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# Using Electrocoagulation as Green and Efficient technology for Removing Toxic heavy metals from Industrial Wastewater

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**Abstract:** Copper is a very toxic heavy metal to the environment when it is dissolved in the water in a high concentration, many studies have focused on eliminating copper from industrial wastewater through different methods. Electrocoagulation has been used as a suitable industrial wastewater treatment technology to use in removing copper. For this research, aluminum electrode was used as anode and cathode for removing Copper (Cu) from synthetic wastewater. Batch tests were conducted to know the performance of copper removal through EC system. Different factors were studied such as pH (4, 6, 8 and 10), initial concentration (10, 20, 30 and 40) ppm, contact time (1, 2.5, 5, 10, 15 and 30) min, stirring speed (50, 100, 150 and 200) rpm, inter-electrode spacing (1, 2, 3 and 4) cm and current (0.1, 0.2, 0.3 and 0.4) A, at room temperature. The results showed an increase in removal efficiency of copper ions within the first 30 minutes, while equilibrium was occurred within 15 minutes, and the optimum pH was found to be 6, The removal efficiency for copper ions reached to 98% by using aluminum electrodes.

**Keywords**: Heavy metals, Copper ions, Electrocoagulation, Current, Industrial wastewater.

## 1. Introduction

Water pollution is a significant problem that we face in these days, so it is essential to interest in wastewater treatment with different technologies [1].

wastewater resulting from many industries is source of water pollution because of its important environment problem. When pollutants exist in water, they cause danger to the environment [2],[3].

In these days, the world has started to produce green methods and technologies for treating industrial wastewater to be sure that is an increase in removal efficiency of the pollutants level according the standards [4], [5].

One of these pollutants is heavy metal, copper (Cu) is a heavy metal existing in high concentrations is a toxic because it can be existing in the brains, livers, skin and pancreases [6].

Copper, which is a hazardous heavy metal, is an important element required by humans and has an important role in enzymes synthesis, bones development, and tissues. Copper Cu (II) is widely used in electroplating industry, paints and dyes, petroleum refining's, fertilizers and steel industries, it considered to be one of the most hazardous heavy metals in industrial wastewater effluents [7].

One of the most important technologies that can remove heavy metals from industrial wastewater is electrocoagulation (EC) [8].

Electrochemical, electrolytic cells are used in EC technology and consist of anodes and cathodes, electrical source and electrolyte are existed in the solution. Anode which is the positive pole oxidation is happened and generate electrons. Cathode which is negative pole where the reduction reactions are happened. Some factors that are affected on EC efficiency are current, gap distance between electrodes, pH, reactions time, and mixing of speed of sol. [9],[10]. EC is a suitable technology for removing particles and other pollutants from wastewaters [11],[12].

EC technology has highly regarded for treating various industrial wastewaters due to its safety for environment, sustainability, easy in operation, quick treatment time, and the production of small quantities sludge. [13],[14]. The electrons that shared in this method is controlled by Faraday Law [15],[16].

The aim of this study was treatment of synthetic wastewater in efficient and green technology and showing the effect of operating factors such as current, treatment time, pH, mixing of sol. speed, initial conc. of copper and inter-electrode distance on the removal efficiency of copper from synthetic wastewater.

## 2. MATERIALS AND METHODS:

### 2.1 Electrocoagulation system

This experiment consists of two electrodes from aluminum submerged in a 1L glass beaker on a magnetic stirrer for mixing solution and make it homogeneous, and the electrodes are connected to a power supply of 30V/5A. The two electrodes are made of aluminum with dimensions of (5cm ×10cm). The dimensions of the immersed part of the electrodes are (5cm × 5cm). Aluminum electrodes were used from solid waste resulting from aluminum manufacturing workshops. This is a significant saving in the economic cost of the treatment process and a safe and inexpensive way to dispose of solid waste. The system is shown in fig.1.

**Figure.1** Electrocoagulation system

### 2.2 Preparation of copper Solutions:

Copper solution has been prepared and used in the laboratory experiment. Simulated stock of copper ions (1000mg/l) was prepared by dissolving 3.9 gm of the metal salts in distilled water. the salts used are "Copper sulphate $CuSO_4 \cdot 5H_2O$.

### 2.3 Methodology:

The experiment was done in 1000ml beaker and total volumes of the reaction mixtures were protected at 500 ml. The pH of the sol. was adjusted to the coveted values with 0.1M HCL and 0.1 N NaOH until the pH was stabilized and was stirred for 30 min, then the Cu ions was added to the beaker to obtain initial concentration (10- 40) mg/l are studied in a pH range (4- 10) in addition contact time are studied in arrange (1- 30) min at mixing rate (50-200) rpm, varying current in range (0.1-0.4) A and inter electrodes distance (1-4) cm at room temperature, at the end of stirring, the solution was separated from pollutants by using filtration Whatman no.1 filter paper. The conc. of heavy metal was measured by atomic absorption spectrometer. The percentage removed metal ions was calculated using following equation (1),

$$R = \frac{C_0 - C_t}{C_0} \times 100\% \qquad (1)$$

Where,

R: Removal efficiency of pollutants

$C_0$: Initial Concentration of pollutants

$C_t$: Final concentration of pollutants after treatment at a given time t in min.

