Determination of the Optimum Conditions for the Electrocoagulation of Olive Oil Mills Wastewater (OMW) Using Aluminum Electrodes

Nofa Jomaa and Yasser Houriehb*

a Faculty of Civil Engineering, Department of Environmental Engineering, AL-Baath Univ., Homs, Syria.
b Faculty of Chemical and Petroleum Engineering, AL-Baath Univ., Homs, Syria.

Received on Dec. 6, 2010 Accepted on Aug 22, 2010

Abstract

The effective performance of electrocoagulation (EC) technique in the treatment of olive mill wastewater (OMW) has been investigated using aluminum electrodes. The electrocoagulation progress was followed by the measurement of COD, turbidity, color, suspended solids, pH, height of liquor, TDS, electric conductivity, electrode and energy consumption, temperature and the quantity of electricity used. The effects of operating parameters such as current density, initial pH, electrolysis time, and distance between electrodes (D), on COD removal efficiency have been investigated. It has been shown that the removal efficiency of COD increased with the increasing applied current density and coagulation time. The obtained results of treatment of OMW, showed that the effectiveness of the reduction of COD and color by electrocoagulation increased with time and D at a constant current density (i=23.55 mA/cm²), the effectiveness of treatment was also increased with decreasing D at a constant voltage (U=15 Volt). It was Found during the evaluation of results obtained in both cases that the optimal distance between the electrodes is D=1.5 cm, and the optimal time of treatment is t=30 min, and the best current intensity is I=4 A, equivalent to a current density i=31.25 mA/cm² when S_{total electrode}=128 cm². Under these conditions the removal efficiency of COD, dark color, TSS, turbidity, TOC, Phenol, Tannin and lignin, Volatile acids, TIC, and TNb are 22.67, 56.1, 80, 91.31, 28.5, 11.5, 24.32, 26.7, 100 and 100 % from olive mill wastewater respectively. The BOD₅ treated/BOD₅ raw ratio of the electrocoagulated OMW increased to 2. The electrodes consumption was 0.168 kg Al/kg COD_{removed} and the specific energy consumed was 3.59 kWh/kg COD_{removed}.

Keywords: Olive mill wastewater; Electrocoagulation; Aluminum electrode; Water treatment.

Abbreviations: BOD₅, biological oxygen demand; COD, chemical oxygen; demand; EC, electrocoagulation; OMW, olive mill wastewater; TSS, total suspended solids; TOC, total organic carbon.

Introduction

The olive mill industry, which is one of the most traditional agricultural industries in Syria, produces a lot of liquid waste. From the traditional pressing processes, which are operated discontinuously, about 400 l of liquid waste are produced per tonne of
processed olives, while the new three-phase decanting method produces about 750 L of wastewater per tonne of processed olives. The quality and quantity of the constituents in olive oil wastewater are influenced by the type of production process, the type of olives and stage of maturity, the nature of the area under cultivation, use of pesticides and fertilizers, climatic conditions, and harvest time [1, 2, 3, 4].

The great variety of components found in liquid waste (carbohydrates, polysaccharides, fatty oils and polyphenols) makes their disposal difficult in a traditional biological plant.

A volume of $3 \times 10^7$ m$^3$ of OMW per year is generated by the olive oil industry in the Mediterranean area. OMW is a dark colored, mildly acidic liquid. The main toxicity of this effluent is related to its phenolic constituents, with a concentration that may vary from 1.5 g/L up to 10 g/L. Another relevant problem of this effluent is its strong dark color, which is mainly due to chromophoric lignin-related materials with different degrees of polymerization. Because of the high organic and polyphenol content of OMW, its direct disposal may pollute both land and aquatic environments. Antibacterial activity, inhibition of seed germination, and phytotoxicity to herbage crops by OMW have all been demonstrated. OMW contains heavy metal contaminants and its application to soil of low organic matter content, abundant in the Mediterranean basin, would be a sustainable recycling option, if its toxicity to microorganisms and plants was first eliminated. The phytotoxicity of OMW is due to the phenolic substances and some organic acids such as acetic and formic acids. The inorganic constituents at the concentration levels found in OMW are not toxic. In fact, it has been proven that they may potentially act as good sources of plant nutrients [5, 6].

Electrocoagulation (EC) of Olive Oil Mill Wastewater:

Electrocoagulation has been performed at constant and variable currents in an electrocoagulation cell using a dimensionally-stable aluminum anode [4, 7, 8, 9, 10, 11].

