

**Research Article**

Treatment of fruit juice concentrate wastewater by electrocoagulation: Optimization of COD removal

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ABSTRACT

Depending on the growing population and the developing industry, wastewater is encountered with different characteristics and higher temperatures each passing day. For this reason, researches are under way for new treatment methods that will respond to needs in terms of cost and remediation. In this study, treatment of fruit juice concentrate wastewater has been examined by electrocoagulation (EC). For this purpose, the optimum conditions for the best COD removal were investigated. In the EC process, different electrodes (aluminum, iron and steel), pH (5.5, 7, 8 and 9) and current (0.6, 0.8 and 1.0 A) were studied, respectively. The results showed that the optimum COD and color removal were obtained as 66%, 98% respectively when the applied electrode pair were Al(+)/Fe(-), cell current was 0,8A and wastewater pH was 5.5 in 10 min. Also, the operating cost was calculated for the optimized treatment conditions of 1 m³ fruit juice wastewater as 2.69 US\$.

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1. Introduction

High amount of water is used in the juice industry thus it produces a high amount of wastewater [1]. These wastewater contain high concentrations of organics due to usage of fruits or sugar [2]. The typical juice industry produces 10 L wastewater per liter of juice. A wide range of fruits are used to manufacture juice. These include apple, apricot, rosehip, peach, cherry, oranges. So far, conventional treatment methods such as aerobic and anaerobic [3-5], combination of biological and chemical processes [6], membrane filtration [7], proton exchange membrane fuel cell [8], membrane bioreactor [9] have been applied for fruit juice wastewater.

If it is considered that so many different fruits and more than one species of each fruit participate in production; it can be said that the wastewater contains chemicals in a very wide range of different structures. Also, it contains a lot of organic acids which were added as preservatives and additives during fruit juice production. Therefore, there is a need for alternative treatment methods that can treat different characteristic wastewaters.

Recent studies have shown that electrochemical techniques can provide a good opportunity to prevent and remedy pollution problems due to strict environmental regulations. The use of electrochemical technologies for the treatment of organic pollutants contained in industrial wastewaters has received a great deal of attention in recent years [10]. Electrocoagulation (EC) is an emerging technology that combines the functions and advantages of conventional coagulation, flotation, and adsorption in wastewater treatment [11]. Studies show successful results in treatment of textile wastewater [12-14], food and protein wastewater [15], landfill leachate wastewater [16], pulp and paper mill wastewater [17,18], arsenic in wastewater [19], pesticides in wastewater [20], tannery wastewater [21], oil refinery wastewater [22] by electrocoagulation process. According to literature, the EC process can be put forward as an advanced treatment method because of its efficiency, low energy requirement, and lower and more stable sludge production compared with conventional treatment methods [23].

The objective of this research was treatment of an actual industrial wastewater by electrocoagulation and determine

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optimum operating conditions. Also, cost efficiency was calculated based on parameters such as electrode mass loss, voltage, current etc. and obtained results were compared with the conventional treatment methods in the literature.

2. Materials and methods

2.1 Wastewater characteristics

The studies were carried out on the treatment of fruit-juice concentrate production wastewater with a low (1920 mg/L) COD content for this kind of industries. The wastewater used in this study was collected from a fruit juice factory which located in Mersin, Turkey. The wastewater characteristics are listed in Table 1.

Table 1. Wastewater characteristics

Parameter	Unit	Value
pH	-	5.53
Alkalinity	mg CaCO ₃ /L	46
Color	Pt-Co	290
Conductivity	μS/cm	817
TN	mg/L	10.06
COD	mg/L	1920
TS	mg/L	2976
VS	mg/L	1666.60
TSS	mg/L	1334.10
VSS	mg/L	452.0

2.2. Chemicals and analytical method

Sodium hydroxide (NaOH; 98%) and sulphuric acid (H₂SO₄; 98%) used in the experiments were obtained from Merck. In addition, NaCl was used to adjust the conductivity value in the EC experiments. The pH value of the samples was adjusted with the WTW Multi 340i portable multiparameter meter. Velpa Multi Position magnetic stirrer was used for the EC experiments. AA Tech ADC 3303D power supply was used as the current and voltage regulating source and iron, aluminium, steel electrodes were used to perform the electrocoagulation experiments. A Hettich EBA 20 centrifuge (6000 rpm, 5 min) was used to separate the sludge from the samples at the end of the EC experiments. The Hach Lange DR 3900 VIS spectrophotometer was used for the colour removal analysis of the EC experiments. All the chemical analyses were carried out in accordance with the Standard Methods for Examination of Water and Wastewater [24].

