Removal of Copper from Industrial Wastewater by Ion Flotation with Sodium Dodecyl Sulfate as Anionic Collector

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Abstract: ***Copper removal from industrial wastewater is studied for environmental protection and copper recovery. The paper shows the copper removal of copper from industrial wastewater by ion flotation at a laboratory scale, using an anionic collector (Sodium Dodecyl Sulfate, SDS). The optimum values of the main variables affecting this process were determined. These variables are pH of copper solution, initial concentration of copper ions in sample, air flow rate and flotation time. An atomic adsorption spectrometry PERKIN ELMER model 2280 was used to determine the copper content of the wastewater. The copper removal efficiency was calculated with the equation: $R\% = [(C_0 - C_f)/C_0]\times 100$, where C_0 and C_f are the initial and final concentrations of copper ions in wastewater. Using the optimal conditions, high removal efficiency of copper (> 98 %) was obtained.***

Keywords: Environmental, Foam flotation, Froth flotation, Copper removal, Flotation frothers, Flotation collectors

1. Introduction

Industrial wastewaters are the main sources of aquatic environmental pollution. Water pollutants include organic compounds, pathogens and heavy metals. Among these pollutants heavy metals gained great importance because of excess toxicity [5]. Heavy metals are considered a more industrial pollutants damaging when discharged into the aquatic environment, because it cannot be degraded by chemical or biological processes. In addition, the addition of heavy metals to the environment in low concentrations can accumulate inside the plant and animal tissues. These elements are required by living organisms, but their presence in high concentrations will become toxic to the living organisms [1]. Some metals such as cadmium, mercury, silver and lead can become extremely toxic to living beings, while the others such as copper, zinc, manganese, iron, nickel and cobalt though essential for plant and animals, when present in excess concentrations and above certain limits, can be very harmful to living organisms. Copper is considered as micronutrient but is extremely toxic to living organisms at higher concentrations. The main sources of copper pollution are metal cleaning and plating baths, paints and pigments, a pulp, paper board mills, wood pulp production, and the fertilizer industry. Copper may also be found as a contaminant in food, especially shellfish, liver, mushrooms, nuts, and chocolate [2].

World Health Organization (WHO) the metals of most immediate concern due to their high toxic nature even at very low concentrations are chromium, copper, zinc, iron, mercury and lead (WHO, 1998). These toxic metals can cause accumulative poisoning, cancer, and brain damage when they are found above the tolerance levels (ATSDR, 1999). The World Health Organization recommends a maximum acceptable concentration of Cu (II) as 1.5 $mg.L^{-1}$ in drinking water [8]. Without a doubt, the copper ions top the list of the most toxic copper compounds, list of toxic copper compounds involve the following: $Cu(OH)^+$, $Cu_2(OH)_2^{2+}$ and $CuCO_3$ [6]. The copper toxicity is a much overlooked contributor to many health problems; including anorexia, fatigue, premenstrual syndrome, depression, anxiety, migraine headaches, allergies, childhood hyperactivity and learning disorders [5].

Many different methods used in the wastewater treatment to removal of heavy metals such as chemical precipitation, ion exchange, reverse osmosis and so on, these methods are relatively expensive in terms of equipment as well as the generation of large quantities of secondary waste. Of these, flotation has shown to have great potential of modern equipment available owing to its: simplicity, flexibility and effectiveness of operation, low space requirements, the production of small, concentrated volumes of sludge, and the fact that it may be applied to treat large volumes of dilute aqueous waste solutions contaminated by heavy metal ions. Ion floatation is the most important flotation methods that are used to separate the metal ions from waste water [4].

Ion Flotation: Ionic flotation was proposed in the 1950's by F. Seba. Gas bubbles and the collector are introduced into the starting solution. The latter forms surface-active ions in the solution. The charge of these ions is opposite to the charge of the ions to be extracted. The compound formed by the surface-active ions and the ions to be extracted is concentrated at the surface of the gas bubbles and is carried by the bubbles into the foam. The foam is then separated from the solution and broken down. The extracted ion, which is concentrated in the foam product, is then isolated by various methods, depending on the concrete conditions (the nature of the ion and the collector, the purpose of the flotation, and other considerations) [9].

