

# **Performance Evaluation of Electrocoagulation Process in Treating Dairy Wastewater using Mono-polar Electrodes**

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**ABSTRACT:** The removal of COD and turbidity from dairy wastewater was experimentally investigated using direct current electrocoagulation (EC). In the EC of dairy wastewater, the effects of initial pH, electrolysis time, voltage and different electrodes were examined. The batch experimental results revealed that the removal efficiencies of the overall Nitrates, COD depend on the nature of the electrode material. The optimum operating range for each operating variable was experimentally determined. With this latest approach, optimal values of voltage, initial pH and electrolysis time were 20V, 6.9 and 30 min respectively. The batch experimental results revealed that COD and Nitrates in aqueous phase were effectively removed. The overall COD and Nitrates removal efficiencies reached 50% and 86.8%, respectively. It was observed that the removal efficiency is directly proportional to the electrode material, contact time and voltage and inversely proportional to electrode gaps.

**KEYWORDS:** Electrocoagulation, Dairy Effluent, COD, Nitrates, Voltage, DC, Electrodes.

## **I. INTRODUCTION**

Milk may be defined as the whole, fresh, clean, lacteal secretion obtained by the healthy milk animals. It is generally defined by the three components as follows: (i) the fat or oil that is inside the emulsion droplets, (ii) the interfacial matter between the lipidic phase and the aqueous phase representing part (iii) of the emulsion. Each of these phases may be chemically complex. Milk consists also of three parts: (i) an oil-in-water emulsion in which the fat droplets are dispersed in the serum, (ii) a colloidal suspension of casein micelles, protein and lipoprotein particulates and the aqueous phase (iii) containing soluble proteins, mineral salts and vitamins.

Large quantity of wastewater originates due to their different operations. The organic substances in the wastes comes either in the form in which they were present in milk, or in a degraded form due to their processing. As such, the dairy wastewater, though biodegradable, are very strong in nature. Dairy waste effluents are concentrated in nature, and the main contributors of organic charge to these effluents are carbohydrates, proteins and fats originating from milk. The liquid waste from dairies originates from different sections like receiving station, bottling plant, cheese plant, casein plant, condensed milk plant, dried milk plant and ice cream plant. The dairy wastes are very often discharged intermittently. The nature and composition of waste depends on the type of products produced and size of the plant [10].

The Dairy Industry involves processing raw milk into products such as consumer milk, butter, cheese, yogurt, condensed milk, dried milk (milk powder) and ice-cream using processes such as pasteurization, bottling, filling in cans etc. The Dairy Industry is one of the most widely spread of all the industries. These vary from small receiving stations to large plants where most of the products made from milk are manufactured. Wastes from milk product manufacture contain milk solids in a more or less dilute condition, but in varying concentration. These solids enter the

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waste from almost all of the operations. In general, the wastes generated from Dairy Industry are: The washing and cleaning out of product remaining in the tank, trucks, cans, piping, tanks and other equipment is performed routinely after every processing cycle; Spillage is produced by leaks, overflow, freezing-on, boiling over, equipment malfunction or careless handling; Processing losses include Sludge discharge from clarifiers, Product wasted during pasteurized start-up, shut-down and product change-over, Evaporator entrainment, Discharges from bottles and washers, Splashing and container breakage in automatic packaging equipment and Product change-over in filling machines; Spoiled products, returned products or by-products such as whey wasted; Detergents and other compounds are used in the washing and sanitizing solutions that are discharged as waste ; Entrainment of lubricants from conveyors, stackers and other equipment appear in the wastewater from cleaning operations; Routine operation of toilets, washrooms and restaurant facilities at the plant contribute waste; Waste constituents may be contained in the raw water which ultimately goes to waste; Non-dairy ingredients (such as sugar, fruits, flavors, nuts and fruit juices) utilized in certain manufactured products (include ice-cream, flavored milk, frozen desserts, yoghurt and others); Milk by-products that are deliberately wasted, significantly whey and sometimes buttermilk [20].