2.3. Electrocoagulation (EC) experiments

In order to determine the maximum removal efficiency of COD in EC process, various parameters such as pH (5.5, 7-8-9), current (0.6-0.8-1.0 A) and electrode combinations (aluminium, iron and steel) were investigated in different

time intervals (10-20-30-40-50-60 min). Each experiment was carried out in a 1000 mL glass reactor and 800 mL of wastewater was used for the experiments. The reactor contains two electrodes of the same dimensions of 60 mm x 90 mm; one anode and one cathode electrode. The total effective anode electrode area was 54 cm², and the distance between electrodes was 2 cm for the each EC reactor. All the experiments were repeated twice and the average values have been reported. The experimental setup is shown in Figure 1.

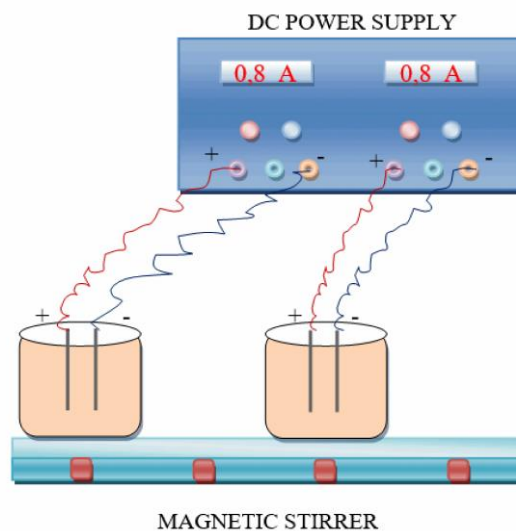


Figure 1. The experimental setup

3. Results and discussion

3.1 Optimum electrode determination

In the first stage of the EC process, the electrode pair that provides the best COD removal was determined. For this purpose, different electrode combinations such as Fe(+)/Al(-), Fe(+)/St(-), Al(+)/Al(-), Al(+)/St(-), Fe(+)/Fe(-), Al(+)/Fe(-) were investigated by keeping pH (5.5), conductivity (2000 μS/cm) and current (0.8 A) constant. The best COD removal was achieved with a pair of Al(+)/Fe(-) electrodes at a rate of 66% in 10 min. Therefore, the next experimental step was continued with this electrode pair. The effect of electrode pairs on COD removal is presented in Figure 2.

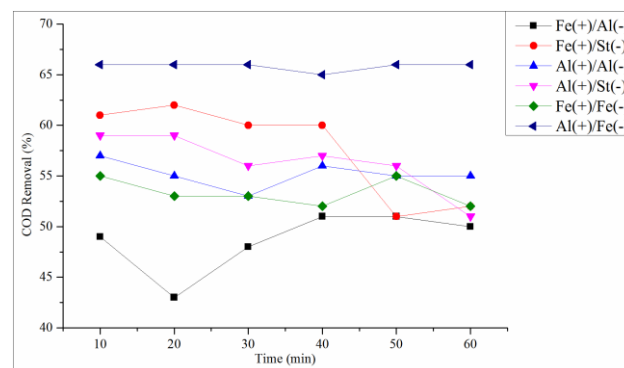


Figure 2. The effect of electrode pairs on COD removal

3.2 Effect of pH

pH is an important operating factor affecting the performance of the EC process also the pH of the medium is constantly changing during the wastewater treatment. In some studies, the desired yield is obtained at a wide pH range and no initial pH regulation is needed in the system [25]. In this study, neutral and basic pH values such as 7, 8 and 9 have also been examined for the reason that the present wastewater sample is already at acidic pH (5.5). Initial pH values were adjusted with 0.1 M H₂SO₄ and 0.1 M NaOH solutions. Conductivity was set to 2000 μ S/cm and the power supply is operated at 0.8A. It has been determined that the best COD removal (66%) occurs at the original pH of the wastewater in acidic conditions in 10 min. Can (2014) also found a similar result for this kind of wastewater. The researcher reported that removal efficiency reached the highest value (52%) at pH 6 in 60 min[26]. The effect of initial pH value on COD removal is given in Figure 3.