The aim of the present study is to establish the optimum ion flotation conditions in term of: pH of copper solutions, molar ratio collector: copper, air flow rate, flotation time and initial concentration of copper.

2. Materials

2.1 Chemicals

- Copper chloride dehydrates (CuCl2.2H2O, purity = 99.5% wt, M.wt = 170.482 g/mole) which dissolving in distillated water.
- Anionic collector (sodium dodecyl sulfate).
- 15% and 1M NaOH solutions.
- 1M HNO3 solution.

2.2 Apparatus

- Bench–scale of Denver Equipment Co. (ion flotation machine, figure 2.1)
- pH–meter.
- Surface Tension Measurement Instrument.
- Atomic Absorption Spectrometry (AAS).

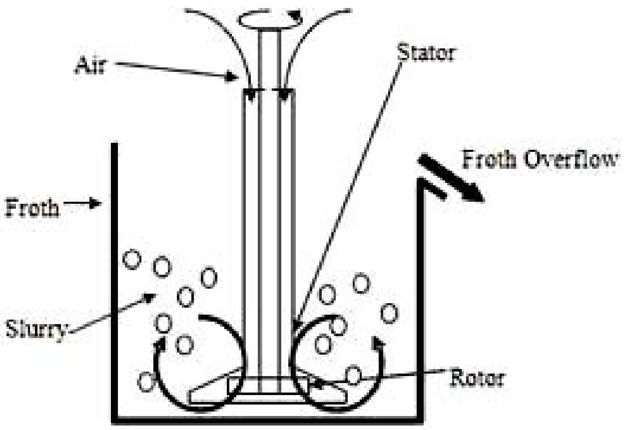

Figure 2.1: A schematic view of the flotation machine [3]

2.3 Working Procedure

Ion flotation experiments were conducted in a one liter cell using a Denver type laboratory flotation machine. A schematic view of the flotation machine is given in Figure 2.1. It consists of a cell where the separation takes place and impeller for mixing the pulp and introducing the air. Solutions for ion flotation were prepared in a 1000 ml volumetric flask using appropriate amounts of metal ion with double distilled water to make up 1 liter of solution. Then the solution pH was adjusted to a desired value using HCl or NaOH solutions. The solution was stirred for approximately 10 minutes to ensure consistent mixing of reagents. The solution was then placed in the flotation cell. Firstly, SDS solution was added in certain molar concentration values and mixed with the solution that was in the flotation cell for a time period of 2 minutes. Appropriate amounts of ethanol were added after applying SDS to the solution for 2 minutes. During mixing of SDS, metal ion and ethanol solutions air was flowed through the sparger. Foam samples were taken at preset time intervals as 2, 4, 8, 16 and 20 minutes. The froth products from various time increments were analyzed by atomic absorption spectrometry (AAS) to determine the amount of metal ions that floated. After the experiments the flotation cell was cleaned using 1M HNO_3, with double distilled water. All experiments were carried out at constant temperature (Laboratory temperature, 27 ± 1 °C). The removal percent of copper ions were determined from the equation:

$$R = \left(\frac{C_0 - C_f}{C_0}\right) \times 100$$

Where: C_0 is the initial concentration of copper and C_f is the final concentration of copper.

3. Results

According to flotation processes and the fact that many physicochemical factors affect ion flotation, in the present study, effects of air flow rate and concentration of collector and frother were examined.

3.1 Effect of acidity

The acidity (pH) of the wastewater is an important controlling variable in the ion flotation process and thus the effect of pH has been studied by different values 4, 6, 8 and 10 as shown in figure 3.1 by plotting the recovery vs. time. As shown in the figure a recovery increases suddenly after 2 minutes, then these recovery begain to decrease slowly with time it was found that the highest recovery achieved when the pH of the wastewater was 10, as 53% after 20 minutes.