In the EC process, electrochemically generated aluminum can remove most contaminants present in OMW by precipitation and adsorption [12, 13, 14]. Through the process of electrolysis, coagulating agents such as metal hydroxides are produced [9, 10, 4]. The aluminum species acts as a coagulant by combining with the pollutants to form large size flocks and can then be removed by settling and flotation (electrocoagulation/flotation process) [13, 15, 14, 11, 16].

This method has numerous benefits, including: the use of electric power, allowing the generation of small gas bubbles (resulting from the electrolysis of water) and the exclusion of sludge formed through the flotation. The method includes several processes: oxidation, sterilization, and coagulation [17, 18, 4]. In this process, wastewater flows in the reactor which is designed in particular for the treatment of the OMW by electrodes connected to a direct current power. Electrocoagulation technology can be applied to most types of wastewater, but is particularly appropriate in the case of low volume, because it requires less capital investment than traditional methods; the
treatment is faster; does not require the addition of chemicals (except for the addition of salt in some specific cases)\textsuperscript{[18]}; does not require large infrastructure; can increase the capacity of processing and the reduction of many pollutants in some cases, in addition to the recycling of treated water\textsuperscript{[16, 19]}. Electrocoagulation (EC) as an electrochemical method was developed to overcome the drawbacks of conventional water and wastewater treatment technologies. In EC, aluminum or iron hydroxide flocks which destabilize and aggregate the suspended particles or precipitates and absorb dissolved contaminants. In a recent study, Nafa’a Adhoum et al.\textsuperscript{[20]} investigated decolourization and removal of phenolic compounds from olive mill wastewater by electrocoagulation. The optimum current density allowing the quickest treatment with a low cost was found to be $75 \text{ mA cm}^{-2}$, and the electrode consumption was found to be $2.11 \text{ kg m}^{-3}$. The electrocoagulation has successfully been used for the treatment of wastewaters including paper mill effluents wastewaters\textsuperscript{[4]}, cutting oil emulsions oil suspensions wastewaters\textsuperscript{[8]}, defluoridation of semiconductor wastewater\textsuperscript{[11]}, textile wastewaters\textsuperscript{[12]}, oil suspensions wastewaters\textsuperscript{[17]}, poultry slaughterhouse wastewaters\textsuperscript{[19]}, and also of drinking water\textsuperscript{[21]}. Treatment of oil refinery wastewater at a fixed current density using Ti/TiO$_2$-RuO$_2$-IrO$_2$ electrode and an undivided reactor was studied by Rajkumar and Palanivelu\textsuperscript{[22]}. The initial COD value of 602 mg/L was reduced to 152 mg/L with an energy consumption of 235.3 kWh/kg after 20 Ah/L of charge input. Waste from noncyanide stripper, a toxic liquid associated with the production of olive oil, was treated by an electrochemical method using Ti/Pt as anode and stainless steel 304 as cathode by Vlyssides et al.\textsuperscript{[23]}. After 1 and 10 h of electrolysis total COD was reduced by 41 and 93 %, respectively, total organic carbon was reduced by 20 and 80.4 %, and colors were reduced by 70 and 99.4 %. Mean energy consumption was 1.273 kWh/kg of COD reduced and 12.3 kWh/kg of COD reduced for 1 and 10 h, respectively.

Electrocoagulation is based on the fact that the stability of colloids, suspensions and emulsions is influenced by electric charges. Therefore, if additional electric charges are supplied to the charged particles via appropriate electrodes, the surface charge of the particles is neutralized and several particles combine into larger and separable agglomerates\textsuperscript{[24]}.

The objective of the present study was to assess the electrocoagulation treatment of OMW using aluminum electrode. The effect of three operational parameters namely electrolysis time, current density ($i, \text{ A m}^{-2}$), distance between the electrodes ($D, \text{ cm}$), have been examined on COD, TOC, energy consumption, electrode consumption, and dark color removal efficiency.

**Experimental Setup**

*Reagents and analytical procedures:*

Fresh olive mill wastewater was collected from a local olive extraction plant which uses a traditional process. OMW was collected in a closed plastic container at
10 °C. The main characteristics of fresh olive mill wastewater used in this work are presented in (table 1). Analysis of COD was determined by the procedure described in the standard method [21]. Analysis of TOC was determined by Liqui TOC Elementar equipment. The total solid content was measured by drying a 100 ml aliquot of OMW at 105 °C until a constant mass was obtained. The dark color intensity was determined by measuring the sample absorbance at 455 nm (UV-Vis spectrophotometer, DR-5000). The TSS was determined by measuring the sample absorbance at 810 nm (DR-5000). The turbidity was determined by measuring the sample absorbance at 695 nm (DR-5000). A digital calibrated pH-meter (Inolab pH Level 2) and a conductivity-meter (Hach Conductivity/TDS Meter) were used to measure the pH and the conductivity of the OMW wastewater samples.