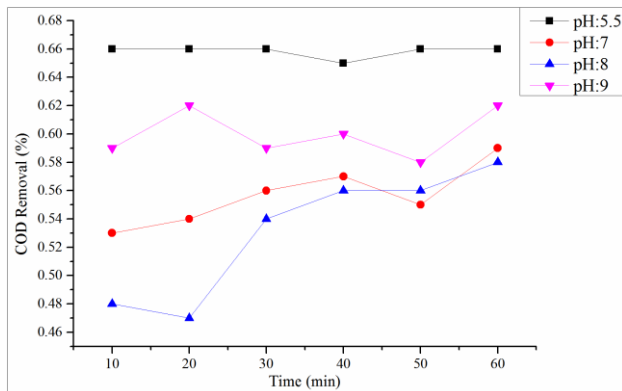


Figure 3. The effect of initial pH value on COD removal

3.3 Effect of current on electrocoagulation

The amount of current density affects the production rate of metal ions dissolving in the anode, the bubble velocity and the size of the cathode. Accordingly, the quantity, structure and formation of the flocks are also affected. Also, the current density should be checked to avoid excessive oxygen and possible temperature increase [27]. Because of the formation of small bubbles at low current densities, sedimentation is more dominant than flocculation in the removal of contaminants [28].

Experiments were carried out at 0.6 A, 0.8 A and 1.0 A in the study. Conductivity was set to 2000 μ S/cm and the pH was 5.5. It has been determined that the best COD removal (66%) occurs at the 0.8 A in 10 min. The effect of current on COD removal is given in Figure 4.

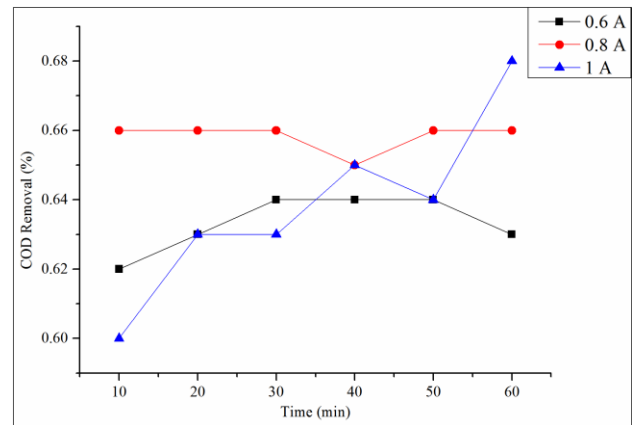


Figure 4. The effect of current on COD removal

3.4 Operating cost

The operating cost includes electrode cost, electrical energy cost, labor, maintenance and etc. In this study, energy and electrode material costs are taken into account as major cost items, in the calculation of the operating cost as kWh per m³ wastewater of COD removed. The calculations were made by using Equation (1);

$$\text{Operating cost} = a * C_{\text{energy}} + b * C_{\text{electrode}} \quad (1)$$

Where C_{energy} and $C_{\text{electrode}}$, are consumption quantities per kg of COD removed, which are obtained experimentally. Unit prices, a and b, given for Turkey Market, September 2017, are as follows:

(a) electrical energy price 0.06 US\$/kWh.

(b) electrode material price 4.57 US\$/kg for aluminium (anode)

Cost calculations showed that, in the case of aluminium electrode, operating cost is approximately 2.69 US\$ per kg COD removed.

4. Conclusion

In this study, it has been tried to treat fruit juice wastewater by advanced treatment methods. Experiments were carried out using electrocoagulation process as the advanced treatment method. Chemical oxygen demand and colour were used as optimization parameters. Various operating parameters, such as current density, initial pH, and electrode type were evaluated to define optimum conditions.

According to the obtained results; the most efficient combination was found as Al/Fe electrodes for removing COD and colour. The Optimum COD and colour removal were obtained as 66%, 98% respectively when reaction time was 10 minutes, cell current was 0.8 A and wastewater pH was 5.5. In experiments performed for electrode optimization, the increase in the time seemed to have no effect on removal efficiency. When we compared the results of 10th and 60th minutes, removal efficiencies were either stable or decreased. Meanwhile in the pH optimization studies, it has been determined that the best recovery

efficiency is at the original pH of the water. It has been found that the recovery efficiency increases as the current increases. Although the recovery efficiencies are close to each other, the cost is taken into consider and thus 0.8 A is used for optimization. The cost of treating 1 m³ fruit juice wastewater is calculated as 2.69 US\$.

When all these studies are examined, we have come to the conclusion that electrocoagulation can provide much more preliminary treatment than the final treatment of wastewater plants.

Nomenclature

A	: Ampere
Al	: Aluminium
COD	: Chemical Oxygen Demand
EC	: Electrocoagulation
Fe	: Iron
St	: Stainless Steel
TN	: Total Nitrogen
TS	: Total Solids
TSS	: Total Suspended Solids
VS	: Volatile Solids
VSS	: Volatile Suspended Solids

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