SINGLE STAGE ELECTROCOAGULATION OF INDUSTRIAL CUTTING OIL WASTEWATER USING IRON PLATE ELECTRODES

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Abstract- In this study, a single stage electrocoagulation of industrial metal cutting oil wastewater was carried using iron two layered Rushton type turbine anode. Effect of operating parameters like current density (CD), initial pH and supporting electrolyte concentration were investigated in detail. The initial COD concentration of 45,000mg/L was reduced to 8,000mg/L at pH 3 and 40 mA/cm^2. The resulting overall removal efficiency of 82.2% emphasizes that this single stage process can be used as an effective pre-treatment process for metal cutting oils.

Index terms- Metal cutting oil wastewater, electrocoagulation, iron

I. INTRODUCTION

The cutting oil wastewater, otherwise called as Metal working fluids (MFW) or cutting fluids, is the water that is discharged from metal cutting or metal shaping industries. Majorly these cutting fluids are used for lubrication, cooling and surface cleaning [1,2,3]. In general these cutting oil wastewater were found to possess mineral oil, additives such as fatty acids, surfactants, heavy metals, biocides, corrosion inhibitors, anti-foam etc in high concentrations [1,4,5]. As a result the cutting wastewaters usually have high COD, TOC and turbidity [6]. They can affect the environment to a great extent if discharged without proper treatment. Hence a thorough investigation for treating these fluids is required in order to find a feasible method, which industries can readily adapt.

Some of the potential treatment methods for cutting oil wastewater are flotation [7,8], biological process [2,9], ultrafiltration and nano filtration [10], electrocoagulation [1,6,11]. Out of the above mentioned, recently, electrocoagulation was found to be the most effective way for treating the cutting oil wastewaters [12].

The treatment of metal cutting wastewater by electrocoagulation is limited studied in the literature. Bensadok et al. [1] investigated the treatment of cutting oil emulsions using aluminum parallel plate electrodes. Treatment was carried out in a batch system provided with recirculation of flow. They diluted the oil emulsions by 2%, 4% and 6%. They obtained the COD removal efficiency of 92%. Kobya et al. [6] treated of waste metal cutting fluids using electrocoagulation. The parallel plate aluminum and iron electrodes were used. The metal cutting fluid with the initial COD concentration of 17.312 mg/L was treated with the removal efficiency of 93% using Al electrodes and 92% using Fe electrodes. As seen from the literature, monotype reactor designs such as parallel plate electrode configuration have intensively used in the field of electrocoagulation. In this study, real metal cutting oil wastewater was treated using a uniquely-designed single stage electrocoagulation reactor, not previously encountered in the literature

Generally, aluminum and iron electrode are used in the electrocoagulation process. In the iron electrode, two mechanisms have been recommended [13]:

Mechanism I

Anode:

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

Cathode:

$8H^+_{(aq)} + 8e^- \rightarrow 4H_2(g)$ (2)

In solution:

$4Fe^{+2}_{(aq)} + 10H_2O_{(l)} + O_{2(g)} \rightarrow 4Fe(OH)_3 + 8H^+_{(aq)}$(3)

Mechanism II

Anode:

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

Cathode:

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

In solution:

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

In the electrochemical reactor, iron can be form of monomeric ions, $Fe(OH)_3$ and polymeric hydroxyl complex such as: $Fe(H_2O)_6^{3+}$,$Fe(H_20)_5^{2+}$,$Fe(H_2O)_4(OH)_2^+$,$Fe(H_2O)_8(OH)_2^{4+}$ and $Fe_2(H_2O)_6(OH)_4^{4+}$depending upon the pH of the aqueous medium [13].

In this study, a single stage electrocoagulation of industrial cutting oil wastewater was carried using iron electrodes. Effect of operating parameters like current density, initial pH and supporting electrolyte concentration were investigated in detail.