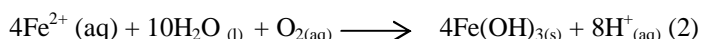
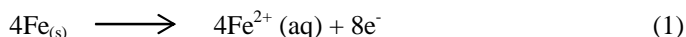
Advantages of Electro coagulation are Electro coagulation requires simple equipment and is easy to operate. The electrolytic processes in the Electro coagulation cell are controlled electrically with no moving parts, thus requiring less maintenance. Wastewater treated by Electrocoagulation gives palatable, clear, colorless and odorless water. It is a low sludge producing technique. Sludge formed by Electro coagulation tends to be readily settable and easy to de-water, because it is composed of mainly metallic oxides/hydroxides. Flocs formed by Electro coagulation are similar to chemical floc, except that Electro coagulation floc tends to be much larger, contains less bound water, is acid-resistant and more stable, and therefore, can be separated faster by filtration. The Electro coagulation process avoids uses of chemicals, and so there is no problem of neutralizing excess chemicals and no possibility of secondary pollution caused by chemical substances added at high concentration as when chemical coagulation of wastewater is used. The gas bubbles produced during electrolysis can carry the pollutant to the top of the solution where it can be more easily concentrated, collected and removed. The Electro coagulation technique can be conveniently used in rural areas where electricity is not available, since a solar panel attached to the unit may be sufficient to carry out the process. This study of Electro coagulation treatment of dairy effluent was tested and the COD removal efficiency was determined [20].

## II. ELECTROCOAGULATION MECHANISM

The reactor consists of an anode and a cathode. When external source applies potential, oxidation undergoes at the anode, while cathode undergoes reduction or reductive deposition of elemental metals. The mild steel electrodes used in this study generates  $\text{Fe}^{3+}$  ions immediately will undergo spontaneous reactions to produce corresponding hydroxides or/and polyhydroxides. Usually  $\text{Fe(II)}$  ions are formed during the dissolution of iron. In this study of iron anodes, mechanism for production of hydroxides metal has been discussed as follows:

Mechanism

At anode:



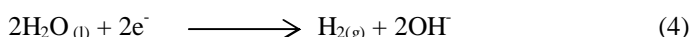
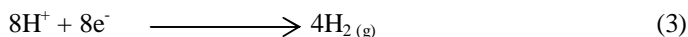
The generated ion and oxygen dissolved react to form  $\text{Fe}(\text{OH})_3$ . The reaction occurring at cathode is dependent on pH. At alkaline or neutral pH, hydrogen is produced through Eq. 4, but according to Eq. 3 under acidic conditions evolution of hydrogen is better at the cathode.

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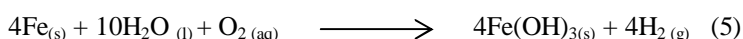
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At Cathode:



Overall:



The  $\text{Fe}(\text{OH})_3(\text{s})$  formed is in the aqueous stream as a gelatinous suspension, which can remove waste matter from wastewater by coagulation and electrostatic attraction.

### III. MATERIALS AND METHODS

This research is a descriptive, analytical and practical study carried out in order to investigate the effect of a continuous electric current on the pollution index (COD) in wastewater samples. A 4500 ml square glass container was used as a reactor vessel. After the addition of wastewater to the beaker, the electric current flowed through different electrodes in variable voltages and times. Before and after each run, the COD value was determined. The wastewater samples used in this study were taken from the Dairy processing unit near Bathi, Davangere, India. Mild Steel and Copper plates (15.0 x 5.0 cm) were used as electrodes and a 15% HCl (by mass) solution was used to clean the electrodes before beginning the experiment. Electrode combinations were chosen as Fe-Cu in this experiment. The experiments were carried out separately at three voltage ranges (7, 14 and 20 V) with a variable contact time for each series of electrodes. One sample was taken every 10 min from the reactor considering the selected contact times for these experiments and after filtration its COD value was determined using a COD reactor. Other tools used in the experiment consisted of: an alternate/continuous transformer (regulated DC power supply) for providing power and a multimeter for measuring voltage and current and also a magnetic stirrer with a stirring speed of 50 rpm for homogenizing. All experiments were done at room temperature (around 20-28°C).