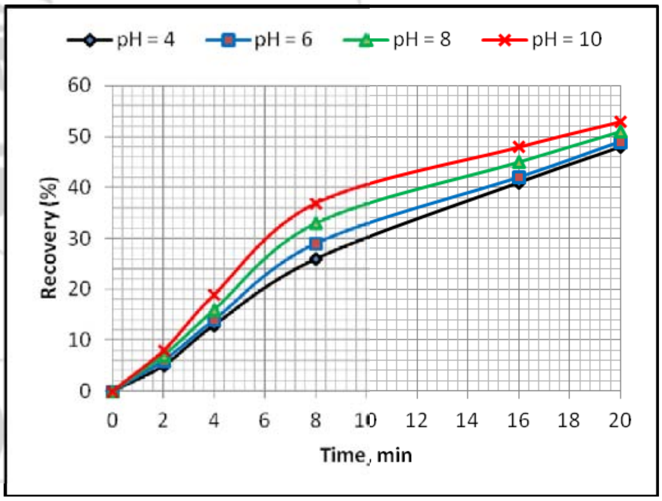

Figure 3.1: Effect of acidity on the floatability of copper in air flow rate: 50 ml/min, 5 × 10^{-4} M SDS, 0.5% Ethanol.

3.2 Effect of Air flow rate

Figure 3.2 shows the effect of air flow rate on the flotation of copper in the presence of the collector SDS. As noted from the figure that the increase in the air flow rate increase the removal efficiency of copper. Maximum value was observed when the air flow rate of 250 ml/min, which was 98%. The figure also explained that after the passage of 4 minutes to floatation, there were significant increases in the efficiency of the flotation copper as flotation time increase.

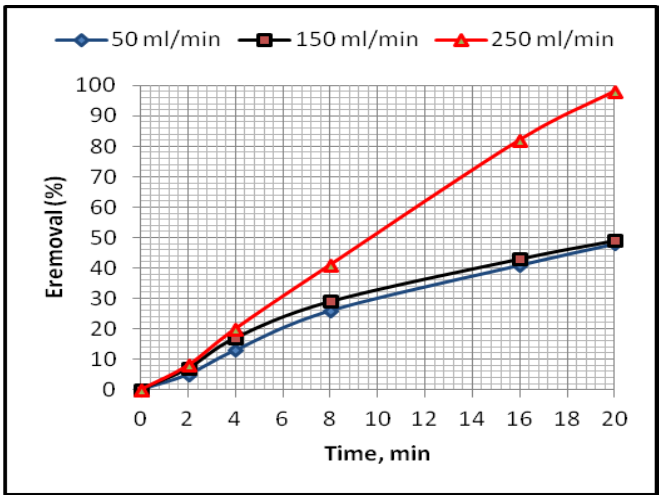

Figure 3.2: Effect of air flow rate on the floatability of copper in pH = 4.0, 0.5% Ethanol, 5×10^{-4} M SDS.

3.3 Effect of Sodium Dodecyle Sulfate (SDS)

Concentration effects of SDS, which acts as a collector, the removal of copper at the operating conditions is shown in Figure 3.3. According to figure, an increase in concentration of SDS enhanced in an increase the removal of copper. Best removal efficiency occurred when SDS

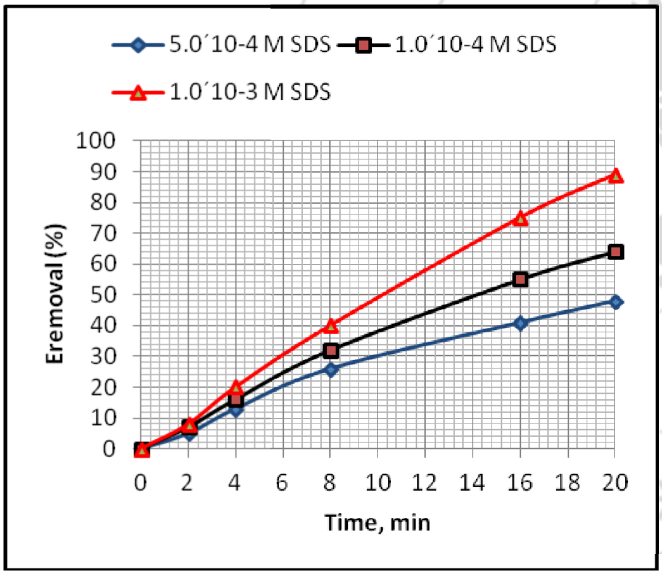

Figure 3.2: Effect of Sodium Dodecyle Sulfate on the floatability of copper in pH = 4.0, 0.5% Ethanol, air flow rate: 50 ml/min.