Electrocoagulation procedure

The electrochemical cell has two aluminum plates, one serving as a cathode and the other as anode (Figure 1). The total effective electrode area was 96 cm² (8 cm×6 cm×2 faces). The electrodes were fixed in the cell at a distance of 2 cm between the bottom of the electrodes and the bottom of the cell which allowed easy stirring. The electrodes were connected to a digital DC power supply (5 A, 20 V). For each run, 1000 cm³ of 100 % (v/v) of OMW were placed into the electrolytic cell and a gentle stirring rate of about 200 rpm (revolutions per minute) was applied to allow the chemical precipitate to grow large enough for removal (the dimensions of stirring bar were 6 mm×15 mm). The samples were centrifuged at 3000 rpm (Labofuge 200 Heraeus Sepatech) for 5 min before being used for analysis.

**Figure 1:** Electrolytic cell.

Results and discussion:

Determination of optimum distance between the electrodes:

Determination of optimum distance between the electrodes depending on the variations of COD removed:

Figure 2 shows the variations of COD with the distance between the electrodes in two cases: (1) constant current intensity at variable voltage, (2) variable current
intensity and constant voltage). The curves show a decrease in the COD conversion with the increase in D at (U=15 V), and a decrease in COD conversion with decrease D at (I= constant). The two types of curves intersect when t = 10- 20- 30- 45- 60 min at: D_{opt} = 1.45-1.65-1.85-1.48-1.75 cm. and COD Conversion equal to 9.12-11.21-13.87-17.78-21.97 % respectively.

When the inter-electrode distance D was 1.0 cm, the removal efficiency of COD reached 32 % after 60 min reaction, while it was only 12 % when the distance was 6.0 cm. These results could be explained by the effectiveness of floatation by gas bubbles generated at the electrodes.

**Figure 2**: Effect of D on COD conversion at constant current or voltage

**Determination of optimum D depending on electrode consumption**:

Figure 3 shows the practical and theoretical consumption of the electrode at constant current (I = 3 A) and constant voltage (U=15 V). It is clear that the two curves are crossing at D = 2.2 and 2.4 cm, respectively, and these are the optimum values. Moreover, figure 4 shows that the curves intersect at 2>D>1 cm and D≤1 cm at constant current (I = 3A) and constant voltage (U = 15 Volt), respectively.

**Figure 3**: Effect of D on electrode consumption at (I = 3 A) or (U=15 V).
Figure 4: Effect D on electrode consumption for one unit of COD removed

**Evaluation of the specific consumption of electrode** $m_{Al}$ (kg Al/m³):

As mentioned above, (figure 4) shows the variations of specific consumption of electrode with D in two cases (constant current intensity and variable voltages, and constant voltage and variable current intensities) and it shows that the electrode consumption is almost constant at 60 min for different D values with constant current intensity 3A. The theoretical consumption of electrodes was calculated by faraday’s law, $m_{Al} = \frac{M_{Al} \times I \times t \times 3600}{Z \times F}$ where M= the atomic mass of the Al, I the current intensity, t the time of treatment, the charge number Z and F faraday’s constant.

As mentioned in the theoretical part, the treatment efficiency should increase with increasing specific consumption of electrode, which is practically constant at $I = 3$ A. Therefore, are expects this efficiency to be constant. Therefore, the observed increase of efficiency must be due to another factor which we believe is the temperature rise due to the increase U, and increase in collision frequency between the pollutants and the hydroxyl polymer.

Therefore, the simple increase of COD conversion with increasing D at $I = 3$ A is unwanted because of large energy consumption. At the same time, the consumption of aluminum has decreased at a constant voltage with increasing D due to the decline of I.

**Evaluation of the specific consumption of electrical power** $W_{sp}$:

(Figure 5) Shows that $W_{sp}$ increases with increasing D at $I = 3$A and decreasing D at U = 15 V. Comparison of the curves, shows that the curve which represents the variation of $W_{sp}$ by the time, at ($I = 3$A & U = 7.4 Volt & D = 1cm), corresponds exactly to the curve which represents the variation of $W_{sp}$ with time, at (U = 15 Volt & $I = 1.5$A & D = 6 cm). However, the COD conversion in the first case ranged between (7.38 - 19.69 %), whereas in second case it ranged between (4.45 - 10.89 %) when ($t = 10 - 60$ min) respectively.
We conclude that the treatment must be at high current intensity and low voltage, and at low D values which result in increased effectiveness of treatment, low power consumption and economical viability.

