REMOVAL OF COPPER IONS FROM WASTEWATER BY ADSORPTION USING MAGNETITE NANOMATERIAL

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This article presents the study of magnetite nanomaterial applied for wastewater treatment. The influence of wastewater pH and contact time upon the removal of copper ions from synthetic wastewater was studied. Three concentrations of copper ions of the wastewater, namely 0.70, 1.00 and 1.20 mg/L and the two amounts of magnetite, 0.10 and 0.20 g/L, were tested. The maximum efficiency of removing copper ions from wastewater was observed in all cases presented, the difference being the time required for treatment.

Keywords: copper ions, magnetite, adsorption, nanomaterials, wastewater.

1. Introduction

Water is the most important resource used for the survival of plants, animals and humans. Water pollution is caused by human, agricultural, mining, deforestation, power generation, various industries and urban settlements [1]. Wastewater from industries is discharged into the environment or used for irrigation and, in this regard, before discharge, it must be treated to maintain animal life and human health [2, 3]. Every year, worldwide, about 300–400 million tons of toxic sludge, solvents, heavy metals and other organic wastes are stored by industrial plants in the environment [4, 5].

Heavy metals are not biodegradable, are toxic and easily accumulate in the human body at low concentrations. Heavy metals, once ingested, can cause serious diseases such as nervous system damage, kidney failure or cancer [6–11]. The most common heavy metals present in industrial wastewater are nickel, zinc, lead, silver, copper, iron, chromium, cadmium, arsenic and uranium [12–15]. Due to the consideration of copper as the most valuable, is the most used metal in industrial applications such as galvanizing, metal finishing, engraving and others [16–20]. Even in the case of a low concentration, copper is very toxic and thus must be removed from wastewater and when these waters are discharged into the

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environment the concentration value of copper ions must not exceed legal limits [21–25]. According to NTPA-001/2005, the permissible limit value of copper ions from industrial wastewater that are discharged into natural receptors is set to 0,1 mg/dm^3 [26].

To increase the treatment efficiency, the use of nanoparticles is a promising alternative, as they have unique chemical and physical properties such as specific affinity, large surface area and surface activity. Nanomaterials are used to detect and remove both organic and inorganic pollutants from wastewater [27]. The usual size of the nanoparticles is in the range of 1-100 nm. Due to the large surface area of the nanoparticles compared to the volume, they react very quickly compared to other molecules. Nanoparticles have great potential for application in areas such as environmental remediation, biomedical, electrical or optical [28, 29].

The aim of this study was to investigate the application of the magnetite nanomaterial to remove copper ions from wastewater. Copper has been selected since it is used in many industries resulting in wastewater containing copper ions.

2. Experimental part

2.1. Materials and methods

Magnetite was synthesized by the precipitation method and was characterized in another article [17].

Adsorption experiments were performed using synthetic wastewater having three different concentrations of copper ions (0,70; 1,00 and 1,20 mg/L), at two different pH values (8 and 11.5) using two different quantities of magnetite for the adsorption process (0,10 and 0,20 g/L). The system containing water polluted with copper ions and magnetite was homogenized using a mechanical stirrer. All the experiments were performed at room temperature. The results were determined using the PhotoLab S12 photometer. The data were performed before and after contacting with magnetite nanomaterial. The initial concentrations of copper ions were measured after pH reaching at 8 and 11.5. Treatment efficiencies were calculated using the following equation:

$$\eta = \frac{c_i - c_f}{c_i} * 100 \quad (1)$$

where:

c_i - the initial concentration of copper ions (mg/L);

c_f - the final concentration of copper ions (mg/L).

2.2. Results and discussion

The removal efficiency of copper ions from wastewater was evaluated at two pH values, 8 and 11.5, in both cases reaching 100%, so the difference between them is the contact time. The results are shown in Figs. 1a and b.

