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A synthetic textile dye effluent was removed by decolorizationon Ceiba pentandra using Response surface methodology

J. **Anitha[1] and Dr. CH. A. I. Raju[2]**

[1]Research Scholar, [2]Assistant Professor

Department of Chemical Engineering, Andhra University,

Visakhapatnam – 530 003, AP, INDIA

Abstract:

In this paper manages minimal expense, locally accessible, inexhaustible sorbent; Ceiba pentandra plant leaves powder for Aniline blue dye decolorization. Tests at complete dye convergences of 20, 50, 100, 150, and 200 mg/L were done with a synthetic wastewater of Aniline blue dye. The impact of starting dye focusses 20 min, sorbent molecule size 53 µm, amount of sorbent 30 g/L and pH compelling sorbance, 1.5-gram of Ceiba pentandra plant leaves powder was viewed as a superior sorbent, eliminating 94 % of dye from the synthetic wastewater. decolorization of dyes by quicker rate in contrast with Ceiba pentandra.

Keywords: Ceiba pentandra, pH, temperature and RSM

1. Introduction

Dyes continue to pollute water, posing a severe environmental and public health risk **[1]**. In the realm of water pollution, the removal of contaminants such as dyes and pigments from wastewaters is a hot topic**[2]**. Adsorption with solid materials (known as adsorbents or sorbents depending on their origin) is a simple, practical, and successful method of pollution removal**[3]**. The textile sector, as well as wastewater treatment facilities, face a challenge in removing colour**[4]**. As government legislation regarding the release of contaminated effluent has gotten more rigorous, dye removal has become a study subject of increasing interest**[5]**.Wastewater decolorization has been achieved using physical and chemical procedures such as biological oxidation, adsorption, foam flotation, electrolysis, coagulation-flocculation, ozonation, oxidation, filtering, membrane separation, photo catalysis, and electrochemical approaches **[6]**. The adsorption process is one of the most efficient techniques of removing pollutants from wastewater using reactive, acidic, and direct dyes in neutral solutions, and it is an appealing alternative treatment, especially if the sorbent is inexpensive and widely available **[7]**. Because of its low cost, simplicity of construction, high efficiency, availability, and ability to separate a wide range of chemical substances, adsorption is considered to be substantially superior to other approaches **[8]**.

2. Experimental procedure:

2.1 Materials

Aniline blue, sieves, arbitral shaker, pH meter, HCL, NaOH

2.2 Stock solution of Aniline blue

To get ready 1000 ppm ofAniline blue stock arrangement 1.0 g of AR grade (Aniline blue) was broken up in 1.0 liter of twofold refined water. From this stock arrangement engineered tests of various convergences of dyes were ready by suitable weakening. 100 ppm dye arrangement was ready by weakening 100 ml of 1000 ppm dye stock arrangement with refined water in 1000 ml volumetric cup sufficient. Also, arrangements with various dye focuses like 20, 50, 100, 150 and 200 ppm were ready.

2.3 Preparation of Adsorbents

Ceiba pentandra plant leaves were gathered in Visakhapatnam, Andhra Pradesh, India. The gathered plants were washed with refined water a few times until the soil particles are taken out. Later through washing with refined water, sorbents were sun dried until they became fresh, cut into little pieces, powdered and sieved. In the current review, 53, 75, 105, 125 and 152 µm size powders were utilized as sorbents with no other pre-medicines.

2.4 Optimization using Central Composite design

When the factors having the best effect on the reactions were distinguished, a Central Composite Design (CCD) was utilized to enhance these factors.

3. Results and discussions

3.1 Effect of shaking Time:

The gathering Decolorization tests were finished during 5–180 min by making various limits consistent for instance initial obsession 20 ppm, pH 7.0, partition/portion 0.5 g and temp. 30 °C. This impact is showed up in Fig. 3.1. It is clear from this Figure that take-up of the Aniline blue expanded from 5 to 20 min, that had gotten reliable on additional climbing of contact time. The most outrageous take-up of the Aniline blue at 20 min was 1.3 mg/g (65%). As such, 20 min shaking time was preferred as the best one**[9-10]**.

