# Treatment of Dairy Wastewater by Electrocoagulation Technique

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***Abstract:***

*Rapid industrialization plays a vital role for the development of the country, which causes serious pollution problem from the disposal of industrial effluent into natural water resources. Out of that, dairy industry is a major water consumer and waste water generator as well. The dairy wastewater is characterized by high amount of biochemical oxygen demand (BOD), emulsified oil & grease and other pollution load. Before discharging to waterways the treatment of dairy wastewater has become an absolute necessity. In the present study electrocoagulation technique is used in order to treat dairy wastewater because of its versatility, low cost, ease of setup and environmental compatibility. The elimination of turbidity, BOD and emulsified oil & grease from dairy effluent were experimentally examined using direct current electrocoagulation with the help of aluminum (Al) electrodes. By varying the operating parameters such as electrolysis time of 30-120 min, applied voltage in the range of 3-12 V, pH of 3-9, conductivity of 1.5-4.5 mS/cm, stirring speed of 120-300 rpm and inter electrode distance of 1-3 cm, the one factor experiments are conducted and the corresponding pollutant removal efficiencies are noted. From the experimental result, it can be concluded that the electrocoagulation process is a safe, practical, and effective method for the removal of pollutants from dairy wastewaters.*

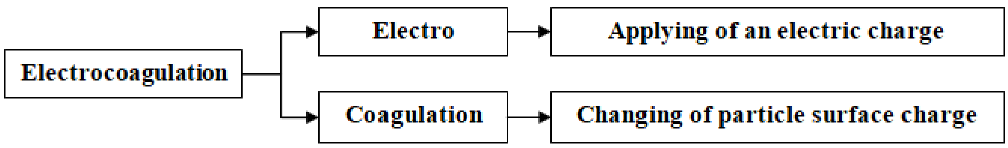
***Keywords:*** *Wastewater treatment; Electrocoagulation; Aluminum electrodes; BOD; Emulsified oil & grease; Turbidity*

## 1. Introduction

Accelerated industrialization is essential for the nation's prosperity, but it also leads to an enormous pollution problem when industrial waste is dumped in natural water sources. Due to increasing demand for milk and milk products, dairy industries have shown enormous growth throughout the world. Out of that, dairy industry is a major wastewater generator and water consumer as well. Indeed, in a survey conducted by environmental protection agency (EPA) of the USA in 1950, the second main cause of water pollution is dairy effluent[1]. Dairy wastewaters are characterized by high amount of Biochemical oxygen demand (BOD), emulsified oil & grease and other pollution load[2].

Due to high pollutant matter, treatment of dairy wastewater has become an absolute necessity before discharging to waterways. Biological technologies such as the activated sludge method, aerobic bioreactors, trickling filters, aerated lagoons, sequencing batch reactors, anaerobic sludge blanket reactors, anaerobic filters, etc. are typically used to treat dairy effluent.[3]. These biological processes are strictly under controlled conditions with large retention time, larger foot print and generate unwanted by-products. Therefore, research for treatment of wastewater is greatly attracted to one of the advanced electrochemical technology that is electrocoagulation process which stands as the most sustainable alternative method for large quantity of wastewater to treat[4].

1.1. *Electrocoagulation process*: Removal of pollutants from water by electrochemical method was first described in the year 1889 in England. And the implementation of electrocoagulation process using Aluminum (Al) and iron (Fe) electrodes was patented in the USA in 1909. Basically, Electrocoagulation process is a simple technique that works on the principle of electrolysis. By the use of electric current, the process destabilizes any substance that is suspended, emulsified, or dissolved in an aqueous medium. [5].




Many authors offer the electrocoagulation process, because it minimizes the use of chemicals and the formation of toxic by-products, it increases the performance of the process with minimum energy requirements. In electrolysis, electrodes made of any metal can be employed [6]. However, aluminium, iron, and steel are most commonly utilised electrode materials in electrocoagulation because they are affordable, widely obtainable, and exhibit good effectiveness in pollution removal operations [7][8][9].