II. EXPERIMENTAL

2.1.Wastewater

The wastewater use in experiments was supplied by a local metal working factory in Eskisehir, TURKEY.

The factory uses ERALUBE BIO CF 325 semi-synthetic cooling fluids. The wastewater had Chemical Oxygen Demand (COD) of 45.000 mg/L, and a pH of 9.3.

2.2.Experimental Procedure

In this study cylindrical iron reactor was used as cathode. Rushton type turbine with the two layer (RT2) was used as sacrificial iron anode. In each layer there is a disc (Φ=4 cm) with a 8 attached blades (height: 2 cm, width: 1 cm). The total effective area of Rushton type turbine was 150 cm^2. The experimental setup was as shown in Figure 1. A DC power was supplied to the setup by using Statron® power supply with operating range of 0-45V and 0-50A. In each experiment the cutting oil wastewater of 600 mL was poured to the reactor and RT2 was placed in the center of reactor. The pH of the sample was adjusted to a desired value using H_2SO_4 or NaOH. A specific amount of supporting electrolyte (Na_2SO_4) was added to the wastewater to increase the conductivity. The anode and cathode sets were respectively connected to the positive and negative outlets of a DC power source and then current was applied to the circuit by a power supply for the period of 90 minutes. The current was held constant for each run.

The samples were taken every 15 minutes and pH, temperature and voltage were monitored during electrocoagulation using pH-meter. Samples were settled and then the supernatant was analyzed for the determining of COD concentration by titrimetric method. All the analyses were repeated twice. The electrodes were polished, washed with dilute H_2SO_4 and rinsed with distilled water before each run.

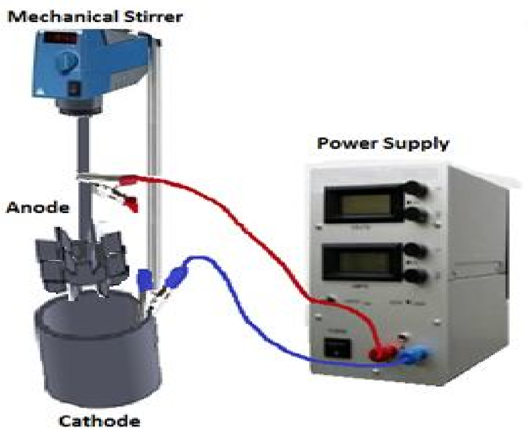

Figure1.Experimental set-up

2.3.Calculation

The COD removal efficiency (RE%) was calculated after electrocoagulation using following equation:

$$RE\% = [(C_o-C)/C_o]x100 \quad (7)$$

C_o and C are the concentrations of COD before and after electrocoagulation (mg/L).

The specific electrical energy consumption was determined as kWh per m^3 of wastewater using the following equation:

$$EEC(kWh/m^3)=V.I.t/m \quad (8)$$

where EEC is the specific electrical energy consumption (kWh/m^3), V is the potential (Volt), I is the current (Amper), t is the time (h), and m is the volume of the solution treated (m^3).

III. RESULTS AND DISCUSSION

3.1.Effect of Current Density

Current density is the electric current applied per unit area of electrode. It is important for the design of electrochemical systems. Current density is a significant operating factor in electrochemical process which determines the coagulant dosage, bubble production rate, size and flocks growth [14].

The effect of the current density was investigatedapplying 13, 27 and 40 mA/cm ^{2}to the anode at original pH of wastewater. The variation of COD removal efficiency versus time is shown in Figure 2. The COD removal efficiencies were 68.8%, 71.1% , 74.8% after 90 min of electrocoagulation at current densities of 13, 27 and 40 mA/cm^2, respectively. As can be seen from Fig. 2, with an increasing current density, the COD removal efficiency increased. This effect can be explained by the high coagulant production rate. The supply of current to the EC system determines the amount of Fe^{2+} ions released from the anode and the amount of the resulting coagulant. An increase in flock production also increases the removal efficiency.The photograph of treated samples can be seen from Figure 3. Similarly, M. Kobya (2008) was obtained %65-92 removal COD at 20-60 A/m^2 with Fe electrode. The energy consumption versus time is shown in Figure4.As seen from Figure 4, with increasing current density the electrical energy consumption also increased. The electric energy consumptions for the current densities of 40,27,13 mA/cm^2 were 380,220,90 kWh/m^3 respectively.