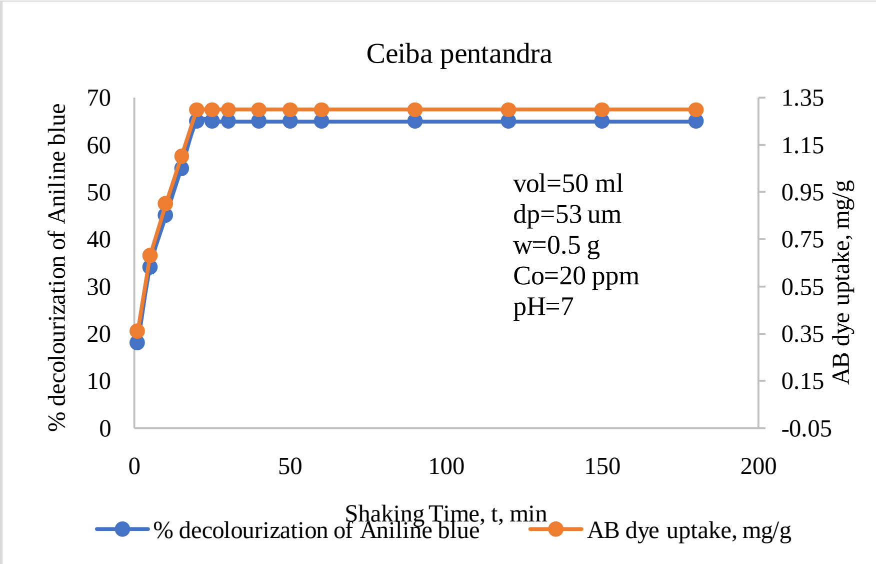

Fig. 3.1. Effect of time on % Decolorization of Aniline Blue dye

3.2 Effect of sorbent Size:

The assortments in % Decolorization of Aniline blue from the liquid course of action with Ceiba pentandra size are gotten. The results are drawn in fig. 3.2 with rate Decolorization of Aniline blue as a component of Ceiba pentandra size. The rate Decolorization is decreased from 65 % to 45 % (1.3 to 0.9 mg/g) as the Ceiba pentandra size lessens from 53 to 152 µm. This miracle is typical, as the size of the atom lessens, surface space of the Ceiba pentandraincreases; likewise, the number of dynamic objections on the Ceiba pentandra moreover augments**[11-12]**.