*1.1.1 Mechanism:* In electrocoagulation process, the electric current is applied to the sacrificial electrodes which are placed in the water that will be treated. At anode, formation of metal ions and the oxidation reaction takes place. The reaction that happens on the cathode is reduction of water [10]

*At Anode:*

$$M_{(s)} \rightleftharpoons M^{n+}_{(aq)} + ne^- \; ; \; H_2O \rightleftharpoons 4H^+_{(aq)} + O_{2(g)} + 4e^-$$

*At Cathode:*

$$4H_2O + 4e^- \rightleftharpoons 2H_{2(g)} + 4OH^-$$

The reduction reaction result in the generation of $H_2$ gas and hydroxyl ions. The metal ions from anode, hydroxyl ions from cathode driven into water and undergoes hydrolysis. The hydrolysis reaction produces metal hydroxides which adsorb the pollutants and float on to the surface of water by produced hydrogen gas bubbles.

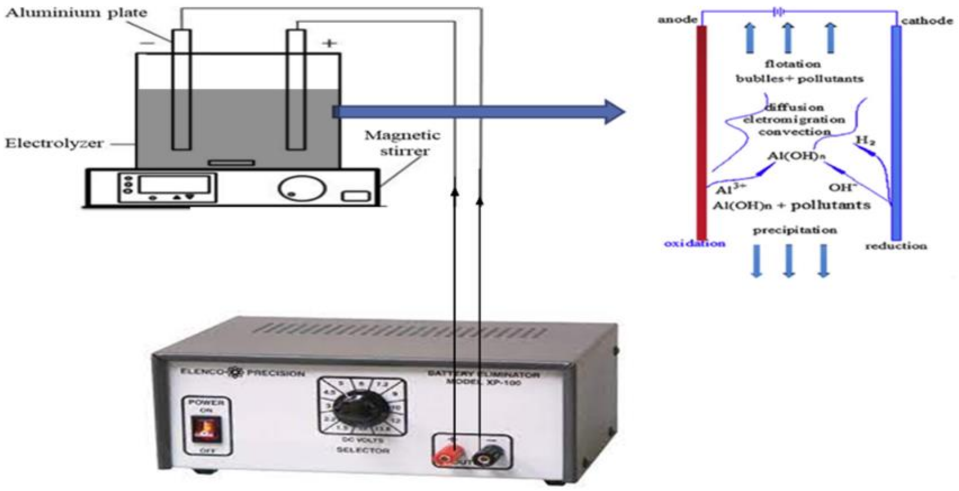



**Figure 1.** Schematic diagram of EC process

## 2. Materials and Methods

a. *Dairy wastewater sampling*: The strictest safety measures are used during sampling, including the usage of hand gloves, goggles, face masks, and shoes to protect the body from the filthy conditions at the collecting site. Grab sampling is done; Effluent is collected from Muthyal reddy dairy which is located in the premises of Anantapur Municipal Corporation. The effluent container is carefully sealed to avoid the sample in contact with the air. The sample is then transported to the laboratory and maintained there at 4 °C in the lab refrigerator to prevent the deterioration of its properties over time because all of the reactions in the sample are inactive at this temperature.

b. *Analytical procedures*: The sample of collected wastewater is tested both before and after the treatment process. Sample parameters include pH, conductivity, turbidity, BOD, and emulsified oil & grease. Sample conductivity and pH are the guiding variables in the electrocoagulation procedure. In this investigation, the pollutant contents of the wastewater were assessed before and after the treatment procedure for BOD, turbidity, and emulsified oil and grease. Standard techniques are used for the examination of wastewater during characterization. pH and conductivity of the sample are determined by using 361 digital pH meter and systronics 306 digital conductivity meter respectively. The turbidity of the water sample is measured by using Nephelo-turbidity meter. BOD of the water sample is determined by using Five-day BOD test and emulsified oil & grease content in the water sample is determined by using Partition gravimetric method. Following the electrocoagulation of the wastewater sample, the initial and final values of turbidity (NTU), BOD (mg/L), and emulsified oil & grease (mg/L) are used to compute the percentage removal efficiencies of BOD, turbidity, and emulsified oil & grease. It is computed using the following formula:

$$\% \text{ Removal efficiency} = \frac{C_i - C_f}{C_i} \times 100 \quad (1)$$

$C_i$ = Pollutants' initial concentration; $C_f$ = Pollutants' final concentration

c. *Experimental work*: The experimental setup consists of a glass beaker of 2 litre volume which acts as an electrolytic cell. This beaker with water sample is placed on a magnetic stirrer for proper agitation of the solution during electrolysis. In this process aluminum plates of size 15 cm x 5 cm x 0.3 cm (l x b x w) are used. Two electrodes are used for each run, and these electrodes are dipped into the cell by using a supporter. And these electrodes are connected to external DC source by using crocodile clips to introduce electricity into the solution. A battery eliminator is used as an external DC source which has different voltages in it. And each experimental run is done in the room temperature only. After completion of each run the water sample from the electrolytic cell collected and filtered without floc and is used to determine turbidity, BOD and emulsified oil & grease by standard methods.

