APPLICATION OF ELECTROCOAGULATION MECHANISM FOR COD REMOVAL OF DAIRY WASTEWATER

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Abstract - In this study the electrocoagulation mechanism was used to remove chemical oxygen demand of dairy wastewater. In the process, the effects of initial pH, electrolysis time, voltage were examined. The optimum operating range for each operating variable was experimentally determined. The greatest removal efficiency was obtained with the use of aluminium as anode and iron as cathode (Al–Fe system).With this latest system, optimal values of voltage, initial pH, boric acid concentration and electrolysis time were 8V, 7.0, 5 g/L and 30 min respectively. The batch experimental results revealed that COD in aqueous phase was effectively removed. The overall COD removal efficiencies reached 88.54%.

Keywords - Aluminium Electrode, COD, Electrocoagulation, Iron Electrode,.

I. INTRODUCTION

The dairy industry generates strong wastewaters characterized by high chemical oxygen demand (COD) content. Since dairy waste streams contain high concentrations of organic matter, these effluents may cause serious problems, in terms of organic load on the local municipal sewage treatment systems. Environmental problems can results from discharge of dairy wastewater. Most of the wastewater volume generated in the dairy industry results from cleaning of transport lines and equipment between production cycles, cleaning of tank trucks, washing of milk silos and equipment malfunctions or operational errors.

The other techniques used to treat the diary wastewaters are conventional aerobic purification and anaerobic processes. However, others techniques have also been used, e.g. coagulation flocculation, nanofiltration (NF), reverse osmosis (RO) and use of membrane bioreactors. Biological processes require big spaces and long time of treatment and generate great amount of sludge. The physico-chemical processes suffer the disadvantage that reagent costs are high and the soluble COD removal is low. Besides, chemical treatments could induce a secondary pollution due to the fact that chemical additives may contaminate the treated water. Among physico-chemical methods, electrocoagulation technique is one of the processes which offer high removal efficiencies in compact reactors, with simple equipments for control and relatively moderate operating cost.

Electrocoagulation (EC)/flotation process can be other alternative process for treating dairy waste effluents. This technology has been very successfully employed in removing oil/grease and SS from a variety of industrial effluentsand is a combined coagulation and flotation process induced by the passage of electric current. It was tested successfully to treat drinking water and other industrial wastewaters[1].

II. ELECTROCOAGULATION MECHANISM

A simple electrocoagulating reactor is made up of one anode and one cathode. When a potential is applied from an external power source, the anode material undergoes oxidation, while the cathode will be subjected to reduction or reductive deposition of elemental metals. If iron or aluminium electrodes are used, the generated $Fe3^+$(aq) or $Al3^+$ (aq) ions will immediately undergo further spontaneous reactions to produce corresponding hydroxides and/or polyhydroxides. The Fe(II) ions are the common ions generated the dissolution of iron. In contrast, OH− ions are produced at the cathode. By mixing the solution, hydroxide species are produced which cause the removal of matrices by adsorption and coprecipitation. In the study of Aluminium as anode and Iron as cathode, the reactions takes place as follows [2].

At the anode:

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

The reaction occurring at the cathode is dependent on pH. At neutral or alkaline pH, hydrogen is produced through Eq. 2, whereas under acidic conditions Eq. 3 describes better hydrogen evolution at the cathode:

$$2H_2O\ (l) + 2e^- \rightarrow H_2\ (g) + 2\ OH^-\ (aq) \qquad (2)$$

$$2H^+\ (aq) + 2e^- \rightarrow H_2\ (g). \qquad (3)$$

The generated metal ions (Al^{3+} (aq)) immediately undergo further spontaneous reactions to produce corresponding hydroxides and/or polyhydroxides. The Al^{3+} and OH^-ions produced at the electrodes can react to form various mono-nuclear ($Al(OH)^{2+}$, $Al(OH)^{2\ +}$, $Al_2(OH)_2^{4+}$) and poly-nuclear ($Al_6(OH)_{15}^{3+}$, $Al_7(OH)_{17}^{4+}$, $Al_8(OH)_{20}^{4+}$, $Al_{13}(OH)_{34}^{5+}$, $Al_{13}O_4(OH)_{24}^{7+}$) species, which are finally transformed into aluminium hydroxide: $Al(OH)_3$. The large specific area of $Al(OH)_3$ then facilitates compound adsorption and traps the colloids.

III. MATERIALS AND METHODS

3.1. Electrochemical reactor

The EC unit consists of two electrodes in an EC cell, a DC power supply. The iron cathode and aluminium anode of dimensions 5cm x 5cm x 5cm are separated by a space of 1 cm and dipped in the wastewater. The EC of dairy wastewater was carried out in the reactor using magnetic stirrer to agitate the solutions. The working volume of reactor was 2L. The total area of electrodes plates submerged into the solution was 5 cm^2. A stirring intensity of 100 rpm was used in order to get a correct homogenization of the wastewater–flocs mixture. EC experiments were carried out at 298 K. The stored energy in the battery which was collected from the solar energy was used for carrying out the experiment.