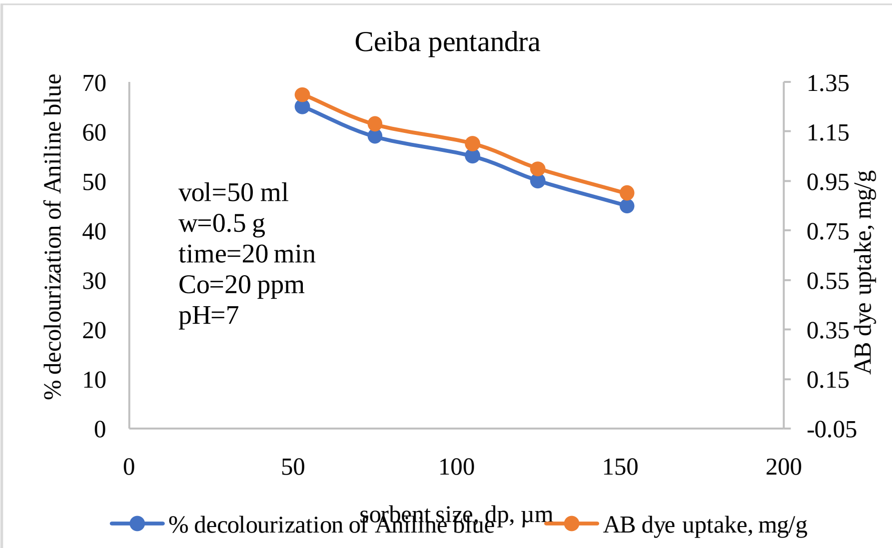

Fig. 3.2. Effect of size on % Decolorization of Aniline Blue dye

3.3 Effect of pH

The bunch Decolorization tests for the Aniline blue were done from 2 to 8 pH by making various limits consistent for instance contact time 20 min, divide/portion 0.5 g/L beginning concentration 20ppm and temperature 30 °C. This impact is showed up in Fig. 3.3. It is showing up from this Figure that from the start Decolorization of the Aniline blue pH was 4. which extended to 1.6 mg/g and 86 % at pH 4. Similarly, the Decolorization extended by growing pH (5 to 8). At high pH the sulfoyl social events of the Aniline blue left as anions, following to raised Decolorization. Regardless, it was lacking as an impressive part of water spring don't contain these pH regards**[13-14]**.

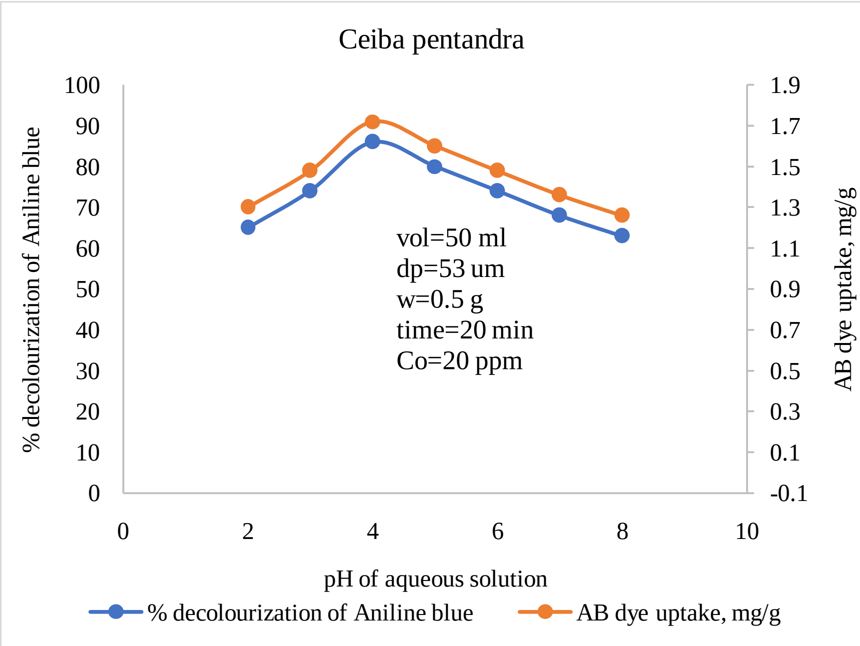

Fig. 3.3. Effect of pH on % Decolorization of Aniline Blue dye

3.4 Effect of Initial Concentration:

The obsession result of removal of Aniline blue was inspected using diverse concentrations (20 to 200 mg/L) while various variables were predictable for instance contact time 20 min, pH 4.0, dose 0.5 g/L and temperature 30 °C. The take-up of Aniline blue went from 86 to 50 % in 1.72 to 10mg/g (Fig. 3.4). It was predictable at raised conc. of Aniline blue. It is obviously shown that the take-up was reliant upon the start conc. of Aniline blue. It might be inferable from the open conceivable reasonable surface district on adsorbent at little conc., which reduced as the conc. of the Aniline blue extended**[15-16]**.

