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Removal of COD from Textile Effluent using Electro coagulation: Statistical Design and Modeling

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***Abstract* - Electrocoagulation is widely used method in waste water treatment. The removal of COD from textile effluent by EC using Iron(Fe) as sacrificial electrodes was investigated in this paper.A Central composite design was developed to examine the individual and combined effects of important process parameters, such as pH ,voltage and electrolysis time on the percentage of COD removal .Analysis of variance (ANOVA) showed a high coefficient of determination value R^2 (99.347%) for the percentage of COD removal. The optimum conditions for predicted maximum COD removal were found to be pH 7.23,voltage 8.77v and electrolysis time of 84.29 min.**

Keywords: Electro Coagulation; Iron Electrode;Textile Waste Water; Response Surface Methodology.

I.INTRODUCTION

The textile industries in India, now-a-days are the important sectors of country's economy, and contributes to the total output of the fast growing industrial sector which is at present revolving around 14%. The textile dyeing industries consumes large quantities of water and produces large volumes of wastewater(1). Many industries consume fresh water and releases wastewater so it should be treated properly to reduce or eradicate the pollutants and achieve the permissible limit to discharge as well as for its reutilization in the industrial/agriculture process to promote sustainability. Effluent with high colour and high COD and turbidities are common in industries like textile, paper, leather ,pharmaceutical and mineral processing(2). Currently there are more than 10,000 varieties of dye and pigments used in dyeing and printing processes. The effluent released from dyeing and printing processes contains mainly strong colourants, inorganic salts, chemicals and toxic compounds(3). Presence of dyes in water resources and aqueous environments, causes aesthetic aspect and affects the transparency and oxygen availability in water and some of these dyes are toxic, mutagenic and carcinogenic to human and aquatic life . Also discharge of colored wastewater without adequate treatment interferes with light penetration that disturbs biological processes and is harmful for aqueous plants(4). Electrocoagulation uses an electrical current and produces several metal ions in electrolyte solution to purify the wastewater. As a result, the electrocoagulation system is very effective removing suspended solids, dissolve metals, tannin and dyes, COD. In a electrocoagulation system, when metal ions are neutralized with ions of opposite electric charges, they become unstable and precipitate in a form that is usually very stable. The hydrogen gas bubbles carry the colloidal pollutants to the top of the solution. These particles can be more easily concentrated, collected and removed from the top of the solution. In the electrocoagulation process, during the evolution of H_2, the metallic ions react with the OH- ions, which are produced at the cathode as a result, the insoluble hydroxides absorb the pollutants out of the solution.(5) .
Electrocoagulation is simple and efficient method which is employed successfully in many waste water treatments. Hence it was chosen here to treat the textile waste water due to its numerous advantages.

A.Design of Experiments and Modeling

Response surface methodology is a collection of mathematical and statistical method used for modeling and optimization where the response of interest is influenced by several variables and the main objective is to optimize the response. The RSM generates empirical model which can describe the process and analyze the influence of independent variables on a specific dependent variable (response). are presumed to be continuous and can be controlled with negligible error.. The individual variables (x_1, x_2, …, x_k) are presumed to be continuous and can be controlled with negligible error The response (y) is postulated to be a random variable. The independent variables denoted by x_1, x_2, …, x_k and the response (y) can be related as follows (6)

$$y=f(x_1,x_2,x_3\ldots\ldots x_k)+£ \longrightarrow (1)$$

where y is the response of the system, f is the unknown function of response, x_1, x_2, x_3 ……x_k the independent variables, k the number of independent variables, and £ the statistical error .In the present study the optimization of COD was done by using CCD in which , 20 experiments was done wih 8 star points,6 axial points(α=±1.68) and 6 centre point techniques useful for the modeling and analysis of problems in which a response of (α=0).As presented in table 2 ,each independent variable was coded in 5 level as (-1.68,-1,0,1,1.68) as x_i according to the equation

$$x_i=X_i - X_0/\Delta X \longrightarrow (2)$$

where X_0 is value of the X_i (selected parameters) at the centre point and ΔX presents the step change.COD removal efficiency was taken as the response of the experiments according equation.

$$Y_i=b_0+\sum_{i=1}^{n} bixi + \sum_{i=1}^{n} biixij2 + \sum_{i=1}^{n-1}\sum_{j+1}^{n} bijxixj \longrightarrow (3)$$

where Y_i is the percentage of dye removal efficiency
b_0= the constant coefficient
b_i = the regression coefficients for linear effects
b_ii = the quadratic coefficients
b_ij = the interaction coefficients
and x_i, x_j are the coded values of the parameters.The accuracy of the fitted model was justified through analysis of variance (ANOVA) and the coefficient of R^2(7). The characteristics of a textile effluent was shown in Table 1.

