ANALYSIS OF THE REMOVAL EFFICIENCY OF ELECTRODES FOR OILY WASTE WATER TREATMENT IN SURAJPUR AREA BY USING THE METHOD OF ELECTROCOAGULATION

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ABSTRACT:
The present study is based on removal efficiency of electrode during the treatment of oily wastewater in the samples of industrial origin in the Surajpur region of Chhattisgarh state through electrocoagulation method. The statistical analysis shows that all the variables set in the preparation of the model, within the tested boundaries, have significant effect on the model. Current density, initial pH, and operating time for the treatment of wastewater influence the COD, TOC, and turbidity removal efficiencies. The optimal electrocoagulation conditions for maximum removal efficiencies of COD, TOC, and turbidity found by RSM are illustrated as current density (64.28 A/m2), initial pH (7.03), and operating time of EC (20.60 min) for Fe electrode and current density (62.67 A/m2), initial pH (5.01), and operating time of EC (24.39 min) for Al electrode. It is characterized by desirability of 0.728 for Fe electrode and 0.819 for Al electrode. At optimized conditions, the actual COD, TOC, and turbidity removals are found to be 93.0%, 83.0%, and 99.8% for Fe electrode and 93.5%, 85.2%, and 99.9% for Al electrode, respectively, which confirms close to the predicted response using RSM. Minimal operating costs for Fe and Al electrodes are 0.371 and 0.337 €/m3. A mathematical approach is useful for picturing the theoretical electrocoagulation of metal cutting wastewater treatment.

KEYWORDS: Electrocoagulation, Oily Wastewater, Electrodes, Removal Efficiency.

INTRODUCTION:

Environmental pollution is a potential threat to living conditions in the earth. Overpopulation has resulted in the larger utilization of natural resources which paved the way for the increase of pollutions in the environment. Oil in wastewater may exist in many forms including free floating, dispersed and emulsified with the later to be the most difficult to treat (Jang and Lee, 2000). Oily wastewater has a complex composition because it may contain mineral, vegetable or synthetic oils, fatty acids, emulsifiers, corrosion inhibitors and bacteriocides. With industrial development, there is increase in the amount of oil used, but various technical and management developments lag behind other reasons that are not perfect and make a lot of oil into the water, forming pollution. Flotation is pouring into the water in the form of fine bubbles, the tiny air bubbles in the adhesion of oil particles suspended in the water, because the floating density of oil is less than that of water, the formation of a scum layer is separated from the water (Moosai and Dawe, 2003). Concrete technology because of its adaptability, can remove emulsified oil and dissolved oil and some difficult biodegradable organic polymer is characterized by the complex and is widely used in recent years in oily wastewater treatment(Ahmad et al., 2006). Biological treatment is the use of microbial metabolism, so that the water was dissolved, colloidal organic pollutants into harmless substances are stable (Kriipsalu et al., 2007).

One of the important physio-chemical operations used in water treatment is the process of **Coagulation**. A process used to cause the destabilization and subsequent aggregation of smaller particles into larger complexes is known as Coagulation. **Chemical coagulation** has been used for decades to destabilise suspensions and to effect precipitation of soluble species and other pollutants from aqueous streams. Some of the chemical coagulants used are the Alum, lime and polymers. **Electrocoagulation,** has proven very effective in the removal of contaminants from water which follows the principle of passing of the electrical current through water,

MATERIAL AND METHODS:

Materials: Oily wastewater samples used in this study were obtained from the nearby industrial area of Surajpur. The conductivity of sample was adjusted to the desired level by adding an appropriate amount of sodium chloride. Aluminum electrodes were used as anode and cathode. Experimental procedures: Three experimental electrode design sets were used in the separation of oil from oily wastewater to enhance the separation rate.

Experimental Procedure

The EC experiments were conducted in a 4.5-l Plexiglas reactor with a dimension of 255 mm×195 mm×90 mm. Aluminum (Al) or iron (Fe) plates (220 mm×50 mm×4 mm) were chosen as the anode/cathode pair for their performances, with the electrodes connected in a monopolar parallel mode, yielding a total effective electrode surface area. Four electrodes were adopted in the electrolytic cell for all experimental run. The electrodes were then connected to a digital DC power supply operated at galvanostatic mode. In each run the waste water solutions were placed into the EC reactor. The current density was adjusted to a desired value and the EC process was started. At the end of EC, the solution was filtered and then it was analyzed. At the end of the run, the electrodes were washed thoroughly with water to remove any solid residues on the surfaces, dried and reweighted. This experimental design is such as the composite central design (CCD). This methodology optimizes for COD, TOC, and turbidity removals from Oily wastewaters in the EC process in terms of the process variables to provide more comprehensive interpretation and quantitative assessment of the treatment process.