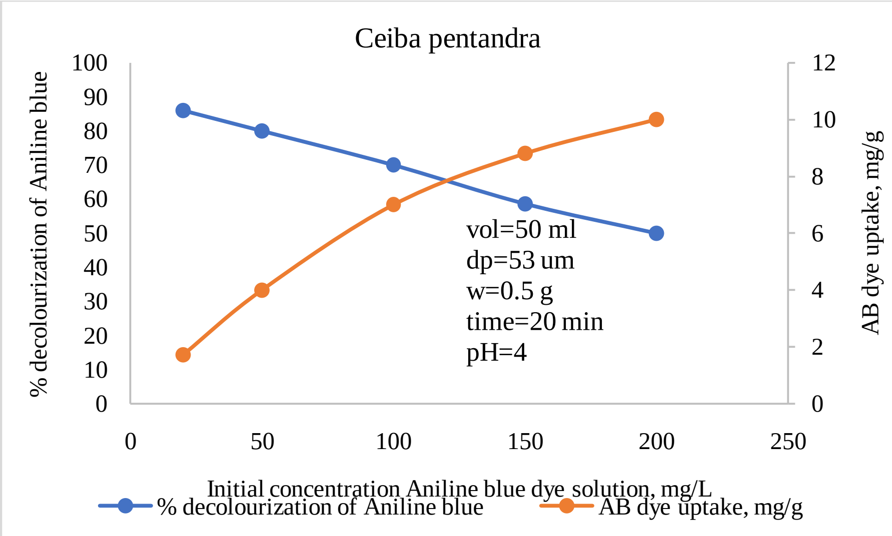

Fig. 3.4. Effect of concentration on % Decolorization of Aniline Blue dye

3.5 Effect of Dosage:

The bundle Decolorization tests for the Aniline blue were surrendered from 0.5 to 4.0 grams measurements by making various limits reliable i.e., pH 4, contact time 20 min, starting obsession 20ppm and temperature 30 °C. This impact is showed up in Fig. 3.5. It is showing up from this Figure that the take-up of the Aniline blue expanded from 0.5 to 1.5 grams part (86 to 94%) and 1.7 to 0.62 mg/g. It was inferable from satisfactory basic passage of the Ceiba pentandra surface regions at raised segment. Further extend in the bit of (1.5 to 4.0 gm) couldn't achieve additional Decolorization**[17-18]**.

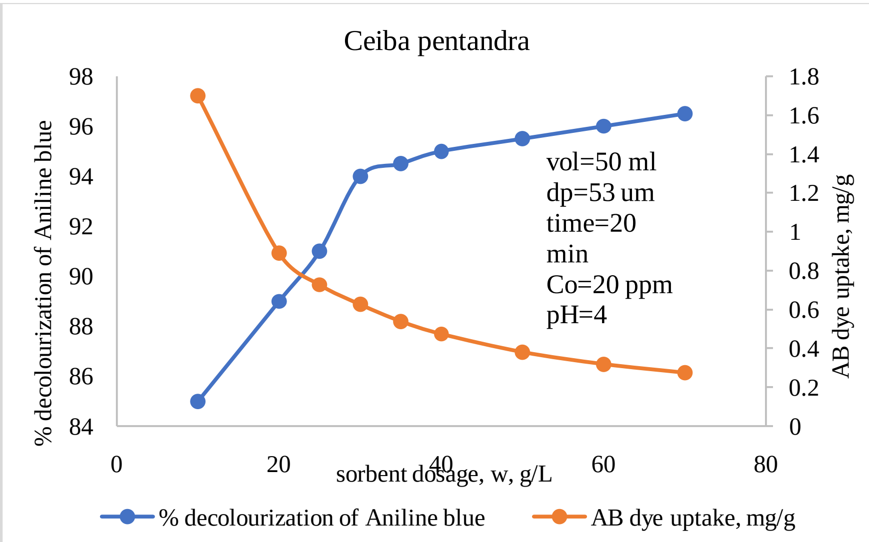

Fig. 3.5. Effect of dosage on % Decolorization of Aniline Blue dye

3.6 Effect of Temperature:

The bunch Decolorization tests for the Aniline blue were yielded from 10, 20, 30, 40 and 50 °C temperature by making various limits consistent for instance contact time 20 min,

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partition 0.5 g/L beginning conc. 20ppm, and pH 4.0. This impact is showed up in Fig. 6. It is showing up from this Figure that Decolorization was indistinguishable up to 20ppm obsession for every one of the temperatures (10, 20, 30, 40 and 50 °C). In any case, it changed by developing the temperature. It was in the solicitation for 30 °C 94% and 0.63 mg/g. Keeping these concentrations into thought, the Decolorization was believed to be exothermic. It might be inferable from the grow in the speed of scattering of Aniline blue askew the external line layer**[19-20]**.