TABLE 1:Characteristics of Textile Effulent

Parameter	value
pH	7.8
Total Dissolved Solids	2400(ppm)
BOD	250(ppm)
COD	8720(ppm)
Color	Purple
Odour	Pungent

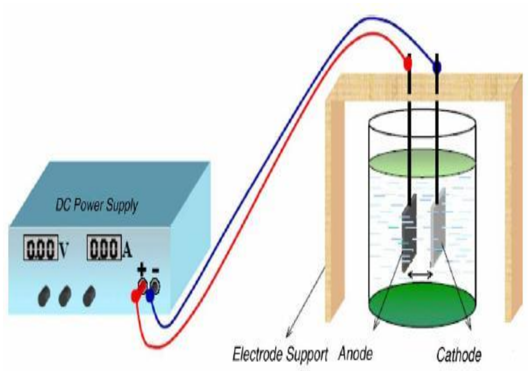

Fig1:Electrocoagulation apparatus

II. MATERIALS AND METHODS

A laboratory scale unit was used to conduct the experiments in the present study. The unit includes two components: The Reactor and the Spacing between the two electrodes was 15mm. the experimental set up was shown in Fig1. Polarity of current was reversed at regular intervals in order to minimize the deposition on the electrodes. The power system was used to supply Direct Current (DC) at desired voltage to the electrodes. The system converted the input Alternating Current (AC) into Direct Current (DC) of desired voltage. Provisions Ampere of 1A range was fitted in the power system to display the amperage of the power supplied. All the runs were performed at room temperature and the agitator speed was maintained constant at 500 were made in the system to regulate voltage of the output and to display it on a handy multi meter. An rpm.Regular samples were collected at respective intervals and the pH adjustment was done by using NaOH and H_2SO_4.The pH was measured by the pH meter and the COD ,total suspended solids (TSS) and total dissolved solids (TDS) were done by the standard methods (APHA,2005) (8) for examination of water and waste water.

III.RESULTS AND DISCUSSION

The range of parameters used in the experiment were listed in Table 2 and the experiments were conducted according to the conditions of CCD coded values and the results were shown in Table3

TABLE 2:Coded and real values of independent parameters used for CCD

Parameters levels	-1.68	-1	0	1	1.68
pH	5	6	7	8	9
Time(min)	40	60	80	100	120
Voltage(v)	4	6	8	10	12

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A.Analysis of variance (ANOVA)

Analysis of variance (ANOVA) was used to determine the significant effects of process parameters on percentage removal of COD. The Anova table was shown in Table 4. It can be noticed from Table 4 that the F-statistics values for the regressions are higher. The large F-values for percentage COD removal indicate that the response fits more favourable for the regression model. The associated p-value is used to estimate whether the F-statistics are large enough to indicate statistical significance. p-values lower than 0.05 indicates that the model is statistically significant for percentage COD removal. The regression model equation fitted by the curve is developed by the second order polynomial equation for percentage of COD removal as a function of x_1(pH), x_2(voltage) and Electrolysis time (x_3)

The regression equation is developed from the responses and is shown below

$$Y=-752.206+115.759x_1+65.581x_2+3.328x_3\text{-}0.609x_1x_2-0.13x_2x_3-0.019x_3x_1-6.873x_1^2-3.328x_2^2-0.01$$

TABLE 3:Design of experiments and response for % COD removal

Run	pH	Voltage(v)	Time(min)	COD Expt(%)	COD Pred(%)
1	6	6	60	46.4	42.87
2	8	6	60	56	59.00
3	6	10	60	63.2	68.85
4	8	10	60	74.8	80.1
5	6	6	100	59.4	55.95
6	8	6	100	60.9	61.65
7	6	10	100	74	78.86
8	8	10	100	79.8	79.68
9	7	8	80	91.5	91.57
10	7	8	80	91.5	91.57
11	7	8	80	91.5	91.57
12	5.29	8	80	72	65.05
13	8.73	8	80	83	79.3
14	7	4.54	80	35.7	34.79
15	7	11.46	80	80.1	71.76
16	7	8	45.4	60.6	71.41
17	7	8	114.6	82.3	82.04
18	7	8	80	91.5	91.57
19	7	8	80	91.5	91.57
20	7	8	80	91.5	91.57

The high coefficient of the R^2 value means best fit of the model.The R^2 value provides a measure of how much variability in the observed response values can be explained by the experimental variables and their interactions. The R^2 value is always between 0 and 1. The closer the R^2 value is to 1, the stronger the model is and the better it predicts the response. In this case, the value of the determination coefficient (R^2 = 0. 99347) indicates that 99.34 % of the variability in the response could be explained by the model. In addition, the value of the adjusted determination coefficient (R^2adj = 0.9876) is also very high to advocate for a high significance of the model

Table 4: Anova for the second order polynomial equation for COD removal percentage

Source	**Regression coefficients**	**SS**	**DF**	**Meansquare**	**F-value**	**p-value**
CONSTANT	-752.206					
X_1	115.759	245.132	1	245.132	69.5455	0.000008
X_2	65.581	1651.399	1	1651.399	468.5134	0.000000
X_3	3.328	136.583	1	136.583	38.7496	0.000000
X_1X_2	-0.609	11.883	1	11.883	3.3712	0.000000
X_2X_3	-0.130	4.728	1	4.728	1.3413	0.000098
X_3X_1	-0.019	54.340	1	54.340	15.4167	0.000001
X_1^2	-6.873	678.578	1	678.578	192.5172	0.096212
$X_2^{\ 2}$	-3.392	2645.063	1	2645.063	750.4228	0.002837
X_3^2	-0.013	397.578	1	397.578	112.7958	0.273714
ERROR		35.248	10	3.525		
TOTAL SS		5401.497	19			

