Journal of Environmental Management 146 (2014) 245–250

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

# Continuous electrocoagulation of cheese whey wastewater: An application of Response Surface Methodology

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A R T I C L E I N F O

*Article history:*
Received 12 February 2014
Received in revised form
7 August 2014
Accepted 11 August 2014
Available online

*Keywords:*
Whey wastewater
Response Surface Methodology
Electrocoagulation
Iron electrode

A B S T R A C T

In this study, treatment of cheese whey wastewater was performed using a uniquely-designed continuous electrocoagulation reactor, not previously encountered in the literature. An iron horizontal rotating screw type anode was used in the continuous mode. An empirical model, in terms of effective operational factors, such as current density (40, 50, 60 mA/cm$^2$), pH (3, 5, 7) and retention time (20, 40, 60 min), was developed through Response Surface Methodology. An optimal region characterized by low values of Chemical Oxygen Demand (COD) was determined. As a result of experiments, a linear effect in the removal efficiency of COD was obtained for current density and retention time, while the initial pH of the wastewater was found to have a quadratic effect in the removal efficiency of COD. The best fit nonlinear mathematical model, with a coefficient of determination value ($R^2$) of 85%, was defined. An initial COD concentration of 15.500 mg/L was reduced to 2112 mg/L with a removal efficiency of 86.4%. In conclusion, it can be said that electrocoagulation was successfully applied for the treatment of cheese whey wastewater.



## 1. Introduction

Whey is the liquid remaining after the recovery of curds formed during cheese production. It contains 80–90% of the total volume of milk used in the cheese-making process. Whey can be processed and reused for animal feed or for human consumption. In small dairies which produce cheese, whey reuse is not practicable and this whey is discharged as waste along with the rest of their wastewater. The disposal of whey produced during cheese production has always been a major problem because of organic material in the dairy industry (Kandemir, 2011).

Laboratory and pilot scale experiments for the treatment of dairy wastewater have been comprehensively studied under anaerobic (Banu et al., 2008; Luostarinen and Rintala, 2005; Leal et al., 2006; Schneider and Topalova, 2011) and aerobic (Carta-Escobar et al., 2005; Seesuriyachan et al., 2009; Tocchi et al., 2012) conditions. Electrocoagulation is an alternative wastewater treatment technology. In the electrocoagulation process, characterized by its simple equipment, easy operation and low levels of sludge, the coagulant is dissolved from the anode with a simultaneous formation of hydroxyl ions and hydrogen gas occurring at the cathode (Tezcan Un and Aytac, 2013).

The treatment of dairy wastewater by electrocoagulation is studied in the literature. Şengil and Ozacar investigated the treatment of dairy wastewater using an iron parallel plate electrode (Sengil and Ozacar, 2006). Tchamango et al. treated synthetically prepared dairy wastewater using a parallel aluminium anode (Tchamango et al., 2010). Bensadok et al. treated artificial wastewater obtained from milk powder using two parallel plate aluminium and platinized titanium electrodes (Ti/Pt) (Bensadok et al., 2011). Kushwaha et al. also treated artificial dairy wastewater using two parallel aluminium plates (Kushwaha et al., 2011) and four parallel iron electrodes (Kushwaha et al., 2010). Tezcan Un and Ozel (2013) studied the electrocoagulation of strained (condensed) yogurt industry wastewater using a rectangular iron cathode compartment and parallel plate anodes.

Although the electrocoagulation of dairy wastewater has been utilized by various researchers, only Guven et al. have studied the electrocoagulation of cheese whey wastewater in the literature (Guven et al., 2008). They prepared whey wastewater synthetically using whey powder. Six parallel plate electrodes were used as anodes and cathodes in batch runs. The electrochemical treatment

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http://dx.doi.org/10.1016/j.jenvman.2014.08.006
0301-4797/

conditions were optimized through Response Surface Methodology (RSM) combining three factors; waste concentration, applied voltage and electrolyte concentration. The highest COD removal efficiency was found to be 53.32% after 8 h of electrocoagulation.

As seen from the reports mentioned, electrocoagulation studies have failed to examine the use of monotype reactors, since the configuration of parallel plate electrodes have been intensively studied in the field of electrocoagulation. In this study, real cheese whey wastewater was treated using a uniquely-designed continuous electrocoagulation reactor, not previously encountered in the literature. An empirical model, in terms of effective operational factors, such as current density, pH and retention time was developed through Response Surface Methodology, and an optimization of operational conditions was conducted.