## 3. RESULTS AND DISCUSSION

### 3.1 Effect of pH:

The pH value of the solution is one of the important controlling factors in the EC process. In case of use of EC for Cu removal PH (4-10) the result show that the removal of Cu was low at pH 4, % removal of copper was 80.4% at first 10 min, but the removal efficiency increased rapidly when we increase the pH from 6 to10, to be (86% - 99%) at first 10 min. The experimental data were showed in figure (2). Increasing in removal efficiency at pH above 6 was due to formation of Al cations produced at anode formed polymer species of Al with hydroxyl ion generated at cathode called floc, it attracted copper pollutant and after neutralizing precipitated and generation of hydroxyl ion greater at this pH range.

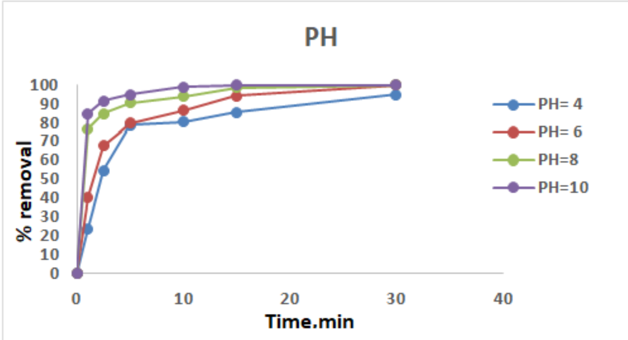


**Figure 2:** Effect of pH for Cu removal efficiency by using EC process

### 3.2 Effect of copper Concentration:

The effect of initial copper concentration on the EC was investigated by varying the initial concentration of copper using DC sources. The experimental data was showed in figure (3). The results showed that, with increasing initial concentration of copper from (10 to 40) mg/L, the removal decreased from (98% to 85%) at first 10 min respectively. It can be seen that the adsorption of copper on flocs is increased with decreased in copper concentration and it remains constant after equilibrium time. The equilibrium time was after15 min for all of the concentrations that were studied. This is due to the circumstance that at fixed operating factors the amount of coagulant generated will be fixed which is insufficient to form floc to attract high pollutant concentration.

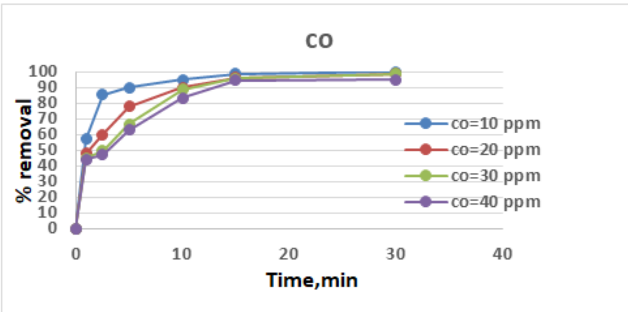


**Figure 3:** Effect of initial concentration on Cu removal efficiency by using EC process

### 3.3 Effect of mixing Speed:

The effect of mixing speed was studied by varying between (50 -200) rpm. It was observed that the removal percentage of copper ions increased with the increasing of mixing speed it reached to 94.7% at 50 rpm and to 98% at 200 rpm after 30 min. it is showed in figure (4) it found that the removal of copper ions increased with increased the mixing speed because of increasing of the velocity of particle, so that increase the removal percentage of copper ions this results from mixing of solution that makes a velocity in the electrolysis creates a uniform the movement of the generated ions for proper mixing that facilitates faster reaction and fast removal.

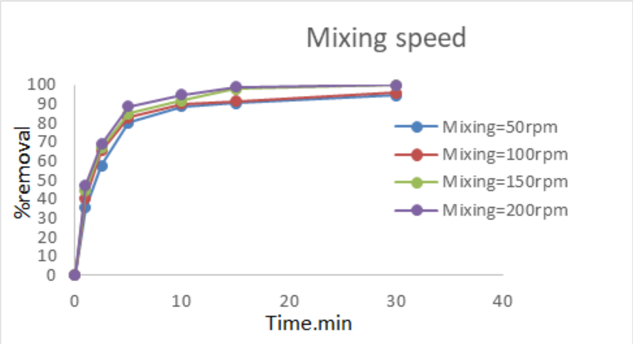


**Figure 4:** Effect of mixing Speed on Cu removal efficiency by using EC process

### 3.4 Effect of applied current on Cu Removal Efficiency Using (Al-Al) Electrodes

In the current study, the effect of applied current is one of the important controlling factors in the EC process. It was studied in a range of (0.1 – 0.4) A.