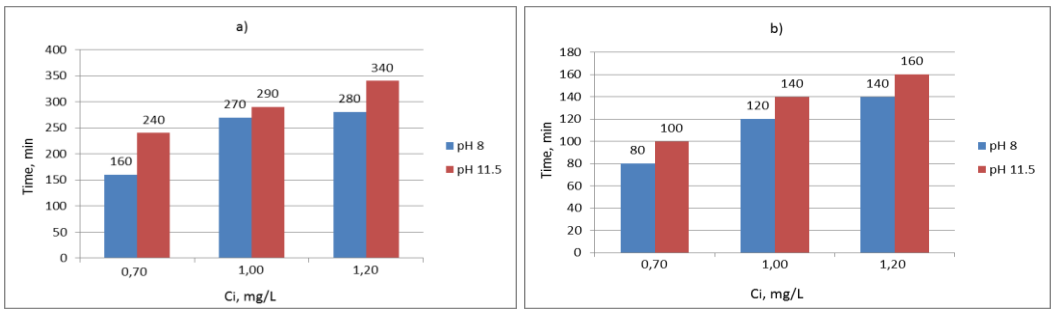

Fig. 1. Effect of pH on Cu^{2+} ions removal for 0.70; 1.00; 1.20 concentrations using 0.10 (a), 0.20 (b) g/L Fe_3O_4

Figures 1 a and b show the importance of the pH value of wastewater in the treatment process. The pH value 8 is much more advantageous for removing copper ions from wastewater by observing the shorter treatment time. In the case of pH 8 of wastewater, the time required to remove concentrations of 0.70, 1.00 and 1.20 mg/L was 160, 270 and 280 minutes when a quantity of magnetite nanomaterial of 0.10 g/L was used. The treatment time required to remove the same concentrations of copper ions shown above was 80, 120 and 160 minutes, respectively, when an amount of 0.20 g/L magnetite nanomaterial was used. The increase of the pH value leads to the increase of the necessary treatment time. Thus, to completely remove the copper ion concentrations of 0.70, 1.00 and 1.20 mg/L from the wastewater, the required contact time was 240, 290 and 340 minutes, respectively, in case of using a quantity of magnetite of 0.10 g/L and 100, 140 and 160 minutes respectively in case of using a quantity of magnetite of 0.20 g/L.

The effect of contact time on wastewater at pH 8 and 11.5 has been studied and can be seen in Figs. 2, 3 and 4.

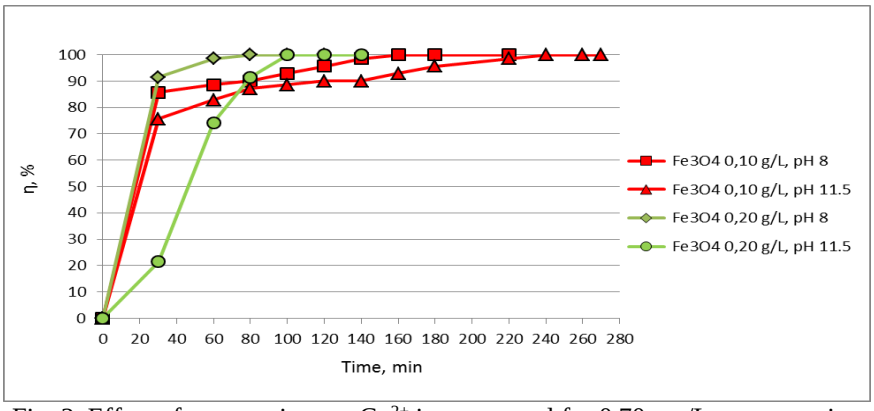

Fig. 2. Effect of contact time on Cu^{2+} ions removal for 0.70 mg/L concentration

