

Effect of the Electrocoagulation Operation Parameters on the Removal of Lead from Industrial Waste Water

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Abstract

A research was conducted to study the process parameters affecting lead removing from industrial waste water using electrocoagulation (EC) process with a unit containing aluminum electrode as anode and stainless steel as a cathode. Synthetic water with pH of 5.6, polluted with lead at initial concentration of 1.65 mg/l was used. Several operation parameters on lead concentration removal efficiency were investigated, such as initial lead concentration, sodium chloride concentration, current density and distance between electrodes. Contact time of 75 minute was maintained constant during experiments. The experimental results revealed that the increase in lead removal was achieved when current density of sodium chloride concentrations were increased and space between electrodes and initial lead concentration were decreased.

Key Words: Lead Removal; Anode; Cathode and Electrocoagulation (EC)

تأثير الظروف التشغيلية لعملية التخثير الكهربائي على ازالة الرصاص

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الخلاصة

تم إجراء بحث لدراسة المتغيرات المؤثرة في زيادة كفاءة ازالة الرصاص بتقنية التخثير الكهربائي باستخدام وحدة تخثير كهربائي مختبرية تحتوي على قطبين الاول من معدن الالمنيوم كقطب انود والآخر من الحديد المقاوم للصدأ كقطب كاثود، واستخدام ماء ذو اس هيدروجيني 5.6 وملوث صناعيا بالرصاص بتركيز 1.65 ملغم/لتر. تم دراسة تأثير كثافة التيار الكهربائي، تركيز كلوريد الصوديوم المضاف، التركيز الابتدائي للرصاص والمسافة بين الاقطاب على كفاءة الازالة باستخدام زمن تماس 75 دقيقة والذي تم ابقاؤه ثابتا خلال التجارب. تم التوصل الى ان كفاءة ازالة الرصاص من الماء باستخدام عملية التخثير الكهربائي تزداد بزيادة تركيز كلوريد الصوديوم المضاف وزيادة كثافة التيار الكهربائي ونقصان المسافة بين الاقطاب ونقصان التركيز الابتدائي للرصاص.

الكلمات المفتاحية: ازالة الرصاص، الانود، الكاثود و التخثير الكهربائي.

Introduction

Heavy metals are pollutants which are non-biodegradable and tend to accumulate in living organism (Imran *et al.*, 2012; Abia and Asuquo, 2006), and are environmentally persistent (Abdul Ghaffar, 2008). The removal of heavy metals by various physical, chemical or biological methods has been repeatedly attempted to overcome the problem (Ahluwali and Goyal, 2005).

Lead is one of the potentially toxic heavy metals when adsorbed into the body, and can be accumulated in living tissues, thus becoming concentrated throughout the food chain and can be readily absorbed into the human body causes diseases such as anemia, encephalopathy, hepatitis and nephritic syndrome. The release of lead into waste water from different industries like lead acid batteries, pulp, refineries, printing, pigments and photographic materials may cause long-term health risks to human health and ecosystem. The tolerance limit for discharge of lead into drinking water according to the Indian Standard Institution is 0.05 mg/l and in land surface is 0.1 mg/l (Senthyl and Gayathri, 2009).

Electrocoagulation has been employed for the treatment of heavy metals (Al Anbari *et al.*, 2008), it is a process of destabilizing suspended, emulsified, or dissolved contaminants in an aqueous medium by introducing an electric current into the medium (Mohammad and Muttucumar, 2009).

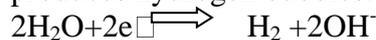
The main advantages of electrocoagulation over other conventional techniques, such as chemical coagulation and adsorption, are the in situ delivery of reactive agents, with no generation of secondary pollution, and compact equipment used in this process. (Muhammad and Muttucumar 2011).

Electrocoagulation involves metal dissolution from the anode with simultaneous formation of hydroxyl ions and hydrogen gas occurring at the cathode (Peter *et al.*, 1999). The process

involves an electrolytic reactor with aluminium (or iron) electrodes the water to be treated passes through the reactor and is subject to coagulation/flotation, by Al or Fe ions dissolved from the electrodes, the resulting flocks floating after being captured by hydrogen gas bubbles generated at cathode surfaces. In the process, the metal anode dissolution is accompanied by hydrogen gas evolution at cathodes, the bubbles capturing and floating the suspended solids formed and thus removing contaminants. In the EC processes, electrolytic dissolution of anodes (take Al anodes as an example) in water produces aqueous Al (III) species:



Water decomposition at Al cathodes produces hydrogen bubbles:



These bubbles float the flocks formed between water contaminants and a range of coagulant species and metal hydroxides formed by hydrolysis (Xu *et al.*, 2009):



Aim of Research

The aim of this research is to investigate the ability of Electrocoagulation process to remove lead from water and effect of the process parameters affecting lead removing percent.