#### EXPERIMENTAL SETUP AND PROCEDURE

Electro coagulation reactor with electrodes connected in parallel was used in the experiments. The reactor having a volume of 4.5 liters was used. Copper Plates and Mild Steel Plates were used as the electrodes for the experiments. A regulated direct current supply (0-30 V, 0-2 A) by Power Supplier was used for the experiments. The experimental setup is shown in Figure 1.



Figure 1: Electro-Coagulation Set up

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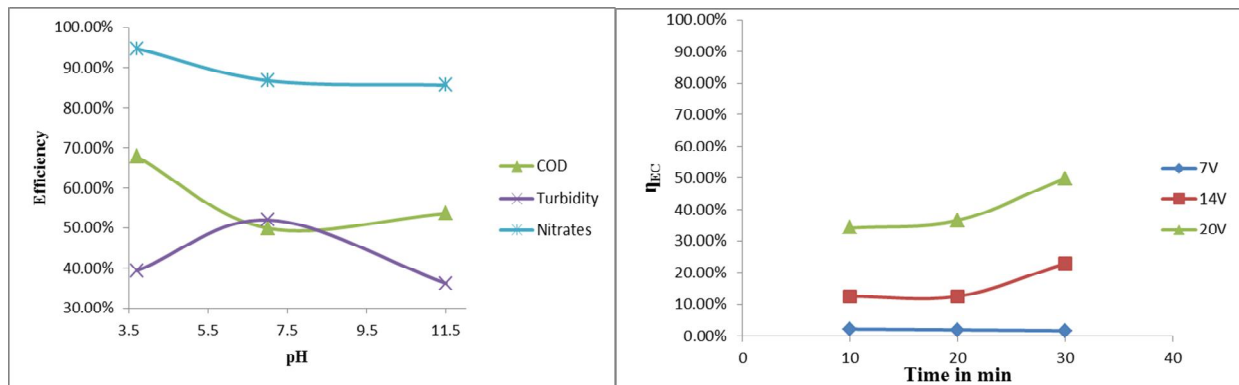
**Table 1.Characteristics of Dairy wastewater**

Parameter	Avg. Value
pH	6.9
Conductivity	0.9ms/cm
Color	whitish
COD	950mg/l
Turbidity	1150 NTU
Nitrates	6.5mg/l
Oil and Grease	21.5mg/l
TDS	790NTU

## IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

### Effect of initial pH

pH is a considerable parameter influencing the performance of the Electrocoagulation process. To examine its impact, the sample was adjusted to a desired pH for each experiment by using hydrochloric acid or sodium hydroxide. The removal efficiency of COD and Nitrates as a function of the initial pH is shown in Fig 2. The maximum removal rates of COD were observed at pH 6.9. Best removal results for 30 min electrolysis duration were observed at a pH of 6.9 and at 20V. The maximum removal efficiencies of COD and Nitrates as a function of pH at pH 6.9 were 50% and 86.8% respectively. It is important to note that the COD removal decreased when pH is in acidic range. The drop of parameters removal, when the initial pH tends toward acid or basic values, is in accordance with the amphoteric character of aluminium hydroxide  $Al(OH)_3$  that precipitates at pH 6–7 and its solubility increases when the solution becomes either more acidic or alkaline.