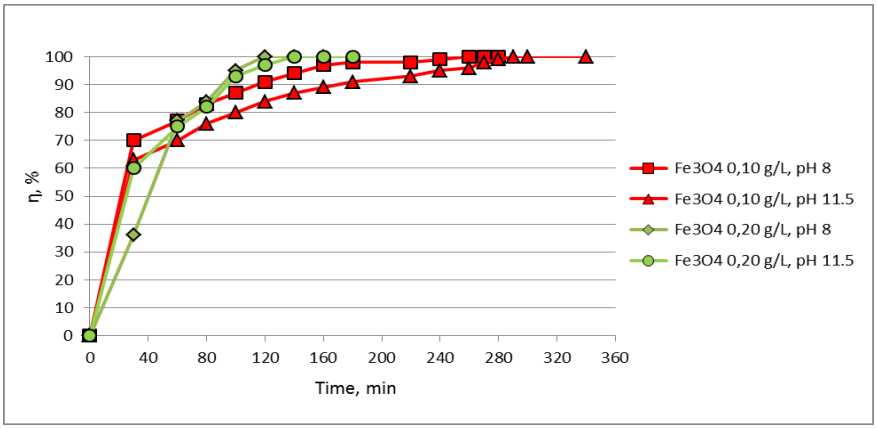

Fig. 3. Effect of contact time on Cu^{2+} ions removal for 1.00 mg/L concentration

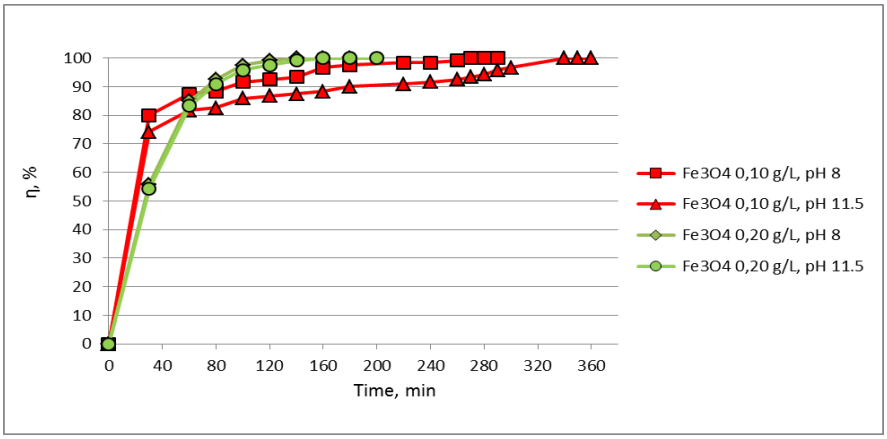

Fig. 4. Effect of contact time on Cu^{2+} ions removal for 1.20 mg/L concentration

It can be observed that in the first minutes of contact time the magnetite nanomaterial was more productive by rapidly occupying the existing sites on the surface, then occupying the sites being slower. The best case of the experiments presented in this study was a maximum treatment time of 140 minutes when a concentration of 1.20 mg/L was removed using 0.20 g/L magnetite.

Since Cu^{2+} is positively charged, at a lower pH value of wastewater it is not easily adsorbed by Fe_3O_4. Increasing the pH value of wastewater (pH>pHpzc) increases the OH^- concentration and the protonated effect that appears on the surface of the magnetite becomes weakened. Thus, the $-FeO^-$ content increases and favors the adsorption of copper ions on the surface of the magnetite.

6. Conclusions

Nanotechnology offers opportunities for wastewater treatment much more efficiently and fast using affordable nanomaterials. Due to the characteristics of their surface and their unique structure, nanomaterials are suitable and effective adsorbents for removing heavy metals from wastewater.

Following the experiments presented in this article, it was found that the efficiency of removing copper ions from synthetic wastewater was maximum. In the case of synthetic wastewater with pH 8, using an amount of 0.20 g/L magnetite, the required treatment time was 80, 140, respectively 160 minutes for the initial concentrations of copper ions of 0.70; 1.00 and 1.20 mg/L. When the pH value was changed to 11.5, the required treatment time was 100, 140, respectively 160 minutes for the same initial concentrations of copper ions. If a magnetite quantity of 0.10 g/L is used, the required treatment time increases, the shortest treatment time recorded was 160 and 240 minutes to remove an initial concentration of copper ions of 0.70 mg/L when the pH of the water was 8 and 11.5, respectively.

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