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Investigating the Removal of Cadmium from Water Using Chemical Oxidation (Fenton)

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Abstract

Background: With the rapid growth and growing industrial activities worldwide, heavy metals-induced contaminations have become a serious important phenomenon. Extraction of heavy metals from mines and their wide-spread industrial use has led to an increase in their concentration in water, wastewater, air and soil. Heavy metals pose a serious threat to human health. The aim of this study was to achieve fast and cost-effective method to remove cadmium. The present study is an experimental study, in which samples were prepared as synthetic and optimum pH, contact time and removal rate of cadmium ions were investigated. Data analysis was carried out using SPSS (mean, standard deviation, absolute and relative frequency) and diagrams were drawn using Excel Software. The results of investigations showed that the cadmium removal was at its highest rate with efficiency of 75.19% when cadmium concentration of 4, optimal pH 7 (neutral), optimal contact time of 15 minutes and optimized H2O2 / Fe + 2 ratio of 1.7 were used. Based on the results of this study, it can be stated that the Fenton's process is an effective process for the removal of cadmium.

KEYWORD: remove, cadmium, oxidation process, Fenton

1. Introduction

Heavy metals are elements, the specific weight of which is more than elements heavier than sodium (atomic mass of sodium = 23). Heavy metals are elements heavier than Fe, but although the cadmium density is less than Fe in this definition and arsenic is also not a metal; they are considered as heavy metals due to their toxicity and environmental risks. With the rapid growth and growing industrial activities around the world, heavy metals induced contamination has become an important serious phenomenon [1,2]. It may be said that this category of industries induced contaminants are considered as the most toxic environmental pollutants. Heavy metals are among materials, discharging small amounts of which leads to sever adverse impacts on the vital ecosystem [3-9]. All heavy metals are very toxic and impose irreversible impacts on the environment. These metals contaminate surface and underground water and eventually soil due to water solubility property [9]. The toxicity mechanism of heavy metals is caused by the intense desire of their captions to sulfur and thereby disrupting the activity of vital enzymes in living organisms [9,10]. Cadmium is a chemical element specified in the periodic table with Cd symbol and atomic number of 48. Cadmium is a relatively rare, soft, bluish white element and a toxic transition metal, which exists in zinc ores and is used at large amounts in batteries [11,12]. Almost three-fourths of this heavy metal is used in batteries (especially Ni-Cd batteries) and much of the remaining one-third is mainly used in paints, coatings and plating, and as stabilizers in plastics [13-16]. It is also used in some low-melting alloys. Due to its low friction coefficient and excellent resistance against fatigue, cadmium is used in bearing alloys. 61% of cadmium is found in electroplating. Many kinds of solder contain this metal. Cadmium-containing compounds are used in black and white television phosphors as well as the blue and green phosphors for color television picture tubes. Various salts are made from cadmium, the most important of which include cadmium sulfate. This sulfide is used as a yellow pigment and is used in some semiconductors. Some cadmium compounds are used as stabilizers in polyvinyl chloride [15,16]. The human complications caused by cadmium include: diarrhea, abdominal pain and vomiting, bone fractures, sterilization and infertility, damage to the central nervous system, immune system damage, mental abnormalities and potential DNA injury or cancer [7,17]. Cadmium (II) plays no structural role in the human body. This element and solutions of its compounds are toxic even at small amounts. Absorption of this element causes problems such as skin allergy and itching. Bivalent cadmium can be absorbed into the body through skin contact, inhalation and ingestion. Cd (II) is hazardous to

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human health, especially for people who work in steel and leather industries [17-20]. Many technologies such as adsorption, ion exchange, deposition, electro dialysis and reverse osmosis are employed to remove element from aqueous resources [21-24]. Fenton process leads to the deformation of the oxidation process and formation if highly reactive hydroxyl radical that attacks mineral compounds and destroys them [25]. Some recent researches have shown that the Fenton reactive oxidation mechanism is the result of production of hydroxyl radicals from H2O2 in the acidic conditions and in the presence of a catalyst [26]. Fe and hydrogen peroxide, which are two important chemicals in terms of cost and efficiency, are used in the Fenton process. [27].