The electrical energy consumed, expressed as kWh per m$^3$ of the wastewater treated was calculated using the equation $EC = V \times I \times t / \text{volume of OMW}$. The COD concentration of 36.8 g L$^{-1}$ was reduced to 25.5 g L$^{-1}$ after 1 h of electrolysis. The removal efficiency was 30.58 % for energy consumption equal to 22 kWhm$^{-3}$.

![Figure 5: Change Wsp according to the time (I = 3A & U = 15 Volt)](image)

**Determination of optimum time**

**Determination of optimum time depending on the TOC and COD conversions**

The optimal time is the time which gives highest COD conversion value at lower electrical energy consumption. Normally, the energy consumption is doubled doubling time.

We have found that during the first 30 min, the conversion of TOC was 33.5 % and 42.4 % at D= 1 and 2 cm respectively. While this conversion was only 10.9 % and 10.7 % in the next 30 min. similar trend was observed for the conversion of COD. Therefore the optimal time is believed to be 30 min.

**Determination of optimum time depending on electrode and electrical energy consumption:**

Practically, the electrode consumption at I=3A, and D=1 cm was increased from 0.765 kg/m$^3$ during the first 30 min to 1.3503 kg/m$^3$ at t=60 min. The ratio of $m_{Al}$ (t=60 min)/$m_{Al}$ (t=30 min) is equal to 1.766. This means that the amount of consumption aluminum in the second thirty minutes is less than that in the first thirty minutes, which explains the reason of decreased COD conversion in the next thirty minutes.

Moreover, the electrical energy consumption at 60 min is double that at 30 min, whereas the COD conversion is not. This is why the optimal treatment time has been chosen as 30 min.
Electrocoagulation of OMW at variable current densities:

Electrocoagulation tests were performed on OMW at t=30 min, D=1cm, S=128 cm² with variable current intensities (I=1-2-3-4 A) and current densities: (i = 7.81 -15.63 - 23.44 - 31.25 mA/cm²) respectively. (Table 1) demonstrates the results of the increase in temperature differences of treated water compared with that of the raw sample at I=1, 2, 3, 4 A. It also shows the increase of the ratio the amount of Al kg / COD removed kg with increasing current density.

Crude OMW was highly colored due to its high content of polyaromatic compounds. At I=1, 2 A of the electrolytic treatment, the color intensity of the effluent increased. This could be explained by the oxidative polymerization of phenols and tannins originally present in the sample, which resulted in dark colored organic compounds [20]. However, color intensity decreased to 50 % of the initial value at 4 A.

Table 1: Effect of current density on electrocoagulation of OMW after 30 minutes

<table>
<thead>
<tr>
<th>parameter</th>
<th>OMW</th>
<th>I = 1</th>
<th>I = 2</th>
<th>I = 3</th>
<th>I = 4</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>∆Temp.</td>
<td>-</td>
<td>11</td>
<td>12</td>
<td>17</td>
<td>23</td>
<td>°C</td>
</tr>
<tr>
<td>Color ×100@455 nm</td>
<td>84</td>
<td>126</td>
<td>141</td>
<td>59</td>
<td>42</td>
<td>Pt Co</td>
</tr>
<tr>
<td>TSS</td>
<td>4.4</td>
<td>8</td>
<td>18.4</td>
<td>29.8</td>
<td>38.6</td>
<td>g/L</td>
</tr>
<tr>
<td>Turbidity×100@659 nm</td>
<td>149</td>
<td>312</td>
<td>714</td>
<td>1202</td>
<td>1245</td>
<td>FAU</td>
</tr>
<tr>
<td>COD</td>
<td>36.8</td>
<td>33.8</td>
<td>33.2</td>
<td>32</td>
<td>30</td>
<td>g/L</td>
</tr>
<tr>
<td>COD removed</td>
<td>3</td>
<td>3.6</td>
<td>4.8</td>
<td>6.4</td>
<td></td>
<td>g/L</td>
</tr>
<tr>
<td>Conv. COD</td>
<td>8.15</td>
<td>9.78</td>
<td>13.04</td>
<td>17.39</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>U</td>
<td>3.5</td>
<td>6.2</td>
<td>8.4</td>
<td>11.5</td>
<td></td>
<td>mL</td>
</tr>
<tr>
<td>i</td>
<td>7.8</td>
<td>15.63</td>
<td>23.4</td>
<td>31.25</td>
<td></td>
<td>mA/cm²</td>
</tr>
<tr>
<td>Wsp</td>
<td>1.75</td>
<td>6.2</td>
<td>12.6</td>
<td>23</td>
<td></td>
<td>kWh/m³</td>
</tr>
<tr>
<td>Wsp/COD removed</td>
<td>0.58</td>
<td>1.72</td>
<td>2.63</td>
<td>3.59</td>
<td></td>
<td>kWh/kg CODremoved</td>
</tr>
<tr>
<td>m Electrodes</td>
<td>0.248</td>
<td>0.485</td>
<td>0.765</td>
<td>1.074</td>
<td></td>
<td>kg/m³</td>
</tr>
<tr>
<td>mₚ Electrode/COD removed</td>
<td>0.08</td>
<td>0.135</td>
<td>0.159</td>
<td>0.168</td>
<td></td>
<td>Kg Al/kg CODremoved</td>
</tr>
</tbody>
</table>