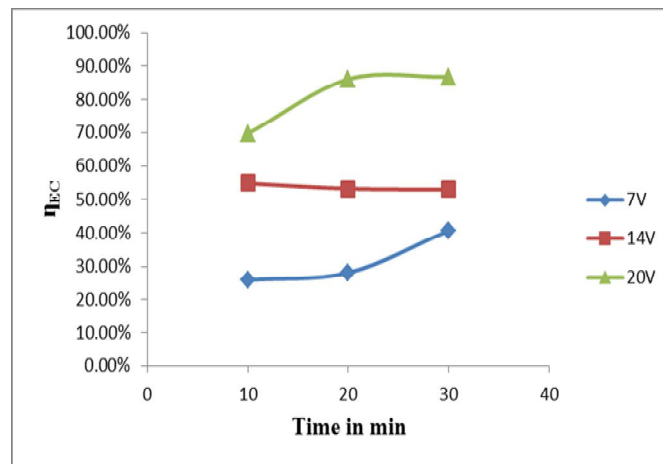
(a)

(b)

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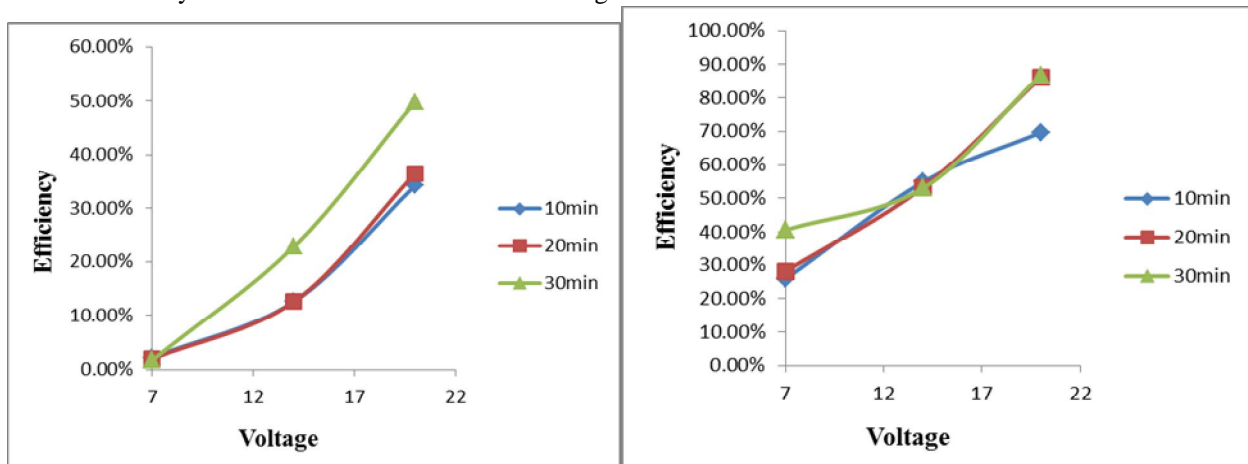


(c)

Fig.2 Effect of Initial pH on the Removal Efficiency (a) COD, Turbidity and Nitrates at 20V after Electrolysis duration of 30min (b) COD Removal Efficiency at 7, 14 and 20V after Electrolysis Duration of 10, 20 and 30min (c) Nitrate Removal Efficiency at 7, 14 and 20V after Electrolysis Duration of 10, 20 and 30min

### Effect of voltage on EC

It is well-known that current not only determines the coagulant dosage rate but also the bubble production rate, size and the flocs growth, which can influence the efficiency of the treatment and operating cost of the EC. EC process was carried out using different voltages 7, 14 and 20V. To determine the effect of voltage on EC process, pH was held constant. It was observed that the COD removal was independent of voltage. The observations were made that the Nitrates removal was dependent on voltage. As the voltage increased the Nitrate removal also increased. The optimum removal efficiency was 86.8% at 20V as shown in the Fig. 3.



(a)

(b)

Fig.3 Effect of Voltage on the Removal Efficiency (a) COD Removal Efficiencies at 7, 14 and 20V for different Time Intervals 10, 20 and 30min (b) Nitrate Removal Efficiencies at 7, 14 and 20V for different Time Intervals 10, 20 and 30min.

