Removal of Heavy Metals from Water using Electrocoagulation

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Abstract - *In this study, removal of manganese (Mn) and copper (Cu) from a sample by electrocoagulation (EC) method using iron and zinc electrode plates were investigated. The influences of various operational parameters such as different electrodes (iron and zinc), time (15,30,45,60,75min) and different supporting electrolyte (sodium chloride (NaCl) and calcium chloride ($CaCl_2$)) on removal efficiency were investigated. It was seen from the results that removal efficiencies were significantly affected by the electrode and the supporting electrolyte. The experimental results indicated that after 60 minutes of electrocoagulation the highest Cu and Mn removal of 93.57% and 76.96% were achieved using iron electrode and supporting electrolyte-NaCl respectively. The experimental results revealed that the removal of heavy metal ions by our electrochemical cell was successful.*

Key Words: Heavy metal removal, electrocoagulation, treatment.

1.INTRODUCTION *(Size 11 , cambria font)*

The presence of heavy metals in water and wastewater causes serious environmental and health problems because of their solubility in water. Although organic contaminants can be biodegradable, inorganic pollutants cannot be biodegradable and they can enter to the food chain and accumulate in living organisms [1].

Heavy metals like manganese, copper, nickel, lead and zinc are resulted from several sources such as metal and processing industries, batteries, mining, fertilizer and pesticides.

Children and adults who drink water with high levels of manganese for a long time may have problems with memory, attention, and motor skills. Infants may develop learning and behaviour problems if they drink water with too much manganese in it. Although copper does not affect body in small concentration, high amount copper accumulation may be resulted with toxic reactions like puking, cramps and spasms which may lead to death [2].

In spite of the fact that electrocoagulation is not a new technology which has been known from 19th centuries, electrocoagulation hasn't been widely applied because of relatively large capital investment, expensive electricity requirement. However, electrochemical technologies have turned back since it is eco-friendly technology [3], [4].

In this study, the removal of manganese and copper from the simulated solution was investigated using iron and zinc electrodes by electrocoagulation (EC). Experiments were performed to determine the effects of varying operational parameters such as; time ,electrode and supporting electrolyte on metal removal efficiency.

2. ELECTROCOAGULATION (EC) PROCESS

Electrocoagulation is an electrochemical process with reactive anode and cathode .When current is applied to the system by a power supply, metallic ions are dissolved from anode and transferred to the bulk. The metallic ions combine into larger flocs and can be removed easily[5].Water molecules are hydrolyzed at the cathode, simultaneously. Two different mechanism proposed for iron electrodes can be seen in the reactions (1)-(6).

Mechanism I

In the anode:

$$4\ Fe_{(s)} \rightarrow 4\ Fe^{2+}{}_{(aq)} + 8e^- \quad (1)$$

In the cathode:

$$8\ H^+{}_{(aq)} + 8\ e^- \rightarrow 4\ H_{2(g)} \quad (2)$$

In the solution:

$$4\ Fe^{2+}{}_{(aq)} + 10\ H_2O_{(l)} + O_{2(g)} \rightarrow 4\ Fe(OH)_{3(s)} + 8\ H^+{}_{(aq)} \quad (3)$$

Mechanism II

In the anode :

$$Fe_{(s)} \rightarrow Fe^{2+}{}_{(aq)} + 2e^- \quad (4)$$

In cathode:

$$2\ H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2\ OH^-{}_{(aq)} \quad (5)$$

In solution:

$$Fe^{2+}{}_{(aq)} + 2\ OH^-{}_{(aq)} \rightarrow Fe(OH)_{2(s)} \quad (6)$$

Metal ions produced at the anode and hydroxide ions produced at the cathode react in the aqueous media to produce various hydroxides species depending on the pH such as $Fe(OH)_2$, $Fe(OH)_3$, $Fe(OH)^{2+}$, $Fe(OH)^{3+}$ and $Fe(OH)_4^-$. The iron-hydroxides coagulate and precipitate to the bottom of system [5].

Zinc is a material that is more feasible technically and economically when compared to iron .The equations for the zinc electrode are:

At the anode:

$Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$ (7)

At the cathode:

$2H_2O\ 2e^- \rightarrow H_{2(g)} + 2OH^-$ (8)

3. MATERIALS AND METHODS

3.1 Reagents and Solutions

A stock solution of metal ions with the concentration of 1000 mg/L was prepared from $CuSO_4$ and $Mn(NO_3)_2$. Required initial concentrations were prepared by diluting the stock solution. Supporting electrolytes like CaCl2 and NaCl were used to increase the conductivity and study its impact on removal efficiency.

3.2 Batch Operation

In the experimental study the uniquely designed EC reactor shown in the Fig. 1 was used. Iron and zinc plate electrodes of dimension 150x50x1mm were used . In each experiment, 1L of solution was poured into the cylindrical cathode and operation was started with by switching the DC power supply on.

