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Treatment of Sugar Waste Water by Electrocoagulation

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Abstract Sugar industry plays an important role in the economy of India by way of farming and creation of employment. The by-products of sugar mills are also used as raw materials in different industry. However sugar mill have a great environmental impact upon the surrounding environment. The change of water chemistry is the main associated environmental impact of discharging sugar mill's effluent on an open water body. The effluents are causing odor nuisance during decomposition and disturbed the plant, human and animal life. Due this an economical treatment has been introduced that is known to be electrochemical process. To treat the sugar industry wastewater aluminium plate was used as electrode material. It has been shown that the removal efficiency of COD increased with the increasing applied current density, increasing wastewater flow rate and polyelectrolyte addition. The results indicate that electrocoagulation is very efficient and able to achieve 84.2% COD removal and over 99% color removal in 90 min at 40 mA/cm^2 and wastewater flow rate of 1000ml/min.

Keywords: *current, electrode, flocculation, settling*

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1. Introduction

Over the last century, continued population growth and industrialization have resulted in the degradation of various ecosystems on which human life relies on. Industrialization is an important tool for the development of any nation. Consequently, the industrial activity has expanded so much all over the world Today, it has become a matter of major concern in the deterioration of the environment [1]. With the rapid growth of industries (sugar, paper, tannery, textile, sago dye industries) in the country, pollution of natural water by industrial waste water has increased tremendously [2]. Among them, sugar industry plays a major role in producing a higher amount of water pollution because they contain large quantities of chemical elements. Moreover, sugar wastewaters are known to exhibit various pH (either alkaline or acidic, depending on the process used), hot temperature, high biological and chemical (COD) oxygen demands and high concentrations of suspended solids.These must therefore be treated before final discharge to achieve legal and aesthetic standards. In the recent years, investigations have been focused on the treatment of wastewaters using electrocoagulation (EC) because of the increase in environmental restrictions on effluent wastewater. Electrocoagulation (EC) is an electrochemical method for treating polluted water which has been successfully applied for treatment of soluble or colloidal pollutants, such as slaughterhouse wastewater [3], vegetable oil refinery[4] and olive mill [5] wastewater, nitrate and arsenic bearing wastewater [6], etc., but also drinking water for fluoride removal [7]. Aluminum or iron is usually used as electrodes and their cations are generated by dissolution of sacrificial anodes upon the application of a direct current. The metal ions generated are hydrolyzed in the electrochemical cell to produce metal hydroxide ions according to reactions 1-3 and only neutral $M(OH)_3$ has a very low solubility mainly at pH values in the range 6.0–7.0. Metal species react with negatively charged particles in the water to form flocs. The in situ generation of coagulants means that electrocoagulation processes do not require the addition of any chemicals. The gases produced during the electrolysis of water and metal dissolution allow the resulting flocs to floated [8].

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

$$Al^{3+}_{(aq)} + 3H_2O \rightarrow Al(OH)_3 + 3H^{+}_{(aq)} \quad (2)$$

$$nAl(OH)_3 \rightarrow Al_n(OH)_{3n} \quad (3)$$

In this regard an effort has been made to treat the sugar industry waste water by electrochemical process. This study, devoted to the effects of parameters such as: current density, flow rate of wastewater, and polyelectrolyte addition on the color and COD removal efficiencies. Information regarding the electrical energy consumption (EEC) is also included to provide an estimation of the cost of fluoride removal by an EC system.

2. Material and Methods

The wastewater used in this work was taken from the sugar factory in India. Although the quality of the effluent was variable, it was pink colored and typically had a COD of 1953 mg/L, absorbance of 0.337 at the wavelength of 533 nm. The aluminum electrocoagulator used to treat real sugar industry wastewater was operated semi continuous mode. The reactor used in this study which has a unique design was a cylindrical electrochemical reactor having a height of 73 cm and an internal diameter of 3.5 cm as shown in Figure 1. Reactor was operated as cathode. The counter electrode was three aluminum rods with a diameter of 1.25cm and a height of 66 cm each and located in the center of the reactor. The three rod anodes were situated triangle approximately 1cm apart from each other and are submerged in the solution. To obtained turbulence mixing, two baffle plates were used in the reactor. The volume of liquid treated each time was 1L. A specific amount of supporting electrolyte (0.2 M Na_2SO_4) was added to the wastewater to increase the conductivity. The reaction was started by switching the DC power supply on. Samples were taken every 10 min interval and centrifuged. The supernatant liquid was analyzed for the chemical oxygen demand (COD) and color removal. COD was determined by the closed reflux, titrimetric method. The absorbance of wastewater was determined using spectrophotometer at 533 nm. The calculation of color and COD removal efficiencies after electrocoagulation treatment was performed using this formula:

$$RE\% = \left(C_o - C \;/ C_o \right) x\, 100 \qquad (4)$$

where C_0 and C are concentrations of COD or absorbance of wastewater before and after electrocoagulation , respectively.