3.2. Wastewater samples and experimental procedure

The synthetic dairy wastewater (SDW) was prepared in the laboratory using dry milk powder .The used milk powder was composed of proteins (12.5 g/100 g powder),carbohydrates (54 g/100 g), fat (28 g/100 g), and inorganic matters (3 g/100 g, including Na 175 mg, K 480 mg, Ca 340 mg, Cl 300 mg, P 190 mg, Mg 41 mg, Fe 6 mg, Zn 3.8 mg, Cu 400 µg, Mn 30 µg,). The actual COD values have been verified each time before initiation of experimental work.The composition of the wastewater is shown in Table 1. The pH was adjusted to a desirable value using HCl and NaOH solutions. The conductivity of the wastewater was adjusted to the desired levels by adding an appropriate amount of boric acid (H_3BO_3).

Table 1.Characteristics of Dairy wastewater

Parameter	Value
Ph	6.0
Conductivity	0.4ms/cm
Color	Whitish
COD	1100mg/l
Turbidity	125 NTU

The salt concentrations of 5g/Lfor increasing conductivity.pH and voltage values were 6.0,7.0 ,8.0 and 4V,6V,8V and 10V respectively. At the beginning of a run, the wastewater was fed into the reactor and the pH and conductivity were adjusted to a desired value. The electrodes Iron as cathode and Aluminium as anode were placed into the reactor. The reaction was timed starting when the DC power supply was switched on.

The electrodes were rinsed in the diluted 15-20% HCl solution and detergent wash after the each experiment. Samples were periodically taken from the reactor. The particulates of colloidal ferric oxyhydroxides gave yellow-brown colour into the solution after EC. All the suspended solids were removed by electrocoagulation and electrolytic flotation. Thus, during electrolysis, the clear solution was obtained. All the suspended solids were removed by electrocoagulation and electrolytic flotation. Therefore, filtration was not markedly effect COD. Sludge generating during treatment was separated from the solution by filtration using Whatman filter paper and then the solution was analyzed. COD analysis was carried out according to the standard methods for examination of water and wastewater.

IV. RESULTS AND DISCUSSION

4.1. Effect of initial pH

pH is an important parameter influencing the performance of the EC process . To examine its effect, the sample was adjusted to a desired pH for each experiment by using sodium hydroxide or hydrochloric acid. Fig 1shows the removal efficiency of COD as a function of the initial pH.pHof the medium increased during the process. The maximum removals of COD were observed at pH 7.0. Best removal results for 30 min electrolysis duration were observed at a pH of 7.0 and at 8V. The maximum removal efficiencies of COD as a function of pH at pH 6.0 were 88.54%. It is interesting to note that the COD removal decreased when pH was greater than 6.0.

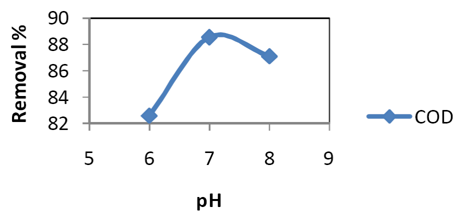

Fig 1 Effect of initial pH on the removal efficiency of COD when V=8V, H_3BO_3 = 5g/L,$C_{0,COD}$:1100mg/L

4.2. Effect of voltage on EC

EC process was carried out using different voltages 4, 6, 8 and 10V.To determine the effect of voltage on EC process, pH was held constant. It was observed that the COD removal was independent of voltage. Though there was increase in voltage, the COD removal efficiency doesnot increased. The optimum removal efficiency was 88.54% at 8V (Fig 3).

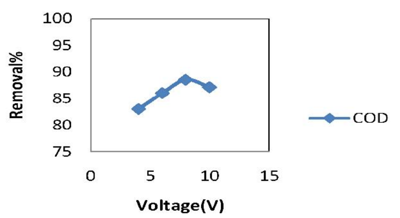

Fig 2 Effect of voltage on the removal efficiency of COD when pH=7.0, H_3BO_3 = 5g/L, $C_{0,COD}$: 1100mg/L

4.3. Effect of operating time on EC

Effect of operating time on the removal of COD is shown in Fig. 4, indicated that an increase in the time of electrolysis from 0 to 30 min yielded an increase in the removal efficiencies of COD. The optimum operating time for this study was chosen as 30 min since the highest removal efficiencies of COD were observed at this time. It was observed that COD remains unchanged after an electrolysis time of 30 minutes. The maximum removal of 88.54% of COD was at 30min of the process.

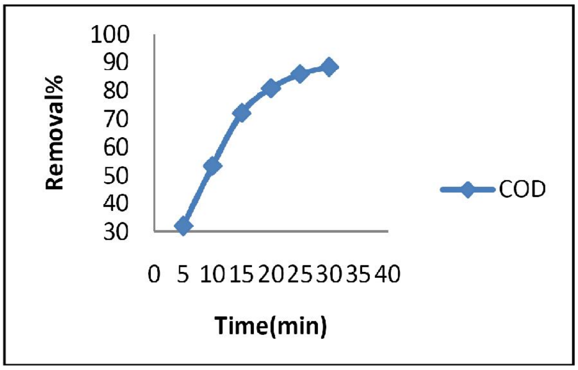

Fig 3 Effect of electrolysis duration on the removal efficiency of COD when pH=7.0,V=8V,H_3BO_3 = 5g/L, $C_{0,COD}$:1100mg/L

CONCLUSIONS

The EC process was successfully applied to the Dairy wastewater. The removal efficiencies of COD was found to be dependent on initial pH, applied voltage and operating time. Optimum operating conditions were obtained as pH 7.0, voltage 8V and operating time of 30 min, respectively. The electrocoagulation setup described in this study is simple in design and operation and can be used as a convenient tool in the removal of food related industrial wastewaters.

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