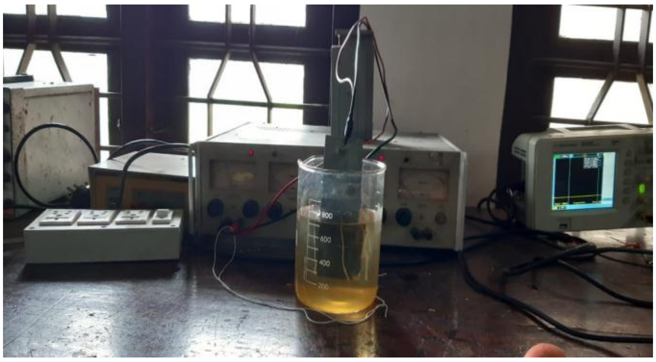

Fig. 1: Experimental set-up

3.3 Analyses In the experiments

20 ml of sample were taken from the reactor at 15 min, 30 min, 45 min, 60 min and 75 min intervals and filtered. The concentrations of metal ions were determined using atomic adsorption. The removal efficiency (RE %) after EC was calculated using the formula

$$RE\% = \frac{(C_O - C)}{C_O} \times 100$$

where Co and C are the concentrations of metal ions before and after EC, respectively, in ppm.

4. RESULTS AND DISCUSSION

4.1 Effect of Electrode

Electrode is one of the effective parameters in the electrocoagulation process. The effect of electrodes were investigated using Iron and Zinc electrodes and supporting electrolyte as NaCl and $CaCl_2$. As seen from Chart 2. The highest removal efficiency was obtained using Iron electrode. It showed an efficiency of 93.57% for Cu and 76.97% for Mn.

4.2 Effect of supporting electrolyte

NaCl and $CaCl_2$ were used as supporting electrolytes. From Chart 2. And Chart 3., it can be seen that NaCl is the better electrolyte. It showed the efficiency for Cu (93.57%) using iron electrode.

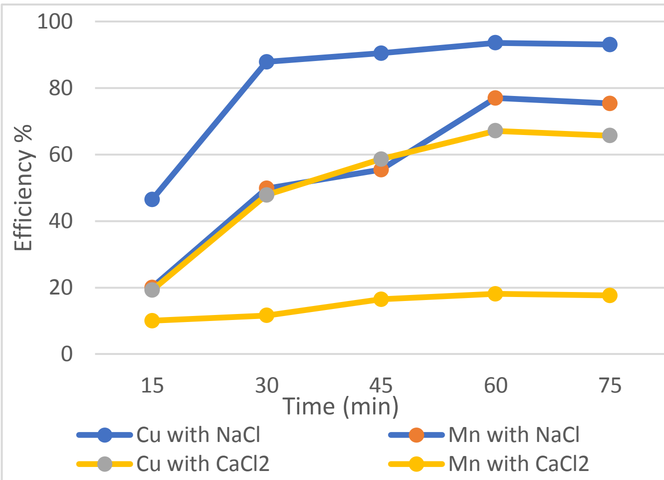

Chart 2: Electrocoagulation of Cu and Mn using Iron electrode

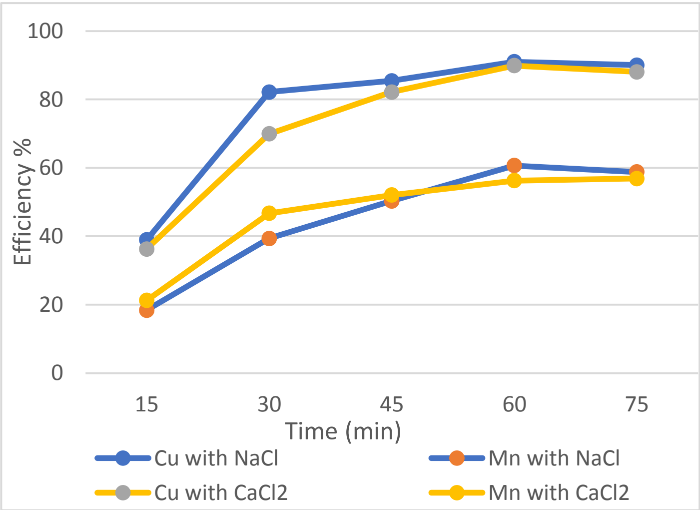

Chart. 3: Electrocoagulation of Cu and Mn using Zinc electrode

5. CONCLUSIONS

In this study, the removal of Cu and Mn from the sample by electrocoagulation using iron and zinc sacrificial electrodes was investigated. The effects of electrode and supporting electrolyte on the removal efficiency were examined in the electrochemical reactor. The following conclusions could be drawn from the present study:

1) The experimental results revealed that the removal of heavy metal ions by our electrochemical cell was successful.

2) The results obtained by varying different parameters in order to elucidate their effects on process performance implied that removal efficiencies were significantly affected by the electrode and supporting electrolyte.

3) The experimental results indicated that the highest Cu and Mn removal of 93.57% and 76.96% were achieved using Iron electrode and NaCl as supporting electrolyte at the end of 60 minutes of electrocoagulation operation.

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