Modeling Of Electro-Coagulation-Flotation Process For Olive Oil Mill Wastewater Treatment

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Abstract: During the past decade, the high volumes of information have been stored in the databases. Today, the quantity of the accessible data becomes double in each five-years, however, according to researches, many organizations can analyze only one percent of these information which gained expensively. Undoubtedly, modeling for performed activities and researches can help us to use our capitals. So, this matter encourages us to industrialize electro coagulation flotation (ECF) process to remove pollutants from olive oil mill wastewater. One of the scientific methods is using least squares regression model. This study done based on mathematical model of least squares regression method. Coefficient's test for mathematical model of each pollutant was analyzed by 95 percent of confidence level. The determination coefficient (R^2) for mathematical model of chemical oxygen demand and phenolic compounds removal were 79 and 81 percent respectively. All of these models' coefficients in 95% probability are significant and have good level of confidence. Undoubtedly, modeling for performed activities and researches by eliciting real and useful knowledge of information is very effective in preserving financial and work force resources in order to protects environment and develop countries.

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Introduction

Modeling is a data decoding analysis process which describes, dissects and controls the effective factors of a phenomenon. During the past decade, the high volumes of information have been stored in the databases. Today, the quantity of the accessible data becomes double in each five-years, however, according to researches, many organizations can analyze only one percent of theses information which gained expensively. Therefore, there are some organizations but the low levels of knowledge. Undoubtedly, modeling for performed activities and researches can help us to use our capitals. This process can backup us for decision- making and by processing the comprehensive information and secure decision- making by eliciting real and useful knowledge of information be very effective in preserving financial and work force resources. Techniques of the modeling or changing the scales can help the scientific researches to be used in the industrial sectors, because the majority of the university activities have been stopped in this step and never reached to the industrial step.

So, this matter encourages us to industrialize electro-coagulation-flotation (ECF) process to remove pollutants from olive oil mill wastewater. There are many methods for modeling. One of the scientific methods is using least squares regression model. The most important environmental pollutants are industrial wastewater [1]. Olive oil mill wastewater (OOMW) is a liquid odorous that contains very high turbidity, organic materials and emulsified oil too [2]. The disposal of this wastewater without treatment can causes problems for the environment [3]. The Significant effects of discharge OOMW in the environment can encompass threatened microbial ecosystems, surface and ground water pollution, changes in soil quality and the annoying smell [4 - 5]. Different methods have been tested for olive wastewater treatment. But any method that is not acceptable in terms of economy and efficiency [6 - 10]. Electro coagulation and flotation using sacrificial anode has been studied to remove suspended particles, organic compounds, color, metal ions and inorganic anions and variety of different compounds of water and wastewater [11 - 17]. Important factors in process can be included pH, current density, type of electrodes and arrangement electrodes.

The goals of this study are preliminary steps for industrialize ECF process and determination manner of effective factors such as pH and current density in efficiency of the process by modeling of ECF process.

Materials and Methods

This research was carried out on the natural olive oil mill wastewater in laboratory scale. Experiments done in a batch reactor with 1750 ml useful volume and equipped with two cathodes made of titanium and two anodes made of iron that installed parallel in monopolar mode and they were connected to the direct current power source (DC power – ZHAOXIN 5A-60V). The gap between the electrodes was 2 cm. The dimensions of electrodes were 0.2 × 8 × 8 cm in thickness, length and width respectively (Figure 1).