3.4 Frother effect

Figure 3.4 illustrates copper flotation in the presence of air flow rate of 50 ml/min and various concentrations of ethanol, as frother. It is clear to see that after 20 minutes of flotation, the highest value of the removal of 71% at ethanol 0.1%.

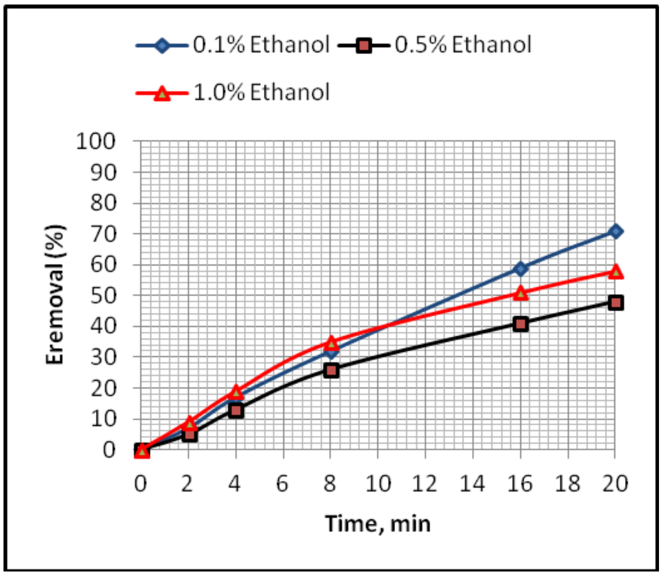

Figure 3.4: Effect of ethanol concentration on the floatability of copper in pH = 4.0, air flow rate: 50 ml/min, 5×10^{-4} M SDS.

3.5 Effect of strength

The effect of ionic strength was studied. For this purpose at tap water with Na^{+}, Ca^{2+} and Mg^{2+} ions were used. The average concentrations of these elements are 18, 26 and 200 mg/lit respectively. The results are shown in figure 3.5. The experiments were done at two different concentrations as 10 and 50 mg/lit. Observes in the figure that recovers copper decreased from 91% to 43% and from 89% to 40% after 20 minutes in the case of tap water for 10 and 50 mg/lit respectively.

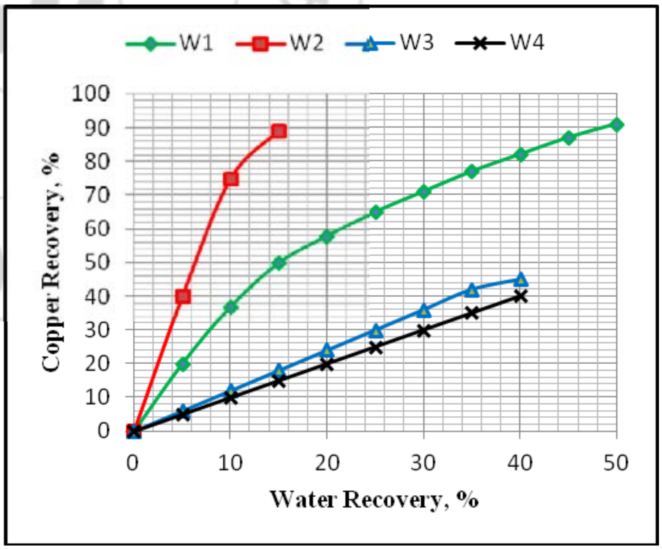

Figure 3.5: Effect of ionic strength on recovery of copper in pH = 4.0, air flow rate: 50 ml/min, 5×10^{-4} M SDS, 0.5% Ethanol

4. Conclusion

This study shows clearly that sodium dodecyl sulfate which is a cheap an available material can be used as an effective adsorbent for separation of copper from wastewater. The ion method is also dependent on many factors such as the solution acidity, the agitation speed, the air flow rate, the collector and frother concentration, the time contact, the ionic strength, etc. using a ion flotation process (at air flow rate = 250 gm/ml) and using sodium dodecyl sulfate as anionic collector, it obtained a high efficiency (> 98%) of copper from wastewater, in a very short time. The study of the operations parameters effects, has confirmed that ion flotation is the major mechanism retention of copper by sodium dodecyl sulfate undergoing no treatment, and showing a high efficiency.

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