Materials and Methods

Materials

Lead acetate (analar)

4% hydrochloric acid solution

Sodium chloride

Distilled water

Ethanol (analar)

Filter paper type Whatman 31

Glass wares

Aluminum sheet with 99% purity with dimension (10×2×0.2) cm

Stainless steel sheet (10×2×0.2) cm

DC power supply type PS-305 D from DAZHENG Company

Magnetic stirrer

Electrical balance (four digits)

pH meter

Analysis of lead concentration

The concentration of lead was analyzed by means of atomic absorption spectrophotometer type novAA400 from Analytik Jena AG with sensitivity ± 0.02 ppm.

Experimental Procedure

A batch electrocoagulation cell made of Plexiglas as shown in Figure (1) was used in the experiments. Lead polluted water with pH 5.6 was prepared by dissolving calculated amount of lead acetate in distilled water to reach the desired concentration of lead, calculated amount of sodium chloride was added to the polluted water to obtain a concentration of 0.3 - 0.9 gm/L, then the polluted water was introduced into the EC cell for each experiment.

Electrolytic cell with monopolar electrodes in parallel connections has been used with an inter electrode distance varying from 2.5 cm to 5 cm depending on each experiment conditions.

Before each experiment the aluminum plate was immersed for 60 minute in 4% hydrochloric acid solution (Milton., 2009) to remove aluminum oxide from its surface, and then the plate was washed with distilled water, ethanol then drying and weighing.

The solution in the EC unit was stirred at 120 rpm by a magnetic stirrer with an initial temperature of 25°C. Each run was timed starting with the DC power supply switching on and this time was kept constant which was 75 minute.

During the experiments, anodic dissolution occurred and hydrogen gas was produced at the cathode. Samples of 10 ml were taken at the end of each experiment at to be filtered and then analyzed. Each sample was taken from a distance between two electrodes and at fixed depth. After each run, the electrodes were washed and brushed the cleaned by ethanol to remove any solids accumulated on the electrode surface.

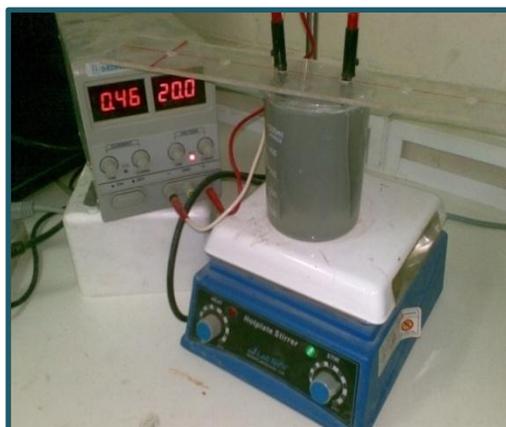


Figure (1) Laboratory electrocoagulation unit

Results and Discussion

Effect of current density

Figure (2) shows the effect of current density on the percentage removal of lead.

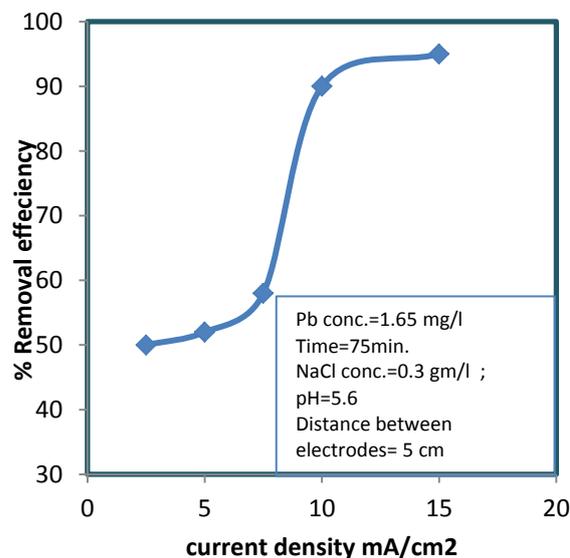


Figure (2) Effect of Current Density on the Percentage Removal of Lead.

Current density is very important parameter that affects the electrocoagulation process because it directly determines both coagulant dosage and bubble generation rates and strongly influences both solution mixing and mass transfer at the electrodes (Miron *et al.*, 2010).

From the figure it can be seen that the lead removal efficiency increases with the increase of current density. At high current densities, the generation of aluminium (Al^{+3}) ions increases due to the increase of anodic dissolution, resulting in a greater lead removal rates.

Effect of initial lead concentration on the percentage of lead removal

Figure (3) shows the effect of initial lead concentration in the polluted water on the percentage removal of lead.