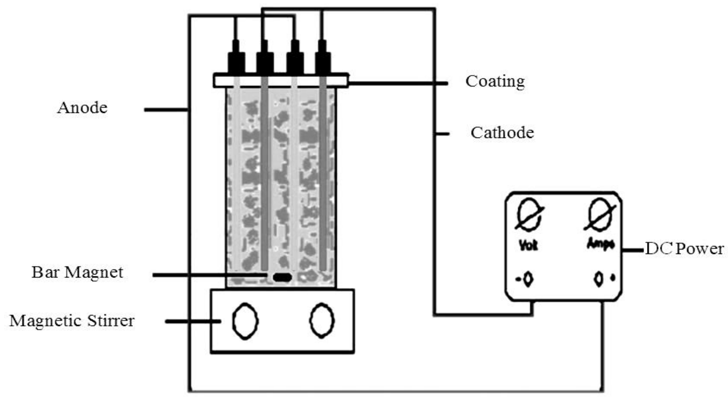

Figure 1. Schematic view of the electrochemical reactor used for ECF process

Pollutants removal modeling were investigated based on mathematical model of least square regression method for analyzing 63 experiments (independent variables product) for each pollutant by using Eviews software version 6001. Therefore, effects of the independent variables such as pH, time and current density on the removal efficiency of each pollutant were provided with mathematical model.

By calculating R^2; the independent variables (COD and total phenolic compounds) overlapping mathematical model for accessing to the dependent variable (For accessing to pollutant removal) was analyzed. In the next step, by calculating the standard deviation (SD) and T- student test, the probability of coefficient's correctness was studied. Coefficient's test for mathematical model of each pollutant's removal was analyzed by 95 percent of confidence.

Results

According to standard methods for water and wastewater tests, olive oil raw wastewater was analyzed. Findings are presented in table 1.

Table 1. The basic characteristics of olive oil mill wastewater analyzes

Parameters	Results
pH	5.2
Turbidity(NTU)	21400
Total Dissolved Solids (TDS) (mg/L)	24900
Chemical Oxygen Demand (COD) (mg/L)	36240
Biochemical Oxygen Demand (BOD) (mg/L)	11600
Total phenolic compounds (mg/L)	299
Chloride (mg/L)	1860

Figure 2 shows comparison between measured parameters in olive oil mill wastewater and strong municipal wastewater.

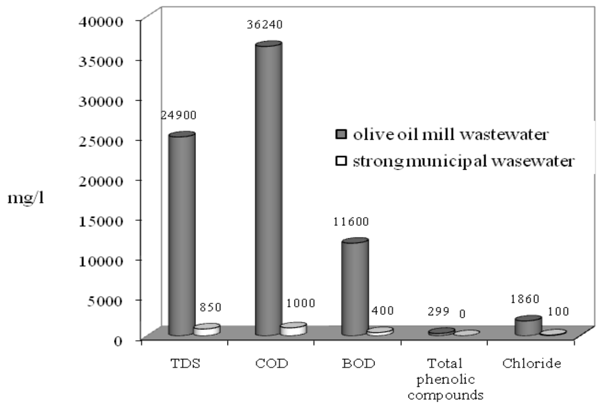

Figure 2. Comparison between OOMW and strong municipal wastewater

Tables 2 and 3 show the effect ECF process on COD and phenolic compounds removal in 39 A/m^2 of current density from OOMW.

Table 2. COD remaining in the reactor after ECF process in 39 A/m^2 of current density (Primary COD wastewater was 36240 mg/l)

pH \ Time (min)	5	10	20	30	40	50	60
5.2	5650	5280	3130	2980	2850	2800	2800
7	5880	5430	3650	3250	3000	2950	2950
10	6150	5900	4450	3930	3800	3800	3800

Table 3. phenolic compounds remaining in the reactor after ECF process in 39 A/m^2 of current density(primary phenolic compounds wastewater was 299 mg/l)

pH \ Time (min)	5	10	20	30	40	50	60
5.2	80	72	58	55	53	53	52
7	85	70	66	61	58	57	56
10	97	75	66	63	60	60	60

So, by selecting the natural pH of the wastewater as the optimum pH; ECF process was studied in range 39 to 117 A/m^2 of current density. Findings show in tables 4 and 5.