RESULTS:

Experimental Design and Data Analysis:

RSM is a collection of mathematical and statistical techniques, commonly used for improving and optimizing processes. It can be used to evaluate the relative significance of several affecting factors in the presence of complex interactions. RSM is an effective tool for optimizing the process (Myers and Montgomery 2002), when a combination of several independent variables and their interactions affects desired responses. RSM uses an experimental design such as the composite central design (CCD) to fit a model by least squares technique. This methodology optimizes for COD, TOC, and turbidity removals from wastewaters in the EC process in terms of the process variables to provide more comprehensive interpretation and quantitative assessment of the treatment process. The Design Expert Software (trial version) is used for the statistical design of experiments and data analysis and performed in duplicate. The three most important operating variables, initial wastewater pH (x1), current density (x2), and operating time (x3), are optimized. The study ranges are chosen as initial wastewater pH4–8, current density 30–100 A/m2 , and operating time 10–40 min for the EC process using Al and Fe electrodes. Initial wastewater pH (x1), current density (x2), and operating time (x3) are chosen as three independent variables in the EC process. Their range and levels are given in Table 3. In this table, the coded values for x1, x2, and x3 are set at five levels −2, −1 (minimum), 0 (central), +1 (maximum), and + 2. Three dependent parameters are analyzed as responses, COD, TOC, and turbidity removals, in order to obtain optimum initial wastewater pH, current density, and operating time and to achieve highest removal of COD, TOC, and turbidity and lowest operating cost for the treatment of Wastewater using the EC process. For Fe and Al electrodes, the actual design of this work is presented in Tables 4 and 5. These tables show the CCD in the form of a 23 full factorial design with three additional experimental trials (run numbers 1, 6, and 17) as replicates of the central point. Analysis of variance (ANOVA) is used for graphical analyses of the data to obtain the interaction between the process variables and the responses.

The quality of the fit model is expressed by the coefficient of determination R2, and its statistical significance is checked by the Fisher F test in the same program. Model terms are evaluated by the P value (probability) with 95% confidence level.

Chemical Analysis and Operating Costs: COD, TOC, and turbidity contents of liquid samples are monitored. All analyses are performed according to the standard method for water and wastewater analysis (Cleceri et al. 1998). COD is measured spectrophotometrically and analyzed by closed reflux colorimetric method. The TOC levels are determined through combustion of the samples at 680°C using a nondispersive IR source. The turbidity (NTU) of samples is analyzed using a turbidimeter control. The pH is measured using a digital pH-meter for pH control, and the conductivity is determined with a digital conductivity meter control system. The accuracy of all measured values for COD, TOC, and turbidity is estimated around 3%. The operating cost for the EC process mainly including chemical, electrode, and electrical energy costs was calculated (Kobya et al. 2009, 2010), and results for both electrodes were obtained.

Table 4 The actual design of experiments and responses for EC using Fe electrodes

