Treatment of various agro-industrial wastewaters using electrocoagulation

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Abstract
Greece, although not over-industrialized, faces issues connected to pollution of its water resources, as conventional wastewater treatment methods often proved ineffective at removing some pollutants such as suspended solids and pigments. Therefore, the need of developing efficient, modern anti-pollution techniques for the preservation of a viable environment is urgent as ever. Electrocoagulation (EC) is one of these widely studied, promising methods. EC consists of generating coagulant species by electrolytic dissolution of sacrificial anode materials triggered by electric current applied through the electrodes, leading to the removal of different pollutants.In the present study EC was studied for the treatment of various agro-industrial wastewaters (table olive, cheese whey and printing ink),examining its efficiency under a wide range of operating parameters (current density, initial pollutant concentration, pH, electrode material).According the results EC proved efficient in most of the experimental sets performed, achieving significant removal efficiencies of color and organic matter. Also,acost analysis of the process that was conducted to evaluate the economic feasibility of the process showed that EC can be a viable and realistic choice for agro-industrial wastewater treatment.
Keywords: agro-industrial wastewaters, electrocoagulation, color, suspended solids

1. Introduction

Pollution caused by untreated wastewater disposal is a serious environmental issue. Olive trees have been exploited not only for the extraction of high-valued olive oil but also for olive fruit, resulting in table olive processing wastewaters (TOPWs).TOPWs contain high levels of inorganic and organic substances and present usually dark brown in color (Papadaki et al., 2016).Dairy wastewaters (DWs) are produced during the different processes applied to raw milk for the production of yogurt, butter, cheese, etc. and are characterized by high organic matter content (chemical oxygen demand (COD)) (Kushwaha et al., 2011).Printing ink wastewater (PIW) is generated from the industrial equipment cleaning process in various printing enterprises. Printing ink wastewater contains non-biodegradable compounds, trace amounts of metals pigments and adhesives (Boguniewicz-Zabłocka and Capodaglio, 2016).

The above-mentioned intensively colored wastewaters are difficult to be treated by biological methods, while advanced oxidation processes and electrochemical techniques have been extensively developed and proposed for their treatment. Electrocoagulation (EC) is an alternative technology, which combines the functions and advantages of conventional chemical coagulation, flotation, and electrochemistry for the removal of various pollutants, holding several advantages such as simple apparatus operation, short processing times, no additional chemical requirements and colorless and odorless effluents.

2. Materials and Methods

Chemical Oxygen demand (COD) was determined by the closed reflux dichromate method according to the Standard Methods (APHA 2012) and color was measured photometrically.COD of the effluents used in the present study was determined at 3,000mg L^{-1} for TOPW (pH 5.5), 4,500mg L^{-1} for DW (pH 4.0)and 2,500mg $L^{-1}$for PIW (pH 7.0)

Experiments were conducted under batch operating mode. Reactor volume was 500 cm^3 and a magnetic stirrer was used to maintain homogenization in the wastewater's bulk volume. The temperature inside the electrolytic cell was 27-30°C and kept constant using a cooling jacket. The two plate electrodes used (placed in the middle of the reactor) were either both aluminum (Al) or both iron (Fe).The active surface of the anode electrode (as well as cathode) was kept constant at 12 cm^2. Inter-electrode distance was also kept constant at 0.3 cm.The electrodes were connected in monopolar parallel mode to a DC regulated power supply (model QJ3005C) that provided the desired current and voltage to the system. For all studied effluents, current density, initial pollutant concentration, pH and electrode material were examined, in order to be determined the optimal operating conditions. Samples were taken in various time intervals.

3. Results and Discussion

In the present study the optimum experimental conditions are presented.Concerning the TOPW, the percentage of COD removal reached up to80% and 90% for Fe and Al electrodes respectively. Concerning the color removal, complete decolorization was achieved for both examined electrode materials, with Al giving faster removal percentages compared to iron (Figure 1). García-García et al., (2011) also observed the same phenomenon in color removal when applying Al and Fe electrodes to treat TOPWs. The calculated operating cost was 0,80 euro per m^3 of effluent treated.

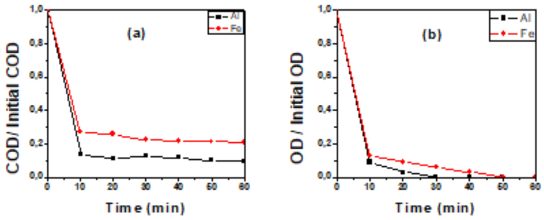

Figure 1. Effect of different electrodes (Al and Fe) on (a) COD and (b) color reduction versus time, for TOPW (current density 83.3 mA cm^{-2}).

For DW, it was observed that COD removal was achieved only when Al electrode was used.Same results were also observed by Bazrafshan et al.,(2013).The factor that seemed to be crucial for the EC process was the pH. When pH was adjusted to 6 and 8, COD removal was up to 23 % and was achieved complete color removal, but with no pH adjustment, COD removal was only 10% and color removal about 80% (Figure 2). Moreover, when pH was adjusted to 8, the total cost was calculated to 1,1 euro per m^3 of effluent treated.

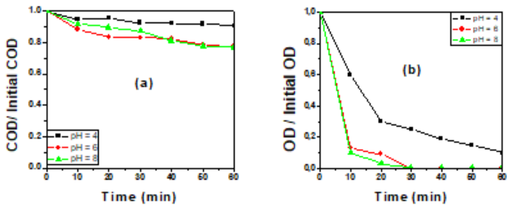

Figure 2. Effect of different pH values (4, 6 and 8) on (a) COD and (b) color reduction versus time, for DW(current density 100 mA cm^{-2}).

For PIW, the percentage of COD and color removal achieved reached up to 75% and 99% respectively, for both electrodes (Papadopoulos et al., 2019). Similar high color removal efficiencies were also observed by Thuy(2017).However, it was observed that COD removal was more rapid when Fe electrode was used (Figure 3) while the calcuted operating cost was less than 1.5€ m^{-3} of the treated effluent.

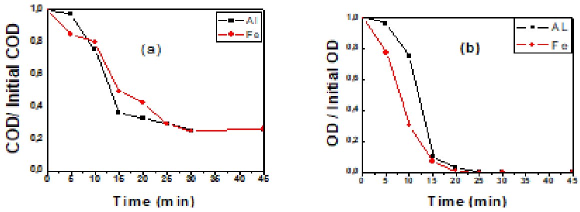

Figure 3. Effect of different electrodes (Al and Fe) on (a) COD and (b) color reduction versus time, for PIW (current density 41.7 mA cm^{-2}).

4. Conclusions

EC was proved to be a very promising, cost-efficient method for removing color and COD content (up to 80% and 100 %, respectively) of various effluents.

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