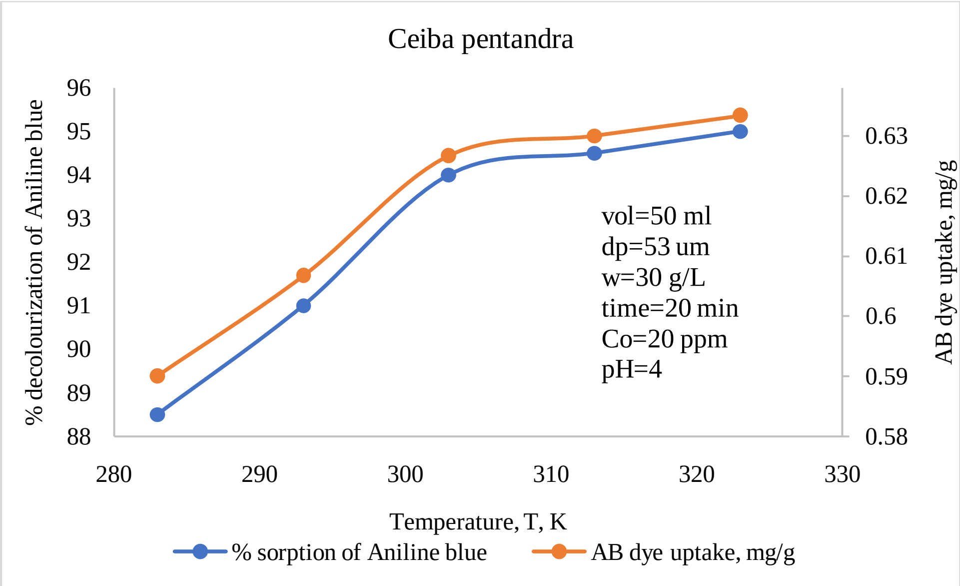

Fig. 3.6. Effect of temperature on % Decolorization of Aniline Blue dye

3.7 Optimization using Response Surface Methodology (RSM):

3.7.1 Optimization using CCD

The parameters that have greater influence over the response are to be identified so as to find the optimum condition for the Decolorization of AB dye. The quadratic model is used in the present study, to relate four independent variables and percentage Decolorization of AB dye. The regression equation for is % Decolorization of AB dye is function of pH (X_1), C_o (X_2), w (X_3) and T (X_4) **[21-22]**.

The variations in the corresponding coded values of four parameters and response are presented in table-3.1.

Table-3.1 Levels of different process variables in coded and un-coded form for % Decolorization of AB dye using Ceiba pentandra

Variable	Name	Range and levels				
		-2	-1	0	1	2
X_1	pH of aqueous solution	2	3	4	5	6
X_2	Initial concentration, C_o, mg/L	10	15	20	25	30
X_3	sorbent dosage, w, g/L	20	25	30	35	40
X_4	Temperature, T, K	283	293	303	313	323

The following equation represents multiple regression analysis of the experimental data for the Decolorization of AB dye:

$$Y = -1608.52 + 59.52\,X_1 + 59.52\,X_2 + 4.44\,X_3 + 5.19\,X_4 - 7.06\,X_1^2 - 0.12\,X_2^2 - 0.08\,X_3^2 - 0.02\,X_4^2 - 0.00\,X_1X_2 - 0.03\,X_1X_3 - 0.00\,X_1X_4 - 0.00\,X_2X_3 + 0.00\,X_2X_4 - 0.00\,X_3X_4$$

------ (3.1)

Table- 3.2 Results from CCD for AB dye Decolorization by Ceiba pentandra

Run no.	X_1, pH	X_2, C_o	X_3, W	X_4, T	% Decolorization of AB dye	
					Experimental	Predicted
1	3	15	25	293	72.00000	76.07167
2	3	15	25	313	75.18000	77.97917
3	3	15	35	293	73.78000	77.50250
4	3	15	35	313	76.73000	79.35000
5	3	25	25	293	74.37000	77.88417
6	3	25	25	313	77.42000	80.30667
7	3	25	35	293	75.77000	79.02500
8	3	25	35	313	78.92000	81.38750
9	5	15	25	293	76.88000	79.59750
10	5	15	25	313	79.48000	81.52500
11	5	15	35	293	77.96000	80.37333
12	5	15	35	313	80.57000	82.24083