The electrical energy consumed per unit volume of treated wastewater was determined using the equation

$$EEC = V.I.t \;/ v, \qquad (5)$$

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

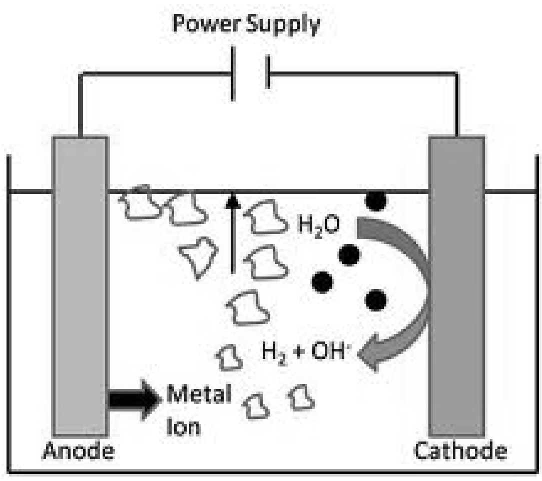


Figure 1. Experimental set up

3. Results and Discussion

The effects of parameters such as pH, current density, flow rate of wastewater and polyelectrolyte addition have been evaluated under specific conditions for a constant reaction time.

3.1. Effect of Current Density

The current density is expected to exhibit a strong effect on EC, especially on the COD abatement and color removal: higher the current, shorter the treatment. The supply of current to the EC system determines the amount of Al^{3+} ion released from the respective electrodes and the amount of resulting coagulant. Thus, more Al^{3+} ion get dissolved into the solution and the formation rate of $Al(OH)_3$ is increased. To examine its effect, six current densities were applied. Figure 2a depicts the effect of current density on the COD removal efficiencies at wastewater flow rate of 303 mL/min. The COD removal efficiencies of 47.4, 64.3, 68.4, 70.1, 78.4 and 79.5% were achieved after 2 h electrocoagulation at 10, 20, 25, 30, 35 and 40 mA/cm^2 respectively. The color removal efficiency of 99% was obtained at all applied current density (Figure 2b). At a high current density, the extent of anodic dissolution of aluminum increases, resulting in a greater amount of precipitate and removal of organics. An increase in the current density also causes a proportional increase of the consumption of electrical energy by the system as seen from the Figure 2c.

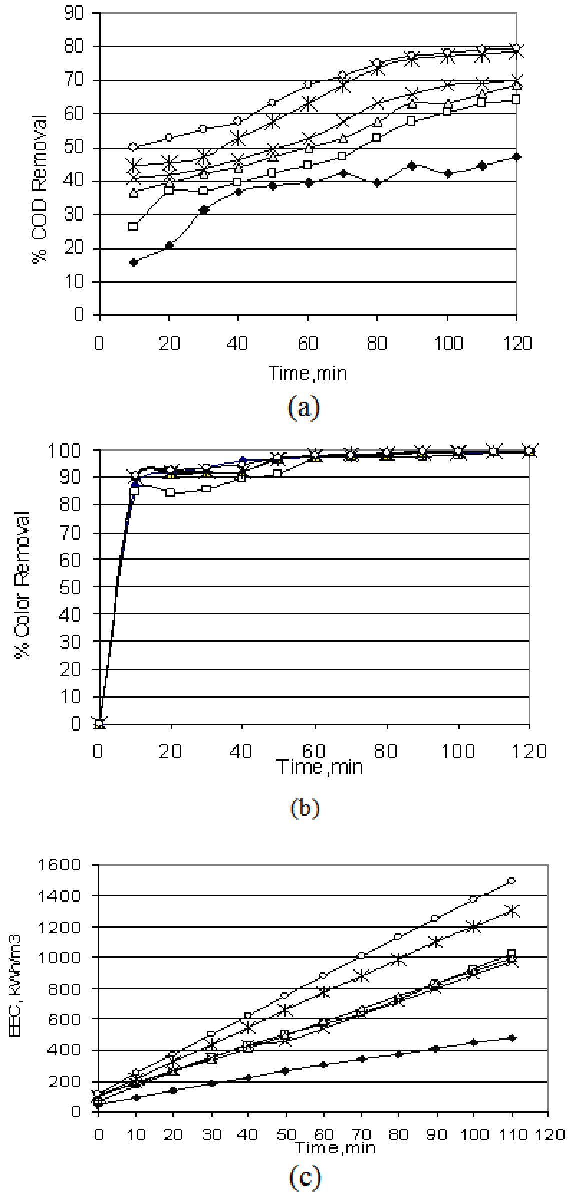
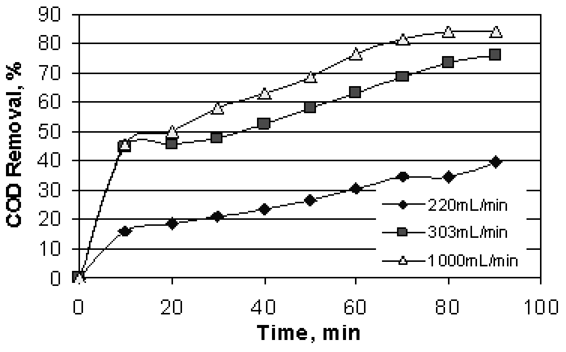


