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Treatment of Dairy Industry Wastewater using Electrocoagulation Technique

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***Abstract*—The cost-effective treatment of dairy industry wastewater for environmental protection is a challenging task. In view of this present study was undertaken to investigate the feasibility of electrocoagulation technology for dairy wastewater treatment. The batch experiments were conducted in electrocoagulation (EC) unit of 1.5L capacity with aluminum electrodes connected in monopolar parallel system. The operating parameters such as pH, applied voltage and electrolysis time were used for the investigation with emphasis on chemical oxygen demand (COD) and turbidity during the study it was found that 98.75% COD and 97.82% turbidity can be removed with vary short electrolysis duration of 10 minutes at applied voltage of 7V and pH 6. Thus COD was reduced from 8000mg/L to 100mg/L; and turbidity reduced to 8NTU from 367.1NTU, with specific electric energy consumption of 0.00011 kWh/kg COD. Hence it can be concluded that EC process could be feasible alternative for dairy wastewater treatment.**

Keywords*— *Electrocoagulation, dairy industry wastewater, Electrolysis time(ET), voltage, Chemical Oxygen Demand (COD), turbidity.

I. INTRODUCTION

The dairy industry is considered to be the largest source of wastewater in many countries among the food processing industries [1]. In India, dairy industry is one of the major industries causing water pollution. Dairy wastewater is enriched in organic matter & also contains biodegradable carbohydrates [2].and is characterized by the high BOD and COD and nutrients, organic and inorganic contents. It generates about 0.2–10 liters of effluent per liter of processed milk.[3] Dairy effluents undergo rapid decomposition leading to dissolved oxygen (DO) depletion of receiving water bodies resulting in development of anaerobic conditions and release of strong foul odors.

Rapid urbanization, industrialization and population growth have led to the severe contamination of most of the fresh water resources with disposal of untreated domestic and industrial wastewaters [4]. Therefore treatment and reuse of wastewaters have become absolute necessity and challenging task to avoid pollution of fresh water resources [5].

Generally dairy wastewaters are treated using aerobic or anaerobic biological methods. Aerobic methods like activated sludge process [6], sequencing batch reactor (SBR) [7], are generally employed. Anaerobic biological methods includes: anaerobic sludge blanket (UASB) reactor [8, 9], anaerobic filters [10]. Aerobic biological processes are energy intensive, whereas anaerobic methods are poor in nutrient removal [11].

Recently the EC technique has been successfully used for the treatment of various wastewaters such as domestic wastewater [12], cyanide containing wastewater [13], tannery wastewater [14], textile wastewater [15], slaughter-house wastewater [16] etc. most of the studies[17,18] of using EC technique for dairy wastewater treatment have adopted bipolar system. In view of the present investigation was undertaken to study the suitability of treating dairy wastewater using EC process with mono polar parallel system of electrodes.

II. THEORY OF ELECTROCOAGULATION

Electro coagulation (EC) is a process in which the anode material undergoes oxidation with formation of various monomeric and polymeric metal hydrolyzed ionic species. These metal ions and hydroxides remove organics from wastewater by sweep coagulation and/or by agglomeration with the colloidal particles present in the wastewater to form bigger size flocs which are ultimately removed by settling [19]. During EC, coagulants are obtained *in situ* by the dissolution of the anode. In this process if M is considered as anode, the following reactions will occur [20]:

At the anode:

$$M_{(S)} \rightarrow M^{n+}{}_{(aq)} + ne^- \quad (1)$$

$$2H_2O_{(l)} \rightarrow 4H^+{}_{(aq)} + O_{2\,(g)} + 4e^- \quad (2)$$

At the cathode

$$M^{n+}{}_{(aq)} + ne^- \rightarrow M_{(S)} \quad (3)$$

$$2H_2O_{(l)} + 2e^- \rightarrow H_{2\,(g)} + 2OH^- \quad (4)$$

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$$M^{n+} + nOH \rightarrow M(OH)_n \quad (5)$$

Freshly formed amorphous $M(OH)_3$ has large surface areas that are beneficial for rapid adsorption of soluble organic compounds and trapping of colloidal particles.