13	5	25	25	293	78.68000	81.36000
14	5	25	25	313	82.34000	83.80250
15	5	25	35	293	79.46000	81.84583
16	5	25	35	313	83.00000	84.22833
17	2	20	30	303	70.00000	62.57417
18	6	20	30	303	72.00000	68.94083
19	4	10	30	303	85.56000	79.77250
20	4	30	30	303	88.27000	83.57250
21	4	20	20	303	90.82000	84.97417
22	4	20	40	303	91.47000	86.83083
23	4	20	30	283	92.78000	85.64250
24	4	20	30	323	93.28000	89.93250
25	4	20	30	303	94.00000	94.00000
26	4	20	30	303	94.00000	94.00000
27	4	20	30	303	94.00000	94.00000
28	4	20	30	303	94.00000	94.00000
29	4	20	30	303	94.00000	94.00000
30	4	20	30	303	94.00000	94.00000

Experimental conditions [Coded Values] and observed response values of central composite design with 2^4 factorial runs, 6 - central points and 8 - axial points. shaking time fixed at 50 min and sorbent size at 53 μm

Table-3.2 represents the results obtained in CCD. Response obtained from regression in eq. 4.6 in the form of ANOVA is presented. From the Fisher's F-test (F_{model}= 38160) and a very low probability value (P_{model}>F=0.000000), it is known from table–3.3 that the model is highly significant. At 5% level, the computed F-value ($F_{0.05\ (14.15)}$ = MS_{model}/MS_{error} = 38160) is greater than that of the tabular F-value ($F_{0.05\ (14.15)\ tabulars}$= 2.42), indicating that the treatment differences are significant

Table – 3.3ANOVA of AB dye Decolorization for entire quadratic model

Source of variation	SS	Df	Mean square (MS)	F-value	*P*> F
Model	1621.133	14	115.7945	192990	0.00000
Error	0.009	15	0.0006		
Total	1621.133				

df- degree of freedom; SS- sum of squares; F- factor F; *P*- probability

R^2=0.99999; R^2 (adj):0.99998:

Table – 3.4Calculated regression coefficients for the AB dye Decolorization onto Ceiba pentandra

Terms	Regression coefficient	Standard error of the coefficient	t-value	*P*-value
Mean/Intercept	-1608.52	4.630642	-347.37	0.000000
Dosage, w, g/L (L)	59.52	0.195329	304.73	0.000000
Dosage, w, g/L (Q)	-7.06	0.004699	-1503.13	0.000000
Conc, Co, mg/L (L)	4.44	0.039066	113.63	0.000000
Conc, Co, mg/L (Q)	-0.12	0.000188	-655.81	0.000000
pH (L)	5.19	0.039579	131.24	0.000000
pH (Q)	-0.08	0.000188	-431.81	0.000000
Temperature, T, K (L)	9.50	0.028927	328.26	0.000000
Temperature, T, K (Q)	-0.02	0.000047	-331.25	0.000000
1L by 2L	-0.00	0.001230	-2.44	0.027674
1L by 3L	-0.03	0.001230	-27.02	0.000000
1L by 4L	-0.00	0.000615	-2.03	0.060272
2L by 3L	-0.00	0.000246	-12.80	0.000000
2L by 4L	0.00	0.000123	21.13	0.000000
3L by 4L	-0.00	0.000123	-1.02	0.325771

[a]insignificant ($P \geq 0.05$)

$\boldsymbol{Y = -1608.52 + 59.52\, X_1 + 59.52\, X_2 + 4.44\, X_3 + 5.19\, X_4 - 7.06\, X_1^2 - 0.12\, X_2^2 - 0.08\, X_3^2 - 0.02\, X_4^2 - 0.00\, X_1X_2 - 0.03\, X_1X_3 - 0.00\, X_1X_4 - 0.00\, X_2X_3 + 0.00\, X_2X_4 - 0.00\, X_3X_4}$ **------ (3.2)**