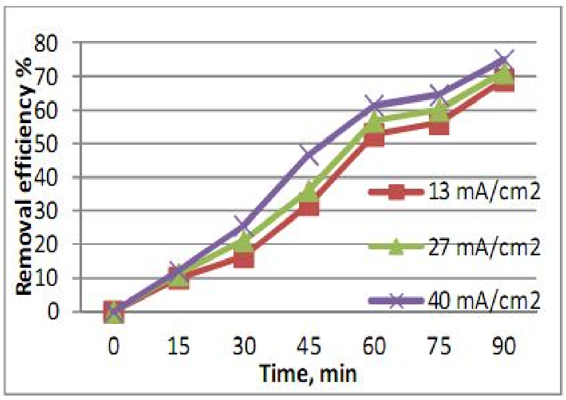

Figure. 2. Variation of COD removal efficiency with time for different current density.

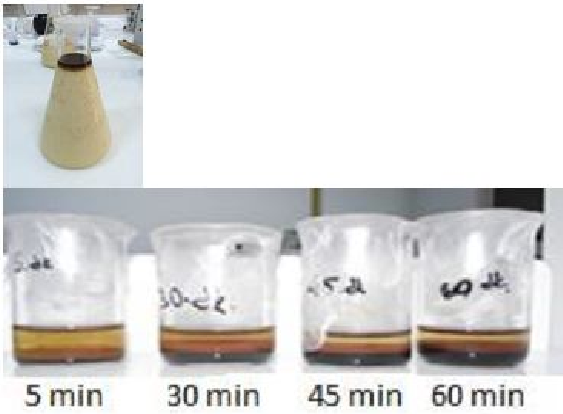

Figure.3 Raw and treated wastewater

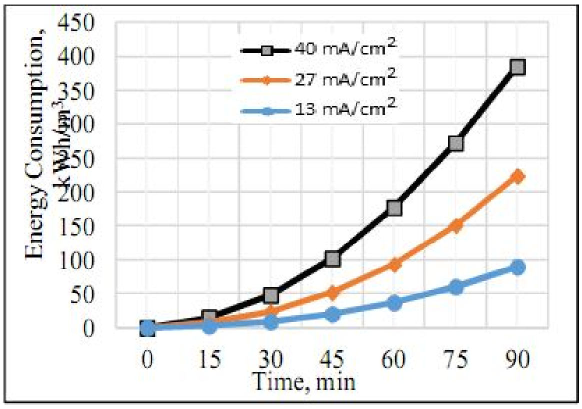

Figure 4.Electrical energy consumption computed from Eq. (8).

3.2.Effect of İnitial pH

It has been obtained that initial pH is an mainly important operating factor of electrochemical process [1,11]. pH determine the type of iron hydroxide species formed in the solution and the surface charge of the particle. The effect of the initial pH on the COD removal efficiency is shown in Figure 5.

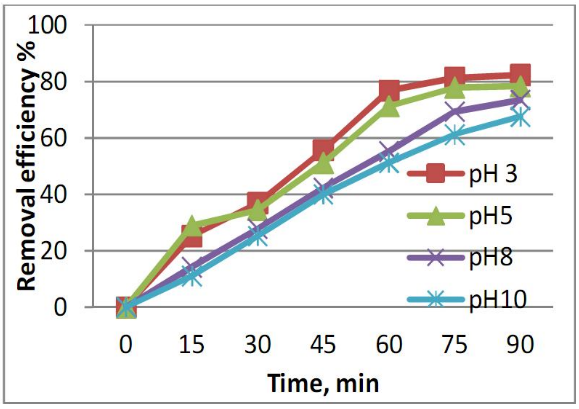

Figure 5.The effect of the pH on the removal efficiency (RE)