2. METHODS

This research is an experimental study. To determine the optimum PH(PHs values of 2, 3, 5, 7 and 10), contact time (contact times of 5, 10, 15, 20, 30, 40), cadmium ions (cadmium ions of 2, 3, 4, 5 mg/l divalent Fe), and 1 mg/l hydrogen peroxide, were examined. Fenton process is carried out in a succession form at ambient temperature based on the following steps:

First, the sample is poured into the 500ml-beaker and is mixed using a Jar test device. PH of samples is later adjusted using salt and sulfuric acid. Second, the bivalent Fe and later the hydrogen are added. After the expiration of the required time, PH is adjusted at 8 so that Fe flocculation increases. In the last step, samples remain in stationary state for 20 minutes so that the resulting flocculation is deposited. The cadmium concentration in the supernatant is measured using spectrophotometer.

3. RESULTS

In the first stage, variable concentrations of cadmium are examined at PH 5, contact time of 20 minutes and ratio of H2O2 / Fe $^{+2}$ 1/5. In this stage, an optimum concentration of 4 was obtained for cadmium. In the second stage, variable PH values were used with the optimum concentration of cadmium and two other items are considered as the first stage. In the third stage, having an optimum PH of 7 and optimum cadmium concentration of 4, H2O2 / Fe $^{+2}$ ratio was set variable and time item is considered to be 20 minutes. In the fourth stage, with optimum values of cadmium, pH and H2O2 / Fe $^{+2}$ ratio, the amount of time was set variable and optimum time of 15 minutes was obtained. In this stage, cadmium concentration was set variable and other items had fixed above values. Optimum concentration of 4mg was achieved for the removal of cadmium. In this stage, cadmium concentration of 4mg/l, PH values were considered variable and other items considered to be fixed. The optimum pH is 7. In this stage, H2o2: fe values are considered variable and time duration of 20 minutes, cadmium concentration and optimum pH values are also considered. Optimum H2o2: fe ratio of 1.7 was obtained. With optimum values of cadmium concentration, pH, optimum ratio of Fenton, time duration was set variable. The optimum time of 15 minutes was obtained.

4. Tables, Figures and Equations

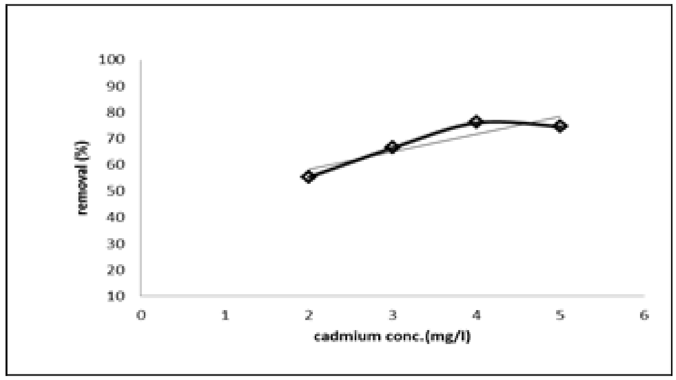

Fig1- The optimum concentration of cadmium (ph=5,t=20min, H2o2/fe:1/5)

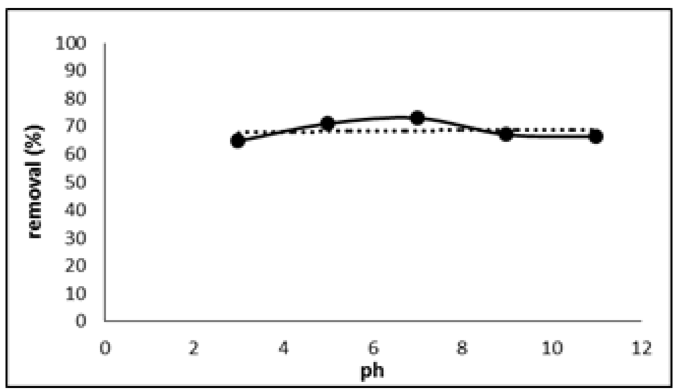

Fig 2- Optimal Ph graph: (cd=4mg/l, h2o2:fe:1/5,t=20 min)

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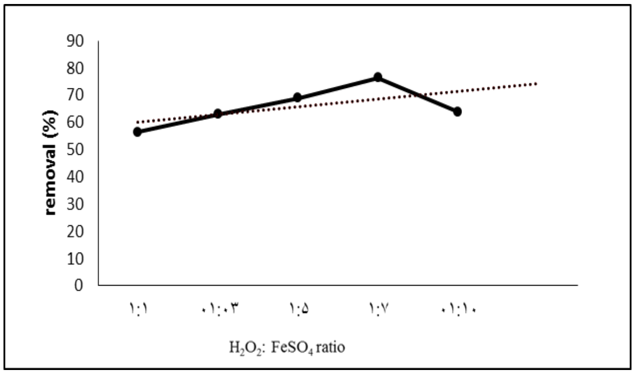