III. MATERIALS AND METHODS

The batch reactor of dimensions 15cmx10cmx10cm, was made up of acrylic material and total volume of the reactor was1.5L. The space between the aluminum electrodes was maintained at 1cm in all the experiments. The DC source of 0-30 V and 0-2A was used as power supply to the system. The electrodes were having dimensions of 10cmx5cmx1mm and were immersed to a depth of 5cm. Experiments were performed with four electrodes connected to the DC power supply in a monopolar parallel system. The schematic representation of the experimental setup is shown in Fig. 1.
The wastewater was collected from dairy industry at Bagalkot (Karnataka state) for the batch electrocoagulation studies. After the initial characterization of wastewater, batch experiments were conducted to optimize the various parameters such as pH, electrolysis time (ET) and voltage. In each run the voltage was varied to a desired value of 3, 5 and 7V; whereas pH was adjusted to 5, 6 and 7 with dilute H_2SO_4.To maintain homogenous mixing of the reactor contents magnetic stirrer was used at 120 rpm. All the EC experiments were performed with 1 L of wastewater for 10 minutes; and in each run samples were collected at every 2 minutes interval to determine COD and turbidity.

Wastewater sample collected from dairy industry was characterized for quality parameters as per standard methods. The various parameters of wastewater are shown in Table1.

Table 1: Characteristics of dairy industry Wastewater

Sl No.	*Parameters*	*Values*
1.	pH	5.23
2.	Turbidity	367.1 NTU
3.	Conductivity	1676 µS/cm
4.	COD	8000 mg/L
5.	Suspended solid	507.66 mg/L

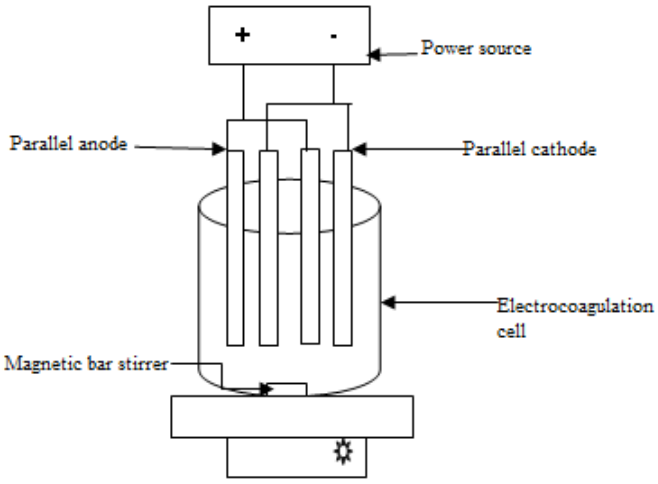

Fig.1. Schematic representation of experimental setup

IV. RESULTS AND DISCUSSION

The study was mainly focused on the electrocoagulation of the dairy industry wastewater for determining effects of operating parameters such as pH, voltage and electrolysis time on COD and turbidity removal.
Initially, the experiments were carried out without adjusting pH of raw wastewater at pH 5 with varying voltages of 3V, 5V and 7V. The COD reduced from 8000mg/L to 2000, 1600 and 1200mg/L thereby giving 75%, 80% and 85% COD removal efficiencies respectively at electrolysis duration of 10 min (Fig.2). However, the COD removal efficiencies remained same for 12 min of electrolysis time. Similarly turbidity reduced from 367.1 NTU to 24, 17.94 and 8.39 NTU thereby giving 93.46%, 95.11%, 97.71% efficiency in removing turbidity from wastewater respectively. (Fig.3)