The larger the value of t and smaller the value of P *(>0 &<0.05)* represents the more significant of the corresponding coefficient term. The 't' and 'P' values are viewed from table-3.4. It is found that the X_1, X_2, X_3, X_4, X_1^2, X_2^2, X_3^2, X_4^2,X_1X_2, X_1X_3, X_2X_3 and X_2X_4 have high significance (as 0<P>0.05) to explain the individual and interaction Impact of independent variables on AB dye Decolorization. The other terms (X_1X_2, X_1X_4, X_2X_3,X_2X_4 and X_3X_4) are insignificant and are not required to explain Decolorization. A synergistic Impact is indicated by positive sign of the coefficient which means response increases with an increase in Impact, while an antagonistic Impact is indicated by a negative sign which means response decreases with an increase in Impact. In the observed response values, a measure of the model's variability is provided by the correlation coefficient (R^2). In the present study, the value of the regression coefficient (R^2 = 0.9999) for eq. 3.2 indicates that 0.001 % of the total variations are not satisfactorily explained by the model. It is proved from that table that $F_{statistics}$ value for entire model is higher. This large value means that % Decolorization can be adequately explained by the model equation. Generally, P values lower than 0.05 indicates that the model is considered to be statistically significant at 95% confidence level. The % Decolorization prediction from the model is shown in table-3.4.

It is implied from table-3.4 that all the squared terms of all the variables and the linear terms are significant (P < 0.05). Among the interaction terms, all the terms (P < 0.05) are insignificant on the Decolorization capacity. Fig. 3.7 and Fig. 3.8 shows pareto chart and experimental and predicted data of residual values. It could be seen that the experimental points are reasonably aligned suggesting normal distribution.

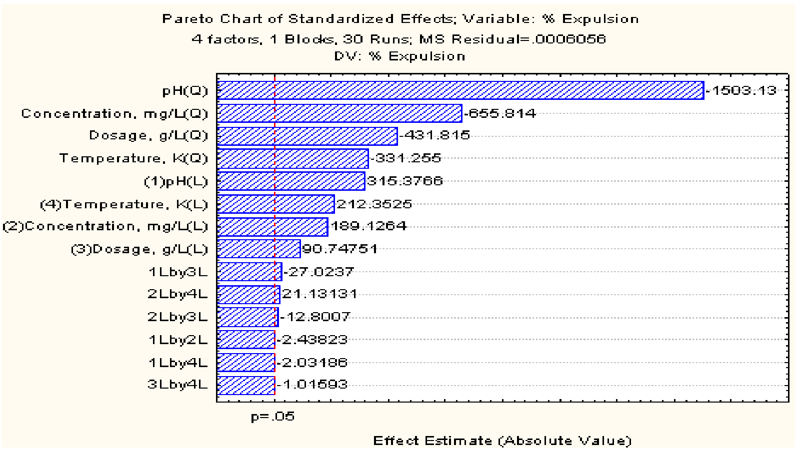

Fig. 3.7. Pareto Chart

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The optimal set of conditions for maximum percentage Decolorization of AB dye is pH = 4.1115, initial AB dye concentration = 20.8000 mg/L, sorbent dosage = 30.5298 g/L, and temperature = 306.5157 K are obtained from critical values table. The extent of Decolorization of AB dye at these optimum conditions was 94.37783 %. It is evident that experimental values of % Decolorization are in close agreement with that of predicted by Central Composite Design. Experiments are conducted in triplicate with the above predicted optimal set of conditions and the % Decolorization of AB dye is 94 %, which is closer to the predicted % Decolorization.

3.7.2 Interaction Impacts of Decolorization variables:

The three-dimensional view of response surface contour plots [Fig. 3.9 (a) to (f)] show % Decolorization as a function of for various combinations of independent variables. The plots are represented as a function of two factors at a time keeping other factors fixed at zero level.