*p≥0.05

3.2 *Effect of Voltage and pH*

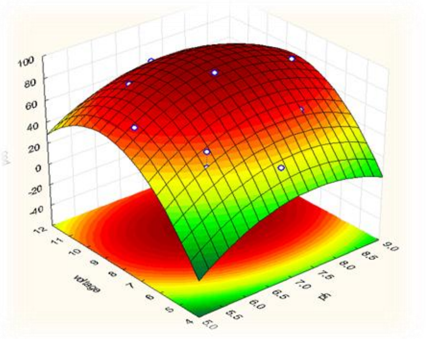

Fig 2: Surface plot shows the combined effect of voltage and pH on COD removal

From the Fig 2 it was proved that the iron works good for neutral pH and for slightly basic nature.As the pH increased beyond that does not shows significant effect on COD removal due to the formation of soluble metal hydroxide.The removal percentage of COD was shown as maximum at voltage 8v, pH 7 for the fixed electrolysis time of 80 min.

3.3 Effect of pH and Electrolysis Time

It was clearly shown that the COD removal increases on increasing time upto the maximum level and further increase in time decreases the removal of COD slightly. As stated above the removal percentage increases for increase in time and pH upto the optimum value pH 7 and electrolysis time 80 min,and then the trend is reversed as shown in Fig 3

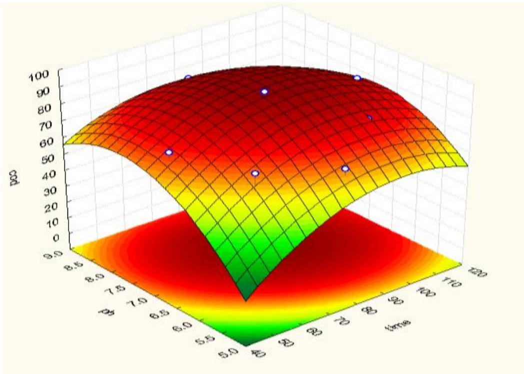

Fig3: A surface plot showing the combined effect of pH and Electrolysis time on % COD removal

3.4 Effect of Electrolysis time and voltage

The effect of Electrolysis time and voltage on COD removal is shown in Fig 4.The COD removal increases with increase in both the time and voltage and after that decreases slightly .The optimum value for maximum COD removal lies near the centre point as shown in the Fig 4.

Table 5: Critical values

The critical values obtained from the experimentwere shown in Table 5

Factor	Observed optimized values in preliminary studies	Critical values obtained in RSM
pH	7	7.2332
Voltage(v)	8	8.77765
Time (min)	80	84.29051

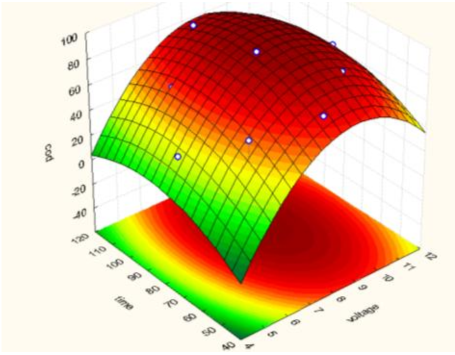

Fig 4: Combined effect of Electrolysis time and voltage on percentage of COD removal .

D: Comparison of predicted values with observed experimental values

The variance of observed and predicted values was shown in Fig 5 and from the figure it is clearly shown that , the points cluster around the diagonal line indicated the optimal fit of the model, since thedeviation between the experimental and predicted values were minimal.

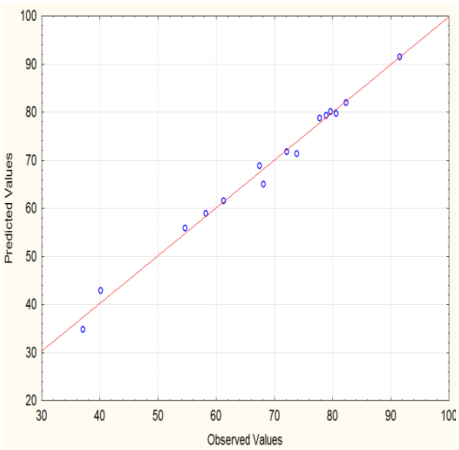

Fig5: Observed Vs predicted values

IV CONCLUSIONS

Experiments were carried to percentage COD removal by EC from textile effluent covering wide range of operating conditions .The percentage of COD removal shows the significant influence by operating conditions, such as voltage ,pH and electrolysis time. The experimental data were analysed using RSM. To overcome problems associated with chemical coagulation,EC has been advocated as a novel approach in removing COD from textile effluent.Nevertheless the general opinion of research works is that for the EC process to be effective in treating waste water parameters such as pH,voltage and electrolysis time used must be considered.

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