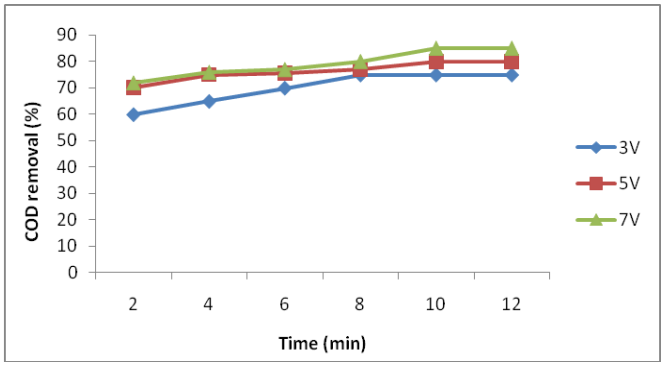

Fig.2 COD removal vs time at different voltages at pH 5

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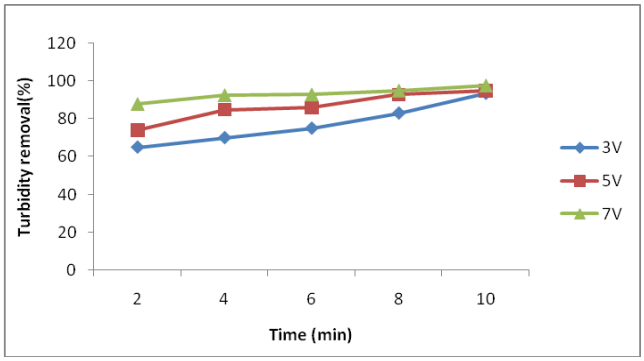

Fig.3 Turbidity removal vs time at different voltages at pH 5

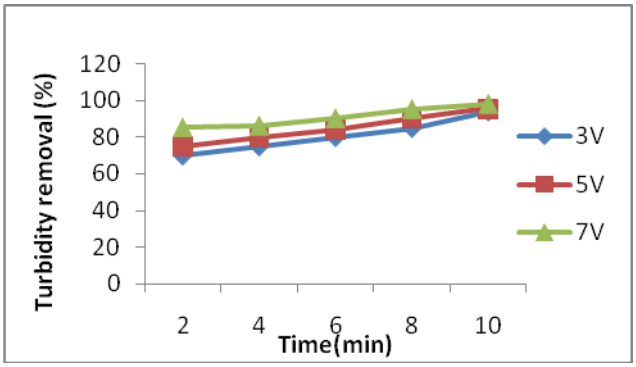

Fig. 5 Turbidity removal vs time at different voltages at pH 6

Next the experiments were carried out by increasing pH to 6.0 with different voltages of 3V, 5V and 7V; the COD reduced from an initial value of 8000mg/L to , 600, 102 and 100mg/L thereby giving COD removal efficiencies of 92.5%, 98.72% and 98.75% respectively at 10 min of electrolysis duration (Fig.4). Similarly, maximum turbidity removal efficiencies of 94%, 95.5%, and 97.82% were obtained. (Fig.5) for 10 minutes of ET.

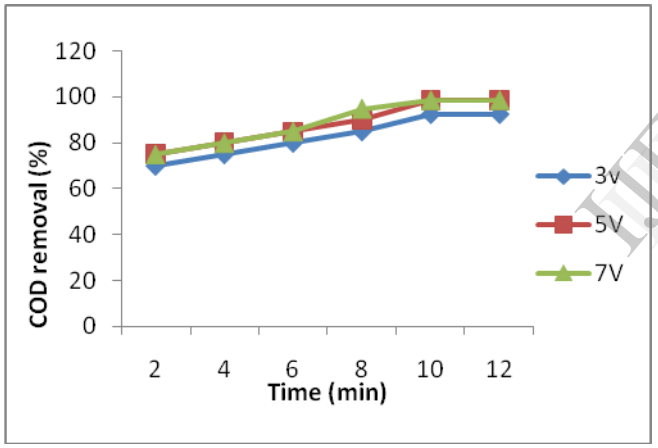

Fig.4 COD removal vs time at different voltages at pH 6

The further experiments were carried out by increasing the pH to 7.0, the COD removal efficiencies were found to be 88.5%, 90.75% and 95% COD from wastewater respectively for varying voltages of 3V, 5V and 7V for 10 min of electrolysis duration. However COD removal efficiency remained unchanged when study was continued upto 12 minutes (Fig.6), similarly, the maximum turbidity removal efficiencies obtained were 88.6%, 90.72% and 94.8%. The results are represented in (Fig.7)