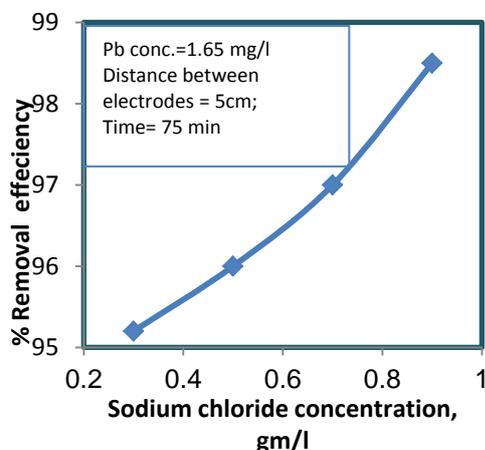


Figure (3) Effect of Initial Lead Concentration in the Polluted Water on the Percentage Removal of Lead.

From the results it can be seen that lead removal efficiency decreased with increasing lead concentration, this can be explained as follows; although the same amount Al^{+3} passed to solution at the same current density for all lead concentration, Al^{+3} was in sufficient for solutions of higher lead concentration.

Effect of Concentration of Sodium Chloride on the percentage of lead removal

Figure (4) shows the effect of sodium chloride concentration added to the polluted

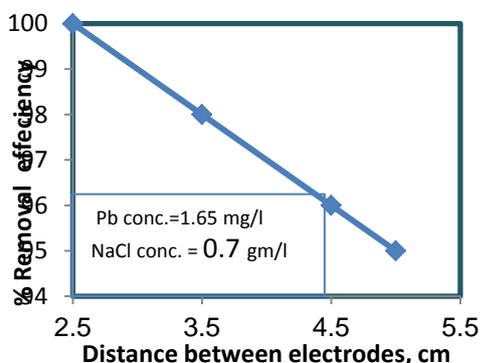


Figure (4) The Effect of Sodium Chloride Concentration on the Percentage of Lead Removal.

The obtained results showed that lead removal increased with increasing

concentration of sodium chloride because of the reduction of the double thickness around the pollutant then decrease of the Zeta potential magnitude (Zeta-meter, Inc., 1993).

Effect of Spacing Between Electrodes on the Percentage of lead Removal

Figure (5) shows the effect of spacing between electrodes on the percentage removal of lead.

From the figure it can be seen that the removal efficiency increases with the decrease of space between electrodes while the highest removal efficiency of 100% was obtained at a distance between electrodes of 2.5 cm.

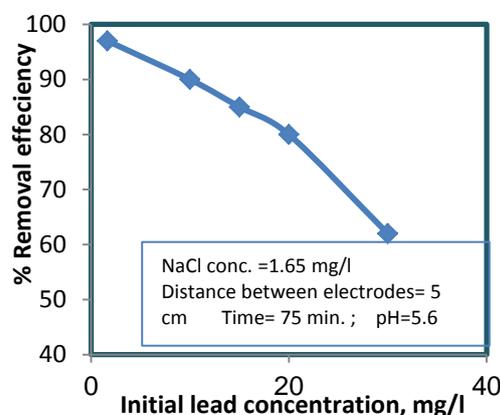


Figure (5) The Effect of Distance Between Electrodes on the Percentage of Lead Removal.

This can be explained that decreasing the space between electrodes results in low resistance through the solution which effect the results in increasing the rate of aluminum dissolution and aluminum ions releases and consequently leads to more lead removal from the solution. On the other hand, decreasing the space could enhance the flotation process by limiting the generated bubbles in a narrow space which results in higher removal efficiencies.

Relationship Between Weight loss of Aluminum and Lead Removal Efficiency

Figure (6) illustrates the relationship between the amount of aluminum removed and percentage of lead removed.

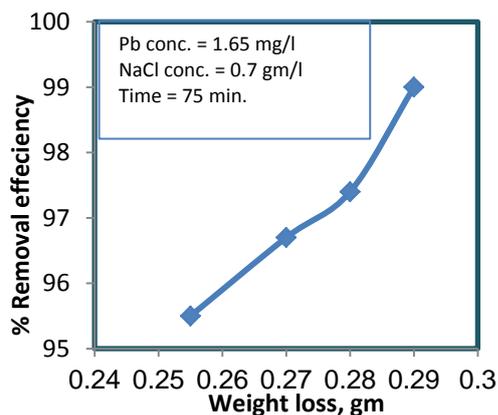


Figure (6) The Relationship Between the Loss of Aluminum Electrode Weight and the Percentage of Lead Removal.

From the figure it can be seen that the lead removal efficiency increases with the increase of the weight loss of aluminum electrode. The increase of the weight loss of aluminum electrode means that more aluminum ions releases and consequently leads to more lead removal from the solution.

Conclusions

Experiments have been carried out to determine the best operating conditions which give an acceptable lead removal. The results showed that the 100% lead removal efficiency was achieved at a current density of 10 mA/cm^2 , distance between electrodes of 2.5 cm, electrocoagulation time of 75 minute, sodium chloride concentration of 0.7 gm./l and initial lead concentration of 1.65 mg/l at pH of 5.6.

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