Table 4. Efficiency of ECF process for COD removal in different current density (pH 5.2)

Current density (A/m^2) \ Time (min)	5	10	20	30	40	50	60
39	84.41	85.43	91.36	91.78	92.14	92.27	92.27
78	86.34	87.58	92.60	93.43	94.21	94.48	94.34
117	88.00	88.69	94.48	95.50	95.72	96.14	96.14

Table 5. Efficiency of ECF process for phenolic compounds removal in different current density (pH 5.2)

current density (A/m^2) \ Time (min)	5	10	20	30	40	50	60
39	73.24	75.92	80.60	81.61	82.27	82.27	82.61
78	74.92	79.60	83.28	83.95	84.62	85.28	85.28
117	81.61	82.61	87.63	88.63	88.96	89.30	89.97

Discussion

- **Modeling for COD removal**

After analysis experiments, according to the least squared regression methods, statistical coefficients were as follow:

Table 6. Statistical results obtained from COD removal experiments

	Variable	Coefficient	Std. Error	t- Statistic	Prob.
1	pH	-0.288725	0.111705	-2.584716	0.0122
2	Time (min)	0.145143	0.011653	12.45534	0.0000
3	Current density	0.026835	0.003467	7.739907	0.0000
4	C	84.59699	1.074142	78.75777	0.0000
	R^2	0.789828			
	Prob. (F- statistic)	0.000000			

According to results of the table 6, the mathematical model for COD is equal to:

$$A = C_{(1)} \times B + C_{(2)} \times F + C_{(3)} \times H + C_{(4)}$$

$$A = -0.288725 \times B + 0.145143 \times F + 0.026835 \times H + 84.59699$$

Removal Efficiency of COD = 84.6 – 0.29 pH + 0.145 time + 0.0537 current density

Coefficients test for the mathematical model of COD removal with 95% level of confidence show that all of the coefficients and total model have validity. 79 percent of determination coefficient (R^2) shows that this model is explanatory, in other word about 79 percents of changes in COD removal by ECF process is explained by the above mentioned model. Also, all of the coefficients in this model are significant and have reliability in probability of 95% ($p \leq 0.05$).

- **Modeling for phenolic compounds removal**

Statistical coefficients of total phenolic compounds removal from OOMW is as follow:

Table 7. Statistical results obtained from phenolic compounds removal experiments

	Variable	Coefficient	Std. Error	t- Statistic	Prob.
1	pH	-0.663249	0.140181	-4.731365	0.0000
2	Time (min)	0.161626	0.014624	11.05229	0.0000
3	Current density	0.046171	0.004351	10.61160	0.0000
4	C	74.23959	1.347969	55.07515	0.0000
	R^2	0.813377			
	Prob. (F- statistic)	0.000000			

According to table 7, for access to the total phenolic compounds removal, the mathematical model is provided as fallow:

$$A = C_{(1)} \times B + C_{(2)} \times F + C_{(3)} \times H + C_{(4)}$$

$$A = -0.663249 \times B + 0.161626 \times F + 0.046171 \times H + 74.2395859$$

Removal Efficiency of phenolic compounds = 74.24 – 0.66 pH + 0.167 time + 0.0462 current density

In the above mentioned model, time and current density as minute and A/m^2 respectively. Coefficients test for the mathematical model of COD removal efficiency with 95% level of confidence show that all of the coefficients and total model have Validity. Determination coefficient (R^2) was equal to 81, in other word; about 81 percent of changes in COD removal are explained by the model. Also, all of the coefficients in this model are significant and have reliability in probability of 95% ($p \leq 0.05$). The negative sign in pH coefficients show the reverse relation of this parameter with pollutants removal, in other word, by increasing pH, pollutant removal efficiency was decreased. Decreased efficiency for pollutants removal in the alkaline pH described by high level of negative charge in the alkaline pH due to anions absorbance from liquid phase to suspension phase [18]. Results of the experiments explained the mathematical model completely.

Conclusions

In this research, the effect of pH, current density and time reaction on COD and phenolic compounds removal from OOMW by ECF process with least squares regression method was modeled. The determination coefficients (R^2) for mathematical model of COD and phenolic compounds removal were 79 and 81 percent respectively. All of these model's coefficients in 95% probability are significant and have good level of confidence ($p \leq 0.05$). Undoubtedly, modeling for performed activities and researches can help us to use our capitals. This process can backup us for decision-making and by processing the comprehensive information and secure decision- making by eliciting real and useful knowledge of information be very effective in preserving financial, energy and work force resources.

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