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Effect of Polyelectrolytes on The Electrocoagulation of Organized Industrial District Raw Wastewater using Aluminum Electrodes

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***Abstract*— Electrochemical treatment of mixed raw industrial wastewater from the inlet of organized industrial district wastewater treatment plant was investigated using sacrificial aluminum electrodes in this study. A pole changer was used between the power supply and the electrochemical reactor to help use of all electrodes as anode. Studies on the parameters such as current density, supporting electrolyte concentration and initial pH, which have significant effects on COD removal and hence the energy consumption, had been performed previously. Coagulant aids, poly aluminum chloride and Kerafloc, were used in different concentrations to observe their effects on COD removal efficiency and the energy consumption. Three different concentrations for both coagulant aids were tested: 10, 20, and 30 mg/L. According to the results, the concentration of both coagulant aids were 30 mg/L to achieve highest removal efficiencies, lowest energy consumptions and sludge productions.**

***Keywords*— Electrocoagulation, mixed raw industrial wastewater, aluminum electrode, coagulant aid**

I. Introduction

Industrial wastewaters vary greatly in both flow and pollution strength. In general, they may contain suspended, colloidal and dissolved (mineral and organic) solids, colored matters and pathogenic bacteria. In addition, they have either excessively acid or alkaline character. It may be necessary to pretreat these wastes prior to discharge to the municipal sewer systems or to treat completely in the case of the wastes will be discharged directly to the surface or ground waters.

In most industries, main wastewaters sources are;

- Sanitary wastewaters
- Wastewaters from the cooling operations
- Process wastewaters
- Wastewaters from the cleaning and maintenance operations

Potential problems originated from industrial wastewaters may be associated with hydraulic overloads, temperature extremes and with excessive amounts of oil, fats and grease; acidic or alkaline constituents; suspended solids; inorganic or organic contents; explosive and flammable materials, and volatile, odorous, or corrosive gases.

In recent years there has been an increasing interest in the use of electrochemical methods for the destruction of toxic and bio-refractory organic pollutants. These methods use the electron as the main reagent and may require a supporting electrolyte in the case of poor ionic conductivity. In general, the supporting electrolytes exist in the wastewaters, but not always in sufficient concentrations. These processes can be operated at ambient temperature without a need of temperature control.

Electrochemical methods such as electrocoagulation-electroflocculation and electroflotation, electro- reduction, direct electro-oxidation, indirect electro-oxidation by using redox mediators such as active chlorine and hydrogen peroxide in the process known as electro-Fenton, and photo-assisted electrochemical methods such as photo-electro-Fenton, photo-electrocatalysis have been applying for the treatment of wastewaters.

According to Rajeshwar *et al.* [1] benefits from using electrochemical techniques include: environmental compatibility, versatility, energy efficiency, safety, selectivity, amenability to automation, and cost effectiveness. In addition to these, the following advantages can be added: electrochemical based systems allow controlled and rapid reactions, smaller systems become viable and instead of using chemicals and micro-organisms, the systems employ only electrons to facilitate water/wastewater treatment. Electrochemical techniques offer the possibility to be easily distributed, require minimum amount and number of chemicals. Besides, these processes can operate at ambient temperature without a need of temperature control [2].

Among these methods electrocoagulation (EC) is based on in situ formation of coagulants from the sacrificial anode such as iron and/or aluminum which is corroded due to the applied current. This technique combines three main interdependent processes, operating synergistically to remove pollutants: electrochemistry, coagulation and hydrodynamics [3]. Simultaneous evolution of hydrogen at the cathode also help remove pollutants by flotation. A range of coagulant species and hydroxides are formed to destabilize and coagulate the suspended particles and to adsorb dissolved contaminants [4, 5].

Electrolytic dissolution of the aluminum anode produces the cationic monomeric species such as Al^{3+} and $Al(OH)_2^{+}$, which at appropriate pH values are transformed initially into $Al(OH)_3$ and finally polymerized to $Al_n(OH)_{3n}$ according to the following reactions [4]:

$$Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3e^{-} \qquad (1)$$

$$Al^{3+}(aq) + 3H_2O_{(l)} \rightarrow Al(OH)_{3(s)} + 3H^{+}_{(aq)} \qquad (2)$$

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$$n\ Al\,(OH)_3 \rightarrow Al_n\,(OH)_{3nc} \qquad (3)$$

According to Kushwaha *et al*. [6] sludge and scum generated in EC can be dried and used as a fuel in the boilers/incinerators, or can be used for the production of fuel-briquettes. On the other hand, the bottom ash obtained after incineration of scum and sludge may be blended with clay with higher ratio of clay to make fire bricks. Few studies have shown that addition of finely divided materials, such as silica, fly ash, etc. to clays and Portland cement not only increases heat resistance of these materials but also improves the microstructure and compressive strength of cement pastes [7]. Thus, sludge and scum generated by EC treatment of dairy wastewater can be disposed off through chemical and physical fixation [8].