## 2. Materials and methods

### 2.1. Wastewater

Cheese whey wastewater used in the experiments was obtained from a small production facility located in Eskisehir, Turkey. This small plant produces white cheese. In the process, the cheese whey was separated from the cheese curds using coarse screening. Then this cheese whey was mixed with process water before entering the treatment plant and our samples were collected from this mixing point. The cheese whey wastewater had a Chemical Oxygen Demand (COD) of 15.500 mg/L, conductivity of 17.00 mS/cm and a pH of 5.2.

### 2.2. Experimental details

A uniquely-designed continuous electrocoagulation reactor was developed. The horizontal rotating screw type iron anode and U-shaped iron cathode were used for the treatment of cheese whey wastewater, which to date, has not been encountered for electrocoagulation in the literature. The iron cathode was U-shaped, 50 cm in length, 7.0 cm high and 4.5 cm width. The screw type anode had a horizontal rotating shaft and impellers with a surface area of 100 $cm^2$. The horizontal screw type anode was placed 1 cm above the cathode bottom and submerged into the wastewater. The performance of the reactor, operated under a continuous system, was evaluated using an experimental set-up which is shown in Fig. 1.

Cheese whey wastewater was fed into the reactor which has 1000 mL of working volume by a peristaltic pump (Heidolph Model No: 5001) with the feeding rates of 16.7, 25 and 50 mL/min corresponding to the retention time of 60 min, 40 min and 20 min, respectively. The pH and the conductivity were monitored during electrocoagulation using a pH-meter (Hanna Ins. 301) and a conductivity meter (Radiometer Pioneer 30). The samples were taken periodically at the effluent port and centrifuged (Hettich EBA 20). The supernatant was analyzed for the determination of COD concentration by a titrimetric method after digestion of the sample by a COD Digestion Reagent (Hach). After the experiments, the electrodes were polished, washed with dilute $H_2SO_4$ and then rinsed with distilled water before each run.

### 2.3. Response Surface Methodology (RSM)

Response Surface Methodology is a collection of mathematical and statistical techniques, commonly used for improving and optimizing processes (Gengec et al., 2012). In this study, the response surface method is used for designing the experiments and evaluating the COD concentrations in the treated whey wastewater by three factors with two levels and three center points. Fifteen experiments were performed randomly according to Box Behnken Design Factors used in the RSM, namely current density, initial pH of wastewater and retention time. The factors were coded as (−1) representing the lower levels, (0) indicating center points and (+1) showing the upper levels as seen in Table 1. The aim of the experimental design and analysis was to define the effective factors, and to select the levels which give the maximum COD removal efficiency. The results were analyzed using MINITAB 14.0 packaged software.

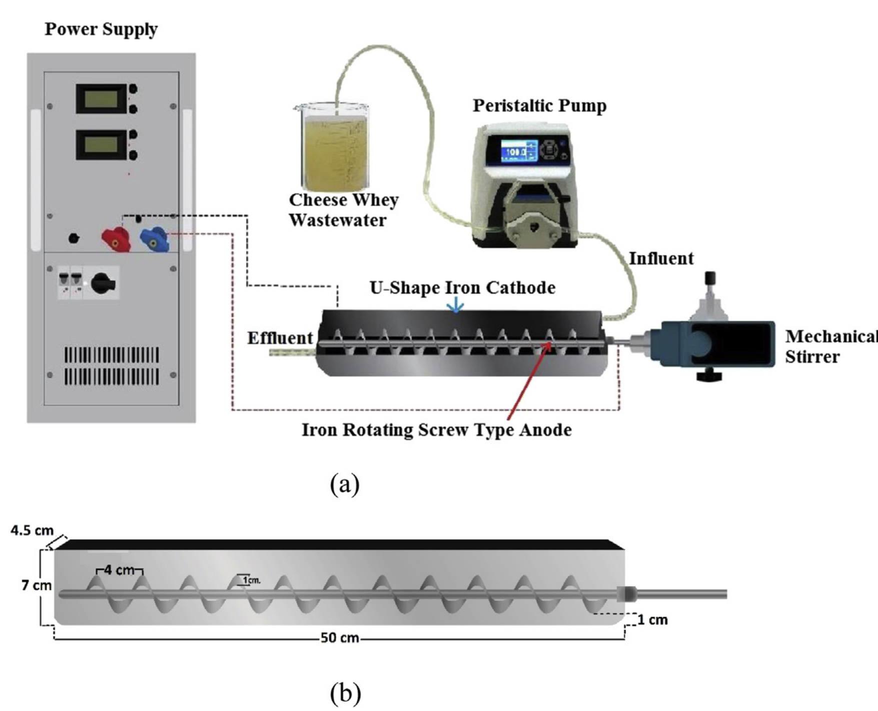


Fig. 1. (a) Schematic diagram of the experimental set-up, (b) Electrochemical reactor.