The COD removal efficiencies of 82.2%, 78.1% , 73.3% and 67.4% was obtained after 90 min of electrocoagulation at pH 3,5, 8 and 10 respectively. When the initial pH increased from 3 to 10, the removal efficiency of COD decreased. The highest removal efficiency was obtained at pH 3. At a high pH, the removal efficiency decreased because of the dominant formation of soluble $Fe(OH)^{-}_{4}$ which is not suitable for the formation of floc [15,16].

3.3.Effect of supporting electrolyte

In this study supporting electrolyte (Na_2SO_4) was used in order to increase the conductivity of the solution as well as eliminate the IR drop. The effect of the supporting electrode concentration on treatment of cutting oil wastewater was studied at various Na_2SO_4 concentrations at pH 3 and 40 mA/cm^2. The effect of the supporting electrolyte on electrical energy consumption can be seen from Figure6. It can be concluded that in the presence of 0.01, 0.05 and 0.1M Na_2SO_4, electrical energy of 380,360 and 330 kWh/m^3 was consumed, respectively.Similar results were found in the literature [17].

Although the addition of Na_2SO_4 is beneficial for the electrical energy requirements, dosage should becarefully selected to avoid the additional cost of Na_2SO_4.

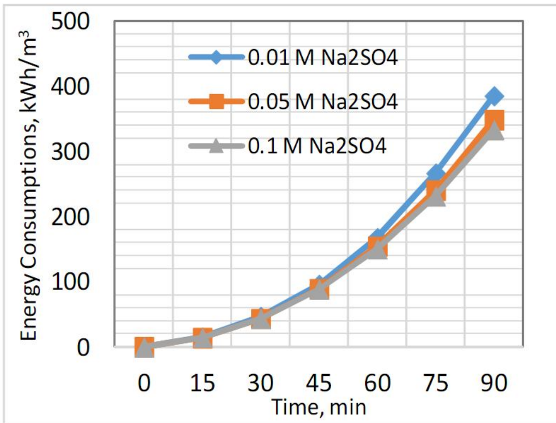

Figure 6. Variation of electrical energy consumption with Na_2SO_4 dosage.

CONCLUSION

In this study the treatment of cutting oil wastewater was performed using iron Rushton type turbine anode with the two layer (RT2). It can be concluded that the treatment of wastewater by EC is effective based on:

• The effect of the current density was investigated applying 13, 27 and 40 mA/cm ^{2}to the anode at original pH of wastewater. The COD removal efficiency was enhanced by increasing current density. The COD removal efficiencies were 68.8%, 71.1% , 74.8% at current densities of 13, 27 and 40 mA/cm^2, respectively. The initial COD concentration of 45,000 mg/L was reduced to 11,340 mg/L at 40 mA/cm^2 using 380 kWh/m^3 energy consumption.

•The effect of pH was determined using pH 3, 5, 8, and 10. The highest removal efficiency of 82.2% was obtained at pH 3. When the initial pH increased from 3 to 10, the removal efficiency of COD decreased.

The initial concentration of 45,000mg/L was reduced to 8,000 mg/L at pH 3 and 40 mA/cm^2.

•The effect of supporting electrolyte on electrical energy consumption was determined using 0.01, 0.05 and 0.1M Na_2SO_4.The electrical energy consumption was reduced from 380 to 330 kWh/m^{3}with using 0.1 M Na_2SO_4. Although the addition of Na_2SO_4 is beneficial for the electrical energy requirements, dosage should be carefully select to avoid the additional cost of Na_2SO_4.

Considering the results, it can be said that electrocoagulation with Rushton type turbine anodefor the treatment of metal cutting oil wastewatercan be used as an effective pre-treatment method.

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