Figure 2. Variation of removal efficiency of COD (a) and color (b) with respect to time for different current densities, c) variation of electrical energy consumptions with current densities

3.2. Effect of Wastewater Flow Rate

In order to investigate the effect of the wastewater flow rate on the color and COD removal efficiency, the flow rate of wastewater (Q_L) was increased from 220 mL/min to 303 and 1000 mL/min. Figure 3a shows the COD concentrations versus time curves for different flow rates in the same operation conditions (40mA/cm^2 and 0.2M Na_2SO_4). As shown in Figure 3, the COD of sample decrease with increasing flow rate. The effluent COD concentrations of 1182, 465 and 308 mg/L (which corresponded to the removal efficiency of 84.2%) were obtained at the wastewater flow rate of 220, 303 and 1000 mL/min, respectively after 90 min electrocoagulation. The color removal efficiencies were higher than 98% for all the flow rates studied as show from Figure 3b. The initial absorbance of the wastewater of 0.337 was reduced to 0.020 at first 10 min and to 0.003 at the end of 90 min electrocoagulation.



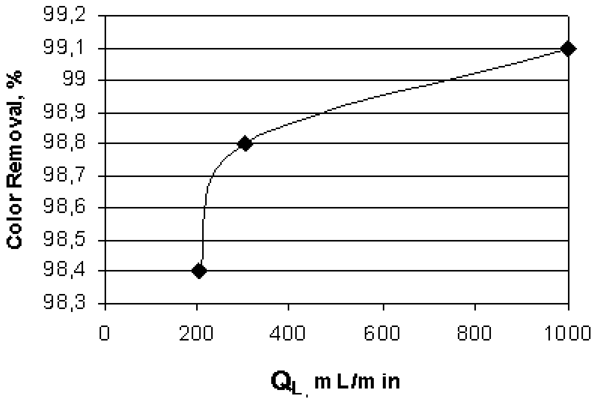


Figure 3. Variation of removal efficiency of COD (a) and color (b) with respect to time for different wastewater flow rate

3.3. Effect of Polyelectrolyte Addition

To increase the performance of the aluminum reactor and to obtain dischargeable effluents, polyelectrolyte was intended to be used as the coagulant aid. Therefore, polyelectrolyte was added to achieve particle instability and increase in the particle size, consequently achieving effective removal of organic substances present as COD. The results obtained from processing at 40mA/cm^2 are shown in Figure 4. The COD removal efficiency of 76% was increased to 80% for an operating time of 90 min with addition of polyelectrolyte.

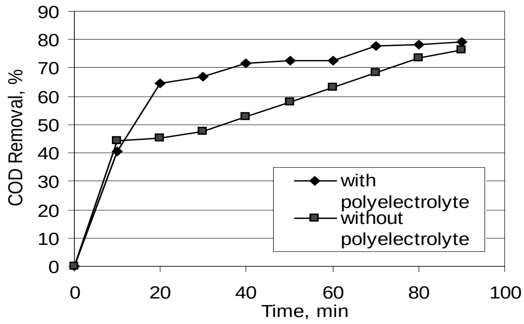


Figure 4. Effect of polyelectrolyte addition to the removal of COD

4. Conclusion

The results of this study have shown the applicability of electrocoagulation in the treatment of sugar industry wastewater. The treatment rate was shown to increase upon increasing the current density. However, increasing the current density caused the energy consumption to increase. Indeed, the highest current produced the quickest treatment with an effective reduction of COD concentrations. The color removal efficiencies were higher than 98% for all the experiments studied. The highest COD removal efficiency was obtained at highest wastewater flow rate. The effluent COD concentration of 308 mg/L was obtained at the wastewater flow rate of 1000 mL/min after 90 min electrocoagulation. The addition of polyelectrolyte to the system improved the COD removal efficiency from 76 % to 80%. Consequently, it can be inferred that EC is a comparatively suitable process for removal of both COD and color using aluminum electrodes to effectively treat sugar industry wastewater.

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