EC OMW had a turbidity value of 312, 714, 1202, 1245 FAU, at I=1, 2, 3, 4 A respectively, which was higher than the initial value. It should be noted that turbidity depends on the amount of TSS and the presence of gas bubbles produced during the electrolysis process. Thus, an appropriate technique should be adopted for TSS and turbidity removal after electrolysis treatment. 80 % of TSS was removed after 10 min of centrifugation time at 3000 rpm for I = 4 A. The centrifugation step yielded the removal of 17.39 %, 50 % and 91 % of COD, color, and turbidity, respectively.

After electrocoagulation, the sedimentation step seems necessary to separate the suspended solids from the wastewater. For this reason, EC pre-treated OMW was allowed to stay in the settling column for 3 h. The behavior of both crude and EC OMW inside the settling column was observed through the analysis of collected samples.

Experimentation showed that small suspended particles appeared in wastewater which increased in number and size as the electrolytic treatment continued. Crude
OMW contained a smaller quantity of suspended solids (4.4 g L$^{-1}$) compared to EC OMW (38.6 g L$^{-1}$) for $I = 4$ A.

*Effect of current density on the removal efficiency of COD and electrical power consumption $W_{sp}$:*

Figure 6 and table 1 show that the removal efficiency of COD increased significantly with increasing current density, they also show the change of the specific energy consumption versus $i$ for Al electrodes during the EC expressed in kWh consumed per m$^3$ OMW. The minimum energy consumption and maximum COD removal were observed at ($i \approx 31.26$ mA/cm$^2$) for 30 min of electrolysis time.

![Figure 6: Effect of current density on energy consumption and COD conversion](image)

*Effect of current density on electrode and energy consumption:*

Figure 7 illustrates the effect of current density on electrode consumption expressed in kg of Al per kg of COD removed, and the effect of current density on energy consumption (kWh/kg COD$_{removed}$). As expected, the amount of aluminum oxidized increased with current density, resulting in a greater amount of precipitate for the removal of pollutants, and greater energy consumption kWh/grCOD$_{removed}$. The curves intersect at optimum $i$ ($i=31.25$ mA/cm$^2$ approximately).

![Figure 7: Effect of current density on electrode and energy consumption](image)
Since the best value of D was found to be between 1 and 2 cm, the optimum value was chosen 1.5 cm. Table 2 summarizes the qualities of OMW before and after treatment under optimum conditions.