II. Materials and Methods

Parallel plate reactor was employed consisting of three pairs of aluminum anode and cathode as can be seen in Fig. 1. The total anode surface area was ~ 100 cm^2.

Experiments were carried out in the batch mode at ambient temperature, and COD concentration of the wastewater in the samples taken at certain time intervals during the experimental runs of 60 minutes was analysed after centrifuged according to the Standard Methods in Examination of Water and Wastewater. COD, pH and electrical conductivity of the untreated wastewater were in the range of 800 to 1400 mg/L, 5 to 7 and 2.1 to 3.5 mS/cm, respectively. Schematic diagram of experimental set up has shown in Fig. 2.

III. Results and Discussion

After the best experimental conditions were obtained by investigating the effects of current density, supporting electrolyte concentration (Na_2SO_4) and initial pH; poly aluminum chloride and Kerafloc were used as coagulant aids The effects of type and concentration of coagulant aids on the removal efficiency, energy consumption and sludge production can be seen in Tables I and II, respectively.

Figure 1. Aluminum electrodes in the parallel plate configuration used in the experiments.

Although both coagulant aids led to increase in removal efficiency, Kerafloc arisen as more economical choice when the energy consumption values were compared. According to the results, the concentration of both coagulant aids were 30 mg/L to achieve highest removal efficiencies, lowest energy consumptions and sludge productions. It has to be noted that the highest removal efficiency achieved without coagulant aid was 85% with the energy consumption value of 32 kWh/m^3 whereas it was 92% for the case of using Kerafloc as coagulant aid with the energy consumption values of 46.19 kWh/m^3. Sludge production per g of COD removed were 7.40 for the run without coagulant aid and 6.35 for the run with 30 mg/L Kerafloc.

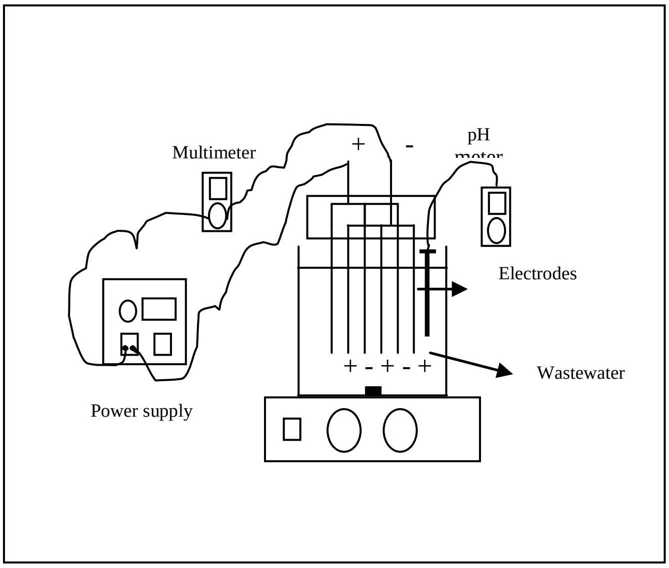

Figure 2. Scheme of experimental setup.

TABLE I. Experimental results for PAC (i: 30 mA/cm^2, 5mM Na_2SO_4, t= 60 min).

PAC, mg/L	10	20	30
Removal efficiency, %	77.50	85.00	92.50
Energy consumption, kWh/m^3	100.57	108.75	108.23
Sludge production, g/g COD removed	9.91	7.55	6.53

TABLE II. Experimental results for Kerafloc (i: 30 mA/cm^2, 5mM Na_2SO_4, t= 60 min).

Kerafloc, mg/L	10	20	30
Removal efficiency, %	70.00	75.00	91.67
Energy consumption, kWh/m^3	104.77	60.26	46.19
Sludge production, g/g COD removed	9.44	7.73	6.35

IV. Conclusions

The best experimental conditions obtained previous studies are: i= 30 mA/cm^2, SE= 5 mM Na_2SO_4, pH= natural pH (6.58).

Highest COD removal efficiency obtained at the best experimental conditions was 85 %. Total energy consumed to achieve 85% COD removal is 32.65 kWh/m^3.

92% COD removal was achieved with energy consumption value of 46.19 kWh/m^3 for the experiments using 30 mg/L Kerafloc as coagulant aid.

When the complexity of the mixed raw industrial wastewater is taken into account, it is concluded that electrocoagulation using sacrificial aluminum anodes is very effective and can be applicable for the treatment of this kind of wastewater.

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