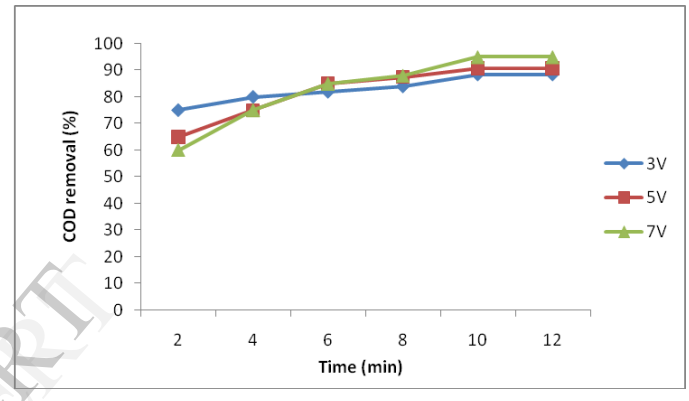

Fig.6 COD removal vs time at different voltages at pH 7

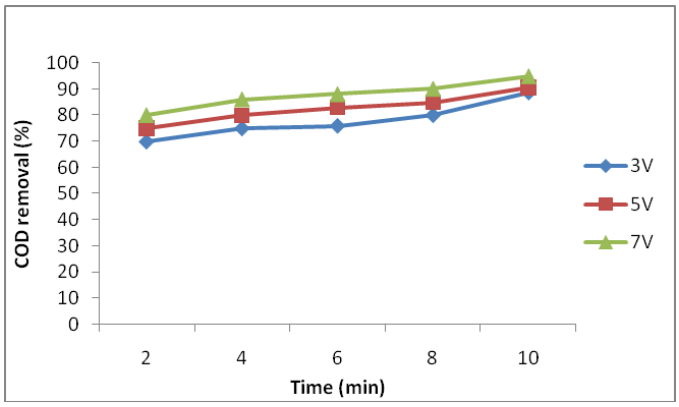

Fig.7 Turbidity removal vs time at different voltages at pH 7

From the above analysis, it was found that maximum COD removal efficiency 98.75% and turbidity removal of 97.82% were obtained at optimum operating parameters of pH 6, 7V and 10 min of electrolysis duration. At these operating conditions COD reduced from 8000 mg/L to 100mg/L and turbidity reduced from 367.1 NTU to 8 NTU. Thus satisfy the effluent disposal standard of India. [3]

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Specific electric energy consumption [SEEC]

One of the most important parameters that greatly affect the application of any method of wastewater treatment is the cost. In addition to aluminium electrodes consumed in the electrocogulation process, the major operating cost is electrical energy consumption.

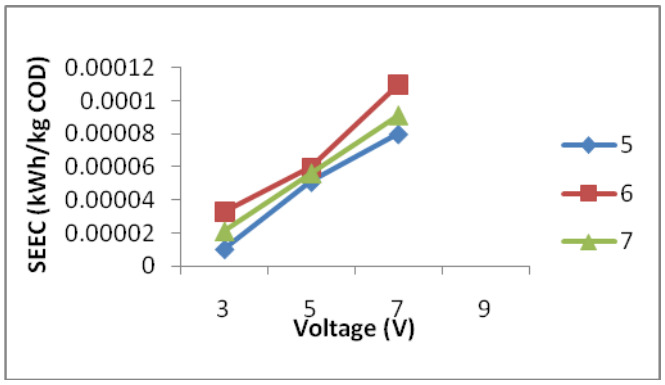

Fig. 7: Specific electrical energy consumption at different pH and voltage ranges

The specific electrical energy consumption at optimum conditions of pH 6.0, 7V and 10 min was found to be 0.00011kWh/kg COD. Thus the electrocoagulation process for dairy wastewater treatment is economical and appears to be feasible for dairy wastewater treatment at low cost.

V. CONCLUSIONS

The experimental results showed that COD and turbidity was effectively removed at pH 6 and 7V for very short electrolysis duration of 10 minutes. High COD of 8000mg/L and turbidity of 367.1NTU were effectively reduced to 100 mg/L and 8 NTU respectively meets effluent disposal standards. The energy consumption was also very less i.e. 0.00011kWh/kg COD removal. Hence electrocoagulation process with monopolar parallel system appears to be feasible alternative for effective and economical treatment of dairy wastewater.

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