Exp. no.	pH (x_1)	*CD* (x_2) A/m^2	t_{EC} (x_3) (min)	Removal efficiency (%)			Energy consumption (ENC)[a]		Electrode consumption (ELC)[a]		Operating cost (OC)[a]	
				COD	TOC	Turbidity	kWh/m^3	kWh/kg COD	kg Fe/m^3	kg Fe/kg COD	€/m^3	€/kg COD
1	6.50	65.00	25.00	89.00	79.00	99.00	5.873	1.334	0.572	0.130	0.959	0.21
2	7.99	85.81	16.08	82.00	75.00	98.70	6.718	1.656	0.429	0.106	0.898	0.21
3	6.50	30.00	25.00	69.10	57.10	10.00	1.791	0.525	0.257	0.075	0.398	0.11
4	4.00	65.00	25.00	83.00	75.00	85.00	5.618	1.368	0.543	0.132	0.916	0.21
5	6.50	100.00	25.00	93.00	79.10	94.00	14.693	3.194	0.829	0.180	1.812	0.38
6	6.50	65.00	25.00	91.00	80.00	99.50	5.975	1.328	0.543	0.121	0.942	0.20
7	7.99	44.19	16.08	76.10	66.00	50.00	2.117	0.563	0.256	0.068	0.421	0.10
8	7.99	44.19	33.92	80.00	70.00	50.20	4.371	1.105	0.514	0.130	0.802	0.19
9	9.00	65.00	25.00	87.30	81.00	91.00	6.129	1.424	0.512	0.120	0.928	0.20
10	5.01	85.81	33.92	90.00	82.20	99.80	12.251	2.752	1.114	0.251	1.879	0.42
11	5.01	44.19	33.92	72.00	65.00	45.00	4.230	1.188	0.542	0.152	0.816	0.21
12	6.50	65.00	40.00	93.00	81.00	97.00	9.234	2.007	0.943	0.205	1.516	0.32
13	5.01	85.81	16.08	83.00	74.10	97.00	5.938	1.446	0.457	0.111	0.866	0.20
14	5.01	44.19	16.08	68.00	61.10	45.40	2.072	0.616	0.243	0.072	0.406	0.10
15	6.50	65.00	10.00	75.00	69.00	95.00	2.431	0.655	0.171	0.046	0.371	0.09
16	7.99	85.81	33.92	91.00	83.00	99.70	14.719	3.270	0.771	0.171	1.766	0.38
17	6.50	65.00	25.00	91.00	82.00	98.00	5.924	1.316	0.541	0.121	0.938	0.20

[a] Operating cost (OC) = *a*ENC + *b*ELC + *c*CC (*a*, *b*, and *c* given for Turkey market in January 2010 are electrical (0.072 €/kWh), electrode (0.85 €/kg Fe and 1.65 €/kg Al), and chemical costs such as NaOH and H_2SO_4 as 0.73 €/kg and 0.29 €/kg). ENC, ELC, and chemical are energy, electrode, and chemical consumptions, respectively

Table 5 The actual design of experiments and responses for EC using Al electrodes

Exp. no	*pH* (x_1)	*CD* (x_2)A/m^2	$t_{EC}(x_3)$ (min)	Removal efficiency (%)			Energy consumption (ENC)[a]		Electrode consumption (ELC)[a]		Operating cost (OC)[a]	
				COD	TOC	Turbidity	kWh/m^3	kWh/kg COD	kg Al/m^3	kg Al/kg COD	€/m^3	€/kg COD
1	6.50	65.00	25.00	90.35	82.30	99.75	4.342	0.9752	0.403	0.090	1.023	0.269
2	7.99	85.81	16.08	81.20	73.80	73.80	5.418	1.352	0.372	0.093	1.053	0.301
3	6.50	30.00	25.00	75.10	65.20	65.20	1.367	0.425	0.114	0.036	0.337	0.139
4	4.00	65.00	25.00	93.45	80.25	80.25	3.677	0.799	0.486	0.106	1.116	0.282
5	6.50	100.00	25.00	87.75	79.85	79.85	9.664	2.220	0.657	0.151	1.830	0.459
6	6.50	65.00	25.00	83.80	82.95	82.95	4.290	0.975	0.429	0.098	1.066	0.281
7	7.99	44.19	16.08	65.10	63.05	95.05	1.538	0.399	0.229	0.059	0.538	0.176
8	7.99	44.19	33.92	83.75	76.30	98.15	3.055	0.735	0.343	0.083	0.836	0.239
9	9.00	65.00	25.00	81.30	74.80	98.30	4.648	1.160	0.343	0.086	0.950	0.275
10	5.01	85.81	33.92	91.90	85.20	99.90	8.685	1.868	0.857	0.184	2.101	0.489
11	5.01	44.19	33.92	87.25	73.15	99.70	2.632	0.612	0.486	0.113	1.041	0.281
12	6.50	65.00	40.00	91.20	83.95	99.90	7.354	1.634	0.601	0.133	1.570	0.388
13	5.01	85.81	16.08	87.95	78.15	99.80	4.031	0.926	0.514	0.118	1.189	0.312
14	5.01	44.19	16.08	78.50	73.15	97.60	1.181	0.291	0.314	0.078	0.654	0.199
15	6.50	65.00	10.00	73.75	67.65	99.60	1.655	0.452	0.143	0.039	0.405	0.147
16	7.99	85.81	33.92	93.30	84.10	99.80	11.062	2.405	0.629	0.137	1.884	0.449
17	6.50	65.00	25.00	88.85	79.95	99.40	4.392	0.998	0.457	0.104	1.121	0.293