Fig 3- Fenton optimal ratio graph: (ph=7, cd=4mg/l, t=20 min)

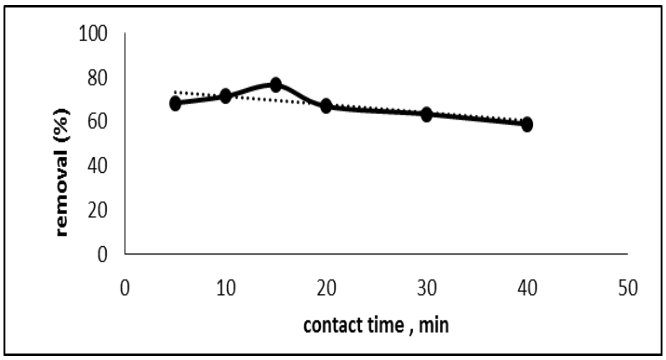

Fig4- Chart optimal time cd=4mg/l, h2o2:fe: 1/7, ph=7

5. DISCUSSION AND CONCLUSION

1. Cadmium concentration

The optimum concentration of 4mg/l was obtained for the removal of cadmium in the present study. This result is consistent with the result obtained in the study conducted by Mr. Mohammad Malakootian et al. In this study, nickel in aqueous solutions has been removed using Fenton process [28]. Nakhzari Moghadam et al in these areas are also found similar results [29].

2. Determining the optimum PH

PH is one of the main factors affecting the efficiency of the Fenton process in the removal of non-biodegradable materials. PH value affects hydroxyl radical production and thus the oxidation efficiency [30,31,32].Acidic PHs forming Fe (OH) $^{+2}$, which slowly reacts with H2O2, decreases the amount of hydroxyl radicals; as a result, the efficiency of process is reduced. Fe $^{+2}$ is also converted into Fe $^{+3}$ at alkaline PHs, precipitates in the form of Fe (OH) 3 and is removed from the catalytic cycle. As a result, there will remain insufficient catalysts in the operation environment, which leads to the decomposition of H2O2 and reduction in the efficiency of the process [33,34,35]. Also, previous researches have shown that OH radicals oxidative potential is decreased with increasing PH [35]. The results of the removal of cadmium at different pH values showed that the removal rate is gradually increased by increasing PH values to 7 and the cadmium removal trend is decreased with a further increase in PH values. These results are inconsistent with the results obtained in studies conducted by Akhondi et al. and Malakoutian et al. [28,36]. In the above studies, the optimum PH values were 10 and 4 respectively; while the optimum PH in the neutral range is 7 in the present study. As PH values are increased, the concentration of hydrogen ions is reduced and cadmium ions absorption rate is increased, accordingly. This increased efficiency in alkaline PH value may be due to deposition of metal ions, which disrupt the test. Mr. Zarei et al.'s study corresponded to the present study [37].In their article titled "Removing fluoride from aqueous solutions by Fenton", Nakhzari et al. have achieved similar results [29].

3. Determination of the optimum Fenton ratio

The concentration of Fe ions has a significant effect on the efficiency of the Fenton process. Hydroxyl radicals are not formed without the presence of Fe ions; thus, the concentration of Fe ions is effective in increasing the production of hydroxyl radicals. The results of the present study are consistent with those obtained in Mohammad Malakootian et al.'s study on nickel removal using Fenton [28].

4. Determining the optimum time

Optimum contact time of 15 minutes was obtained in the present study that is consistent with the contact time obtained in the study conducted by Zarei et al. [37].

I. CONCLUSION

Removal of heavy metals such as cadmium in the Fenton process is affected by several factors, including oxidants, catalysts, contaminant concentration, pH and reaction time. These factors play an important role in producing hydroxyl radical and enhancing efficiency of the Fenton process so that higher H2O2 leads to floating of sludge and biological treatment dysfunction after using Fenton process, higher Fe (II) leads to an increase in TDS and EC waste and the need for sludge treatment, higher than optimum PH values leads to a reduction in the production of hydroxyl radical, rapid decomposition of H2O2 to water and oxygen and deposition of Fe (II) leads to an increase in the treatment costs by forming hydrophobic compound and prolonging the contact time.

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