## Effect of operating time on EC

Effect of operating time on the removal of COD and Nitrates was 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 Nitrates and COD. The optimum operating time for this study was chosen as 30min since the highest removal efficiencies of COD and Nitrates were observed at this time. The degree of treatment involved in electrocoagulation completely depends on the duration of time allowed for the electrodes to exchange ions.

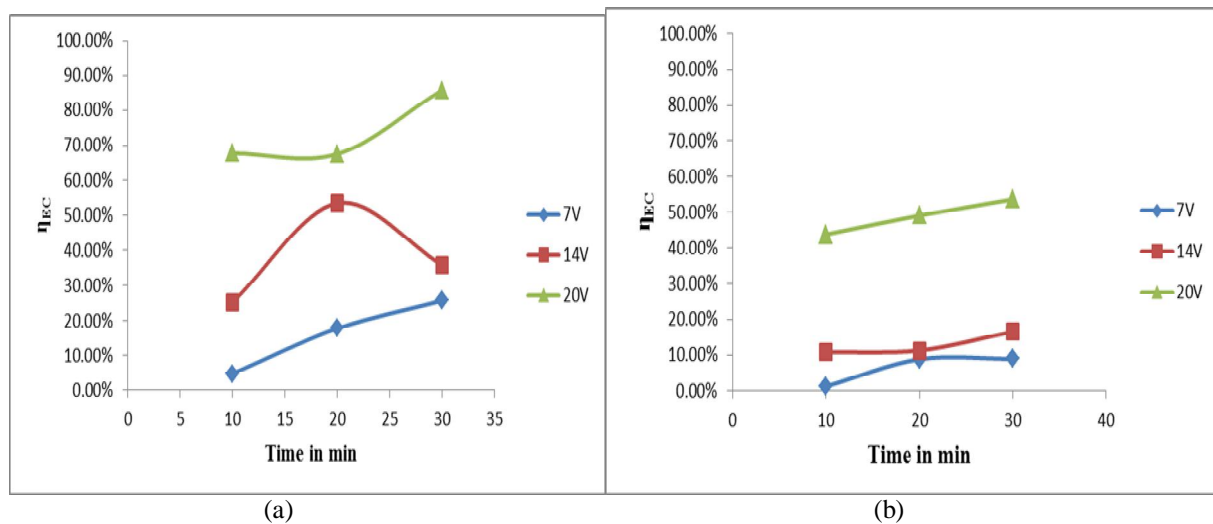


Fig.4 Effect of Operating Time on the Removal Efficiency of COD and Nitrates (a) COD Removal Efficiencies at 7, 14 and 20V for different Time Intervals 10, 20 and 30min (b) Nitrate Removal Efficiencies at 7, 14 and 20V for different Time Intervals 10, 20 and 30min.

## Effect of electrode materials

The nature of the electrode material is a major issue in electrocoagulation treatment and the appropriate selection of electrode material is very important. The most common electrode materials used for electrocoagulation technique are aluminium and iron because they are cheap, readily available and proven effective since their dissolution in aerated media generate trivalent species. The electrode systems used in this study were Mild Steel as anode and Copper as cathode. At an optimum condition initial pH 6.9, voltage 20V and after 30 min of electrolysis process, the removal efficiency of COD and Nitrates was observed to be 53% and 86.8% at Neutral, 68% and 94% at Acidic and 54.5% and 84.5% at Alkaline Range with the Electrodes used in this study.

## V. CONCLUSIONS

EC process is an efficient and feasible process for the treatment of dairy wastewater, constituted of high COD, Oil and grease and SS concentrations. The treatment of wastewater from dairy showed effective removal of COD and Nitrates at pH b/w 6-7, when the initial concentration of COD and Nitrates was 922.80 mg/l and 5.018 mg/l, respectively. For 30min duration of electrolysis, with the increase in the voltage, the initial concentrations of COD and Nitrates were acceptably reduced. The results also showed that COD removal efficiency is directly proportional to input voltage and contact duration. So as per the study electrocoagulation can be concluded as an easy, fast, economical and low cost (less equipment needed) and occupies lesser space.

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