The variation of the removal efficiency with time for each applied current is as presented in Figure (5) showed that the removal efficiency increased with increasing the current. At a low current value of 0.1 A, the removal efficiency does not change for the first 10 minutes of operation. After that, the removal efficiency increases sharply until it reaches its maximum value of approximately 98% after 10 minutes. However, using high currents of 0.2, 0.3 and 0.4 A, made removal efficiency reached to the maximum it reached more than 98% after less than 15 minutes respectively.

Current density plays important role in generation of coagulant amount at anode, and produce bubbles, that caused removing pollutant with coagulant particles or floc.

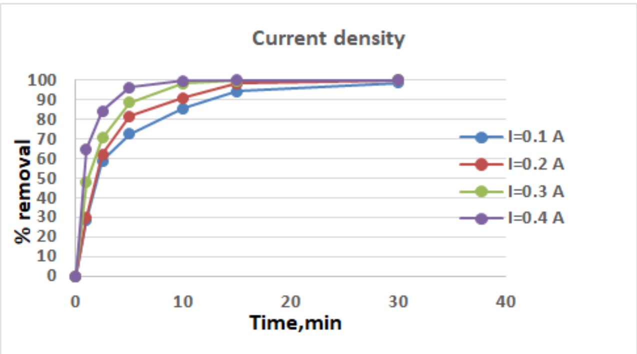


**Figure 5:** Effect of current density on Cu removal efficiency by using EC process

### 3.5 Effect of inter-electrode spacing on Cu Removal Efficiency Using Al-Al Electrodes

The inter-electrode spacing is another important factor since it governs flocs formation. The distance between the anode and cathode ranged from (1 to 4) cm. When the distance between the anode and cathode was increased, the copper removal efficiency was decreased from (98.86 to 94.38) %, The effect of inter-electrodes spacing (1,2,3 and 4 cm) is plotted in figure (6) and it can be concluded from this figure that the removal efficiency increased with decreased the gap between the electrodes it reached more than 98%, that is because the smaller inter-electrode distance typically enhances the coagulation efficiency by creating a stronger electric field, which accelerates the generation of metal hydroxides that speeds up floc formation and removal of copper .

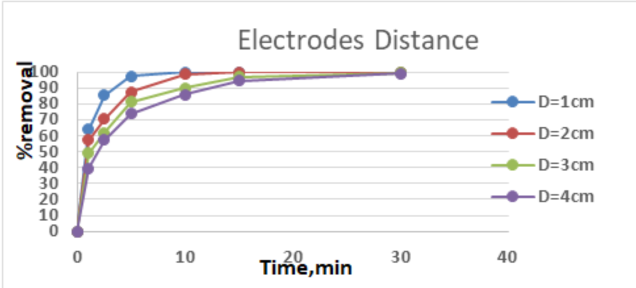


**Figure 6:** Effect of Effect of inter-electrode spacing on Cu removal efficiency by using EC process

### 4. Investigation of the Morphology of Electrode and sludge by using (SEM and X-ray) analysis

SEM scan results for Al electrodes at 100x and 200x magnification before and after treatment are shown in Fig.7 and Fig.8. Before treatment, the electrode's surface is smooth and homogenous, the surface of the electrode is uniform. whereas after treatment, corrosion can clearly be seen on the surface of the electrode, with pits and grooves appearing in the sacrificial anode surface, indicating the occurrence of treatment and the dissolution of Al forming aluminum hydroxide. The corrosion has a uniform appearance, which minimizes the replacement period of the electrodes.