**Table 2: specifications of the sample before and after treatment**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>OMW raw</th>
<th>ECOMW</th>
<th>unit</th>
<th>Abatement %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>22</td>
<td>46</td>
<td>C°</td>
<td>-</td>
</tr>
<tr>
<td>Color x100</td>
<td>82</td>
<td>36</td>
<td>Pt Co</td>
<td>56.1</td>
</tr>
<tr>
<td>TSS</td>
<td>2</td>
<td>0.4</td>
<td>g/L</td>
<td>80</td>
</tr>
<tr>
<td>pH</td>
<td>3.96</td>
<td>4.52</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Turbidity x100</td>
<td>25.9</td>
<td>2.25</td>
<td>FAU</td>
<td>91.31</td>
</tr>
<tr>
<td>COD&lt;sub&gt;raw&lt;/sub&gt;</td>
<td>34.4</td>
<td>30</td>
<td>g/L</td>
<td>12.79</td>
</tr>
<tr>
<td>COD&lt;sub&gt;cent&lt;/sub&gt;</td>
<td>32</td>
<td>26.6</td>
<td>g/L</td>
<td>22.67</td>
</tr>
<tr>
<td>TOC</td>
<td>9.15</td>
<td>6.54</td>
<td>g/L</td>
<td>28.5</td>
</tr>
<tr>
<td>BOD&lt;sub&gt;5&lt;/sub&gt;</td>
<td>10.5</td>
<td>20.5</td>
<td>g/L</td>
<td>-</td>
</tr>
<tr>
<td>BOD&lt;sub&gt;5&lt;/sub&gt; treat / COD</td>
<td>0.328</td>
<td>0.77</td>
<td>g/L</td>
<td>-</td>
</tr>
<tr>
<td>Cl</td>
<td>1020</td>
<td>570</td>
<td>mg Cl/L</td>
<td>44.12</td>
</tr>
<tr>
<td>PO&lt;sub&gt;4&lt;/sub&gt;³⁻</td>
<td>301</td>
<td>18</td>
<td>mg PO&lt;sub&gt;4&lt;/sub&gt;³⁻/L</td>
<td>94.02</td>
</tr>
<tr>
<td>NO&lt;sub&gt;3&lt;/sub&gt;⁻</td>
<td>50</td>
<td>40</td>
<td>mg NO&lt;sub&gt;3&lt;/sub&gt;⁻/L</td>
<td>20</td>
</tr>
<tr>
<td>NH&lt;sub&gt;3&lt;/sub&gt;-N</td>
<td>169</td>
<td>94</td>
<td>mg NH&lt;sub&gt;3&lt;/sub&gt;-N/L</td>
<td>44.38</td>
</tr>
<tr>
<td>Cu</td>
<td>4</td>
<td>2.5</td>
<td>mg Cu/L</td>
<td>37.5</td>
</tr>
<tr>
<td>phenol</td>
<td>44.3</td>
<td>39.2</td>
<td>mg/L</td>
<td>11.5</td>
</tr>
<tr>
<td>Tannin and lignin</td>
<td>1.85</td>
<td>1.4</td>
<td>g/L</td>
<td>24.32</td>
</tr>
<tr>
<td>Volatile acids</td>
<td>9</td>
<td>6.6</td>
<td>g/L</td>
<td>26.7</td>
</tr>
<tr>
<td>Dry residue</td>
<td>15.35</td>
<td>13.66</td>
<td>g/L</td>
<td>11</td>
</tr>
<tr>
<td>TS</td>
<td>6.75</td>
<td>5.47</td>
<td>g/L</td>
<td>18.96</td>
</tr>
<tr>
<td>TN&lt;sub&gt;b&lt;/sub&gt;</td>
<td>1178</td>
<td>0</td>
<td>mg/L</td>
<td>100</td>
</tr>
</tbody>
</table>

**Conclusion:**

This research has shown that electrocoagulation treatment achieves a fast and effective reduction of pollutants 22.67 % of COD, 56.1 % of dark color, 80 % of TSS, 91.31 % of turbidity, 28.5 % of TOC, 11.5 % of Phenol, 24.32 % of Tannin and lignin, 26.7 % of Volatile acids, 100 % of TIC and 100 % of TNb present in fresh olive mill wastewater.

The optimum value of current density was found to be 31.25 mA cm<sup>−2</sup>, and the electrode consumption to be 1.074 kg m<sup>−3</sup> of treated OMW. The optimum operating conditions were 30 min of treatment, 0.168 kg Al/kg COD<sub>removed</sub> and 3.95 kWh/kg COD<sub>removed</sub>. Biodegradability is measured according to the ratio between the biochemical oxygen demand BOD<sub>5</sub> and COD. As mentioned above, the soluble COD of OMW drops to approximately 22.67 % of the initial value, whereas, the BOD<sub>5</sub> value increased from 10.5 to 20.5 g L<sup>−1</sup>. Thus, BOD<sub>5</sub>/COD ratio increased from 0.33 TO 0.77
after treatment. It appears therefore that a significant proportion of the non-biodegradable matter present in OMW was removed by electrocoagulation. Consequently, electrocoagulation can be considered as a suitable alternative to existing methods or applied as pre-treatment step of biological and advanced oxidation processes used for the treatment of OMW.

Acknowledgment
The authors would like to thank Dr. Adnan Atfeh of IUST, for his help in rewriting this paper.

References