[a] Operating cost (OC) = *a*ENC + *b*ELC + *c*CC (*a*, *b*, and *c* given for Turkey market in January 2010 are electrical (0.072 €/kWh), electrode (0.85 €/kg Fe and 1.65 €/kg Al), and chemical costs such as NaOH and H_2SO_4 as 0.73 €/kg and 0.29 €/kg). ENC, ELC, and chemical are energy, electrode, and chemical consumptions, respectively

DISCUSSION:

Statistical Analysis In the present work, the relationship between three variables (namely initial wastewater pH, current density, and operating time) and three important process responses (namely COD, TOC, and turbidity removal efficiencies) for the EC process using iron and aluminum electrodes is analyzed using RSM. Significant model terms are desired to obtain a good fit in a particular model. The CCD for Fe and Al electrodes in Tables 4 and 5 allows the development of mathematical equations where predicted results are assessed as a function of x1, x2, and x3 as the sum of a constant, three first-order effects (terms in x1, x2, and x3), three interaction effects ((x1·x2), (x1·x3), (x2·x3)), and three second-order effects (x2 1, x2 2, and x2 3). The adequacy of the RSM is justified through ANOVA. The ANOVA results for response parameters for Fe and Al electrodes are shown in Tables 6 and 7. Only terms found statistically significant are included in the model. For Fe and Al electrodes, Tables 6 and 7 illustrated the quadratic models in terms of coded factors and also showed other statistical parameters. F values from the ANOVA are 23.55 for COD, 22.67 for TOC, and 55.50 for turbidity removal for Al and 17.68 for COD, 72.12 for TOC, and 156.52 for turbidity removal for Fe electrodes, indicating that the model is significant. The large value of F indicates that most of the variation in the response could be explained by regression equation. The associated P value and F value are less than 0.5 which shows that the model terms are significant. The R2 coefficient gives the proportion of the total variation in the response variable accounted for by the predictors (x's) included in the model. A high R2 value, close to 1, is desirable and has a reasonable agreement with adjusted R2. A high R2 coefficient ensures a satisfactory adjustment of the quadratic model to the experimental data.

In the present study, the adjusted values of R2 (Tables 6 and 7) for Al and Fe electrodes were found to be 0.927 for COD, 0.924 for TOC, and 0.968 for turbidity removal and 0.904 for COD, 0.976 for TOC, and 0.989 for turbidity removal, respectively. The coefficient of variance (CV) as the ratio of the standard error of estimate to the mean value of the observed response (as a percentage) is a measure of reproducibility of the model. As shown in Tables 6 and 7, CV for COD, TOC, and turbidity removal is found to be 3.18%, 1.70%, and 3.73% for Fe electrode and 2.51%, 2.41%, and 0.26% for Al electrode, respectively. Adequate precision (AP) compares the range of the predicted values at the design points to the average prediction error. Ratios of CV>4 indicate that adequate model is desirable. The AP values for Al and Fe electrodes used in the EC process are found to be 12.18 for COD, 28.54 for TOC, and 41.60 for turbidity removal and 16.8 for COD, 15.4 for TOC, and 25.5 for turbidity removal which indicate an adequate signal (Tables 6 and 7). The following fitted regression models (equations in terms of coded values for the regressors) are used to quantitatively investigate the effects of initial pH, current density, and operating time on the characterization.

CONCLUSION:

The protection of the fresh water resources has become a main worry for many countries in the world. Water deficiency is one of the greatest current and future challenges that face humankind, as the world's population and water consumption rates continue to grow. Produced water is the byproduct generated by the oil gas industries and it is becoming a global concern, due to its complex composition. Therefore, the Analysis of the removal efficiency of electrodes for oily waste-water treatment by using the method of electrocoagulation is in addition, killing microorganism in water employing electrocoagulation process. It has significant role for industrial processes.

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