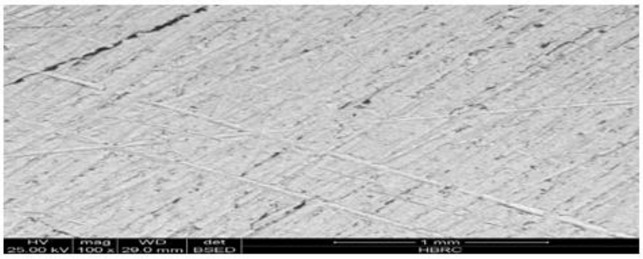

**Figure 7:** SEM scanning of aluminum electrodes before treatment

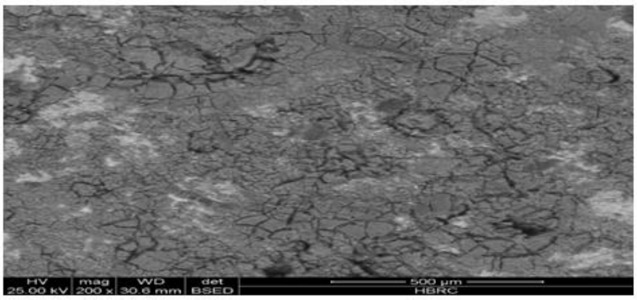

**Figure 8:** SEM scanning of aluminum anode electrode after treatment

### 4.1 Characterization of sludge

#### 4.1.1 SEM analysis:

The sludge generated from electrocoagulation consists of the contaminants removed from the wastewater, including metals, and other particulates, combined with the coagulants that form on the electrodes. SEM images and elemental composition of the generated sludge are shown in Fig. 9. The SEM image did not show any crystalline shape on sludge surface, which indicates the presence of mostly amorphous or ultrafine particular structure at µm size.

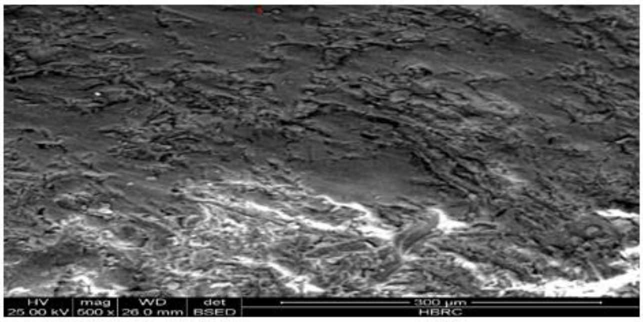


**Figure 9:** SEM scanning of sludge for heavy metals after treatment

### 4.1.2 X-ray analysis:

x-ray analysis is a strong technique used to characterize the composition and structure of materials, including sludge produced during the electrocoagulation (EC) process for industrial wastewater treatment. Specifically, X-ray diffraction (XRD) is used to analysis of the presence of minerals composition and elemental distribution in the sludge. These techniques help in understanding the behavior of pollutants, the effective of the EC process, and the possible environmental impacts or the chances for recycling the generated sludge.

Identify the mineral phases present in the sludge, which may include metal hydroxides Al $(OH)_3$, copper sulfates. Assess the crystallinity of the metal hydroxides formed during the electrocoagulation process. The crystalline forms of the metal hydroxides can affect the stability and environmental mobility of the sludge.

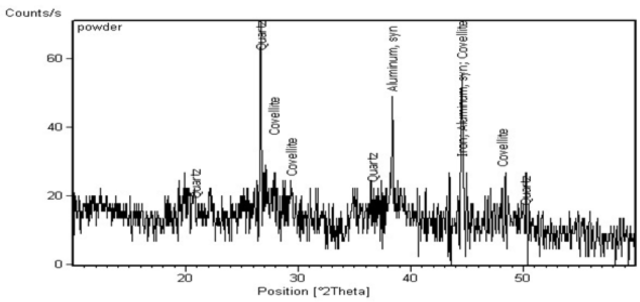


**Figure 10:** X-ray of sludge for heavy metals after treatment

## 5. CONCLUSION

This research work is shown that (EC) has proven to be an effective and sustainable method for removing copper from synthetic wastewater.

it was found that:

Electrocoagulation (EC) technology works by using an electric current to encourage the formation of metal hydroxide flocs, which trap and remove toxic metals such as copper from industrial wastewater. EC process is strongly affected by factors such as treatment time, pH, initial copper ions concentrations, mixing speed, inter-electrode distance and current density.

As a result of research, it is concluded that the removal percentage of copper was 95% at PH 4 and the removal percentage increase to 98% upon increasing the pH from 6 to 10. It was observed that the removal percentage of copper ions increased with the increasing of mixing speed reaching 94.7% at 50 rpm and to 98% at 200 rpm.

When the initial concentration of copper is increased from (10 to 40) mg/L, the removal percentage of Cu decreased from (94.7% to 83.25%) respectively and it increased when current density increased from (0.1-0.4) A from (85.79 % - 99%) respectively after 10 min.

EC proved highly effective in removing copper ions, achieving an 98% removal percentage under optimal conditions of (pH 6, current 0.4 A, 30 min. contact time, 1cm inter-electrode spacing and mixing speed 200 rpm).

From the results, it can be concluded that EC is a suitable method for the removal of copper ions from synthetic wastewater as it is economical and having higher removal efficiency via other conventional treatment methods. This process required simple equipment and easy operation for small scale.

It is recommended that future research should focus on developing EC performance, sustainable and cost-effective for industrial wastewater with a large scale by developing electrode materials for increasing its life time and using renewable energy sources like solar or wind energy.

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