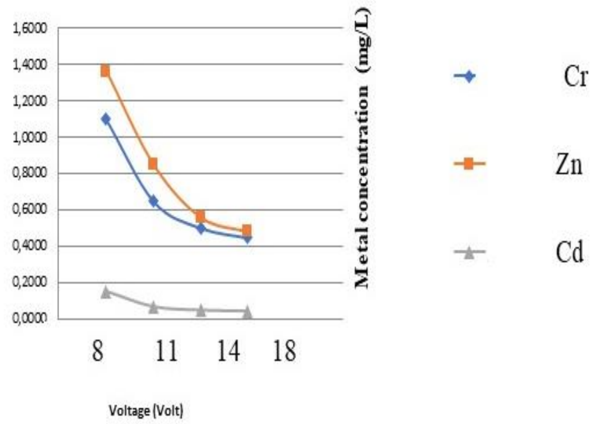

Figure 3. The changes in metal concentration against electrolysis voltage

The figure above shows that the greater the electrolysis voltage, the more metal ions in the solution will be reduced. From the results of this study, the optimal voltage in electrolysis was obtained for 14 volts because of the decrease in Cr, Zn, and Cd metal levels at 14 volts and 17 volts.

4. Conclusion

In conclusion, using carbon electrodes in electrolysis is more effective when reducing heavy metals, such as Cr, Zn, and Cd, in metal plating industry wastewater than adding poly aluminium chloride (PAC). The optimum voltage to reduce the Cr, Zn, and Cd metals levels is 17 volts.

5. Acknowledgements

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6. Conflict of Interest

Authors declare no conflicts of interest

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