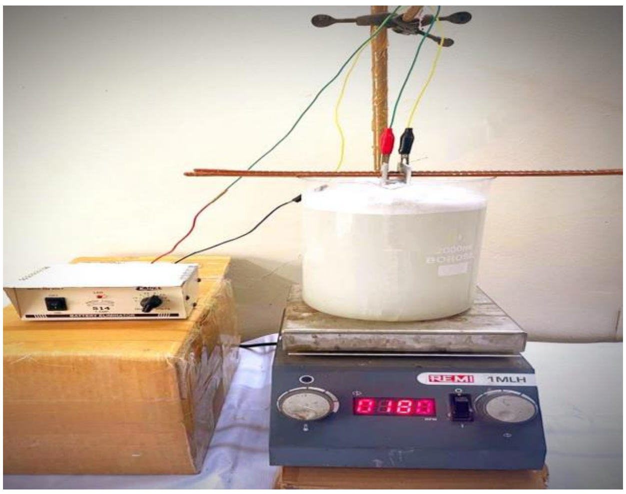



**Figure 2.** Experimental setup

## 3. Results and Discussion

The characteristics of dairy wastewater were studies and listed in the below table

**Table 1.** Physicochemical characteristics of dairy wastewater

| S. No. | Parameter | value |
|---|---|---|
| 1. | pH | 6.30-6.52 |
| 2. | Conductivity | 2.904 mS/cm |
| 3. | Total suspended solids | 3400-3600 mg/L |
| 4. | Total dissolved solids | 920-980mg/L |
| 5. | Turbidity | 507-588 NTU |
| 6. | BOD | 216-244 mg/L |
| 7. | Emulsified oil & grease | 724-892 mg/L |

3.1. *Effect of electrolysis time*: The electrocoagulation is significantly influenced by the duration of the electrolysis. In order to examine the impact of electrolysis time on pollutant removal the remaining operating parameters are kept constant. Turbidity, BOD, and emulsified oil & grease removal efficiencies increases with increasing electrolysis time. This is due to the generation of more metal polymeric species and hydroxyl ions. And the generation of floc continues beyond the optimal electrolysis time. However, the maximum amount of floc is already available since the excess floc generation is no longer efficient in removing pollutants [11][12][13]. And it results to a rise in operational cost. Highest pollutant removal is observed between 90 min and 120 min. And the constant values of remaining operating parameters are voltage: 6 V; pH: 6.5; conductivity: 3.0 mS/cm; stirring speed: 200 rpm; inter electrode distance of 1.5 cm.

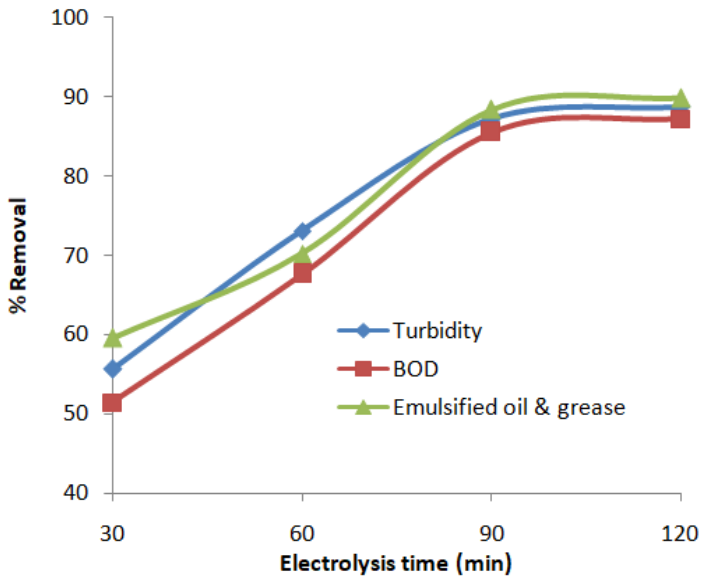



**Figure 3.** Effect of electrolysis time on pollutant removal

3.2. *Effect of applied voltage*: Applied voltage is crucial operating parameter in electrocoagulation process. In order to investigate the impact of applied voltage on pollutant removal the remaining operating parameters are kept constant. The constant values of remaining operating parameters are electrolysis time: 40 min; pH: 6.5; conductivity: 3.0 mS/cm; stirring speed: 200 rpm inter electrode distance of 1.5 cm. Turbidity, BOD, and emulsified oil & grease removal efficiencies increases with increasing applied voltage. This is due to the rate of coagulant production and bubble generation which are both influenced by the voltage. Beyond optimal value of applied voltage there is no significant change in the pollutant removal but leads to rise in operational cost. Additional increase in voltage sometimes results in the secondary reactions and coagulant over dosage occurs which might reverse the charge on colloids and finally leads to reduce the effectiveness of electrocoagulation [14][10]. Highest pollutant removal is observed between 9 V and 12 V.

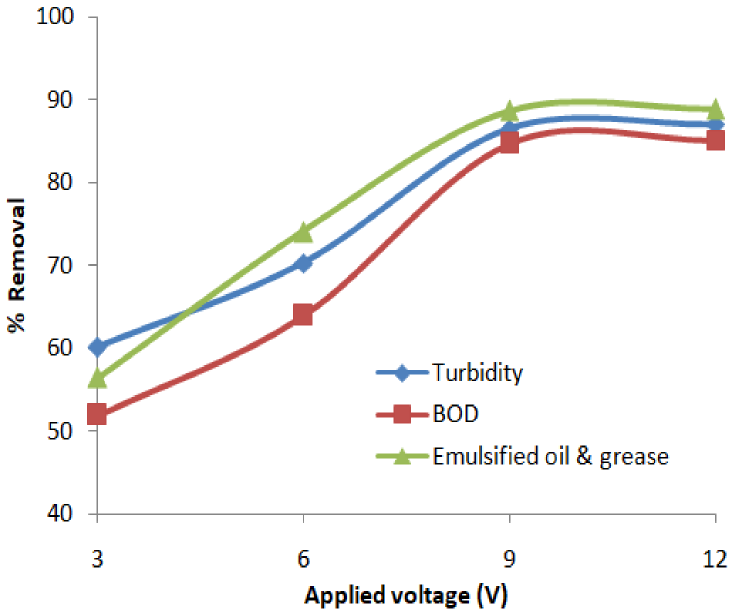



**Figure 4.** Effect of applied voltage on pollutant removal

3.3. *Effect of initial pH*: In the electrocoagulation process, pH is one of the major factors that affect the removal of pollutants [15][16]. The electrode dissolution rate and the formation of metal hydroxide species are affected by pH and highly dependent on pH. In order to investigate the impact of pH on pollutant removal, the remaining operating parameters are kept constant. The constant values of remaining operating parameters are electrolysis time: 40 min; applied voltage: 6 V; conductivity: 3.0 ms/cm; stirring speed: 200 rpm; inter electrode distance of 1.5 cm. The highest pollutant removal rate is observed at neutral pH.

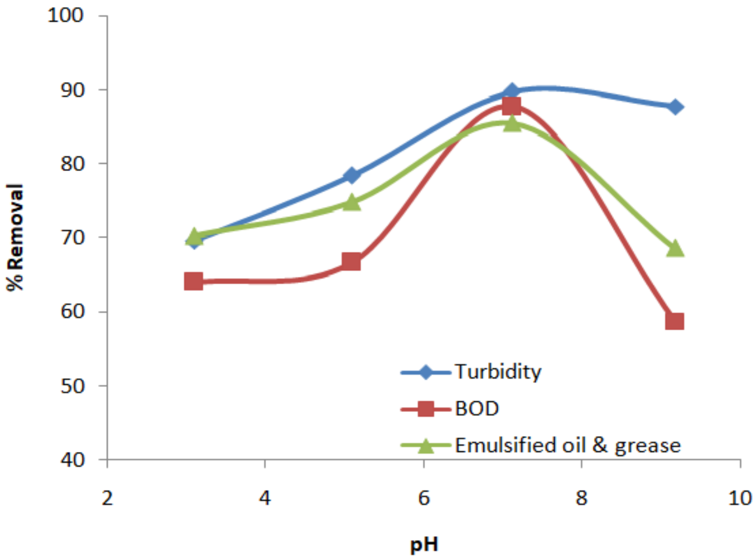



**Figure 5.** Effect of pH on pollutant removal

3.4. *Effect of conductivity*: Conductivity is an important factor that influences the removal of turbidity, BOD and emulsified oil & grease by electrocoagulation. The conductivity of the sample is varied by using NaCl and deionised water [17]. NaCl is used to increase conductivity and deionised water is used to reduce it. Rise in conductivity lowers power consumption. The solution's ionic strength is determined by conductivity. In order to examine the impact of conductivity on pollutant removal, the remaining operating parameters are kept constant. At constant cell voltage, higher conductivity lowers ohmic resistance and boosts current density, and vice versa [10][18]. The constant values of remaining operating parameters are electrolysis time: 40 min; applied voltage: 6 V; pH: 6.5; stirring speed: 200; inter electrode distance of 1.5 cm. rpm. The highest pollutant removal rate is observed at conductivity of 3.5 mS/cm.

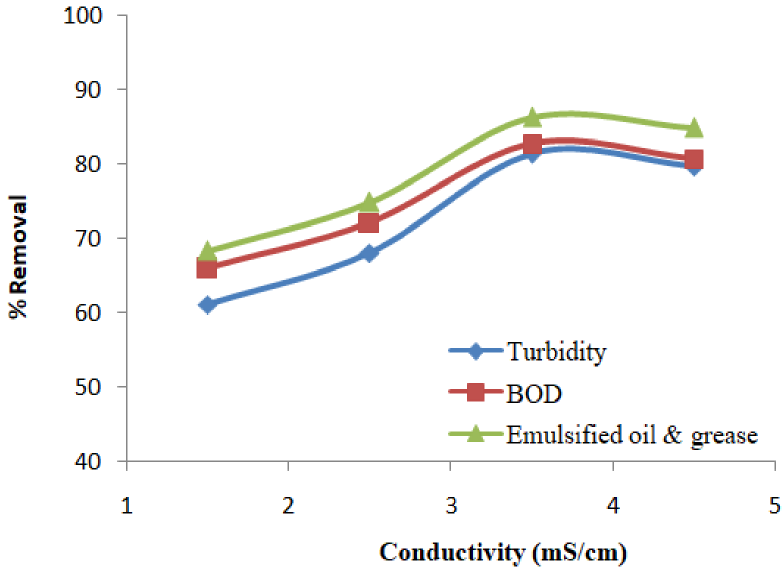



**Figure 6.** Effect of conductivity on pollutant removal

3.5. *Effect of stirring speed*: The agitation or stirring speed is a crucial operational factor in the electrocoagulation process. By adding velocity through stirring, it ensures the homogeneity of the solution in the electrocoagulation system and increases the rate of pollutant removal [19]. Beyond the optimal stirring speed the flocs get destabilized and decrease the effectiveness of the treatment process [20]. In order to investigate the impact of stirring speed on pollutant removal, the remaining operating parameters are kept constant. The constant values of remaining operating parameters are electrolysis time: 40 min; applied voltage: 6 V; pH: 6.5, conductivity: 3.0 ms/cm, inter electrode distance: 1.5 cm. The highest pollutant removal rate is observed at stirring speed of 240 rpm.

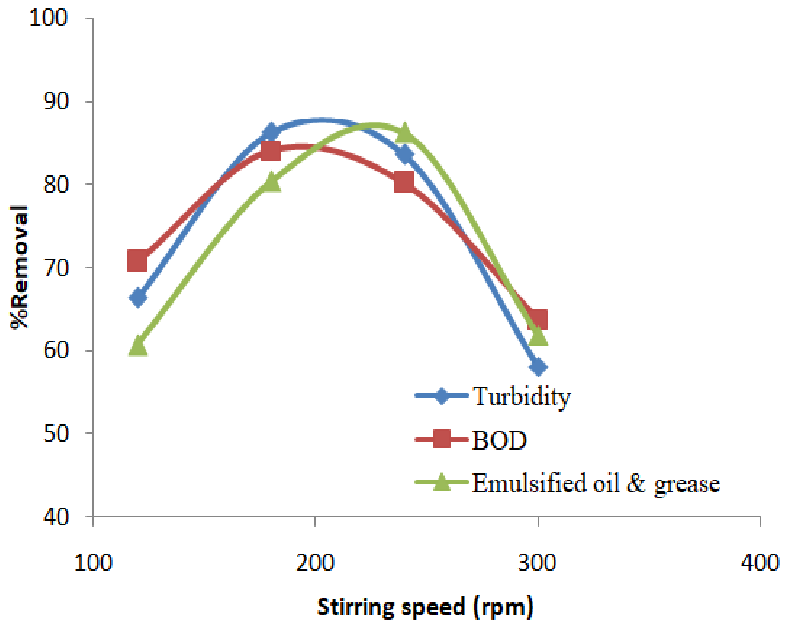



**Figure 7.** Effect of stirring speed on pollutant removal

3.6. *Effect of inter electrode distance*: The inter electrode distance is an essential factor in the electrocoagulation process for the removal of pollutants. As it controls the electrostatic field between the electrodes, the gap that is formed between the anode and cathode is important. Electrostatic force is higher at close distances between electrodes. When there is the maximum distance between the electrodes, the electrostatic force is minimal. Electrocoagulation efficiency is significantly decreased when electrode spacing is beyond the optimal range [21][22]. In order to investigate the impact of inter electrode distance on pollutant removal; the remaining operating parameters are kept constant. The constant values of remaining operating parameters are electrolysis time: 40 min; applied voltage: 6 V; pH: 6.5; conductivity: 3.0 ms/cm, stirring speed: 200 rpm. The highest pollutant removal rate is observed at an inter electrode distance of 1.5 cm.

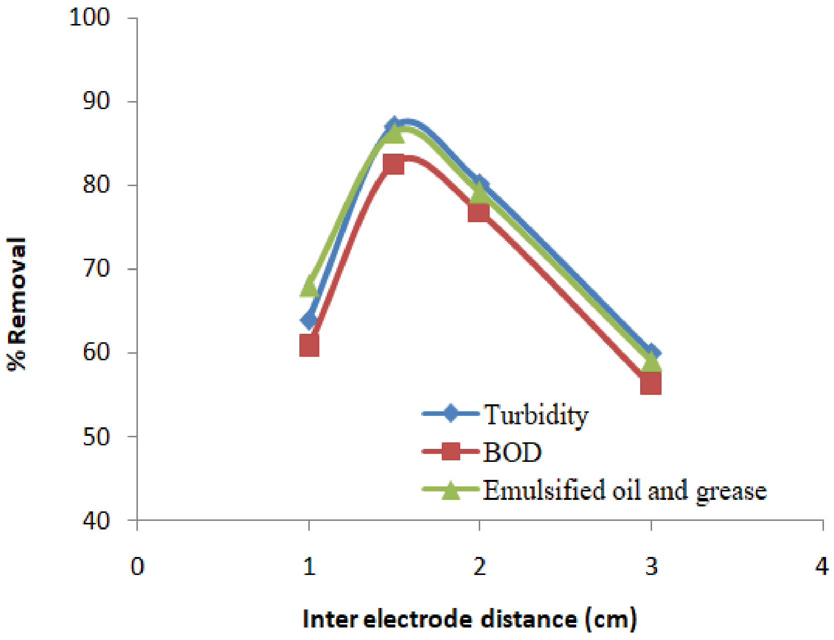



**Figure 8.** Effect of inter electrode distance on pollutant removal

## 4. Conclusions

The operational parameter values where the highest removal efficiencies were obtained in one factor experimentation are regarded as the optimum values.

- The maximum turbidity removal is obtained at electrolysis time of 120 min, applied voltage of 12 V, pH 7.12, conductivity of 3.5 mS/cm, stirring speed of 180 rpm and inter electrode distance of 1.5 cm.
- The maximum BOD removal is obtained at electrolysis time of 120 min, applied voltage of 12 V, 7.12 pH, conductivity of 3.5 mS/cm, stirring speed of 180 rpm and inter electrode distance of 1.5 cm.
- The maximum emulsified oil & grease removal is obtained at electrolysis time of 120 min, applied voltage of 12 V, pH 7.12, conductivity of 3.5 mS/cm, stirring speed of 240 rpm and inter electrode distance of 1.5 cm.

These results illustrated the technical feasibility of electrocoagulation using aluminum electrodes as a reliable, safe, convenient and efficient route for the removal of pollutants from dairy wastewaters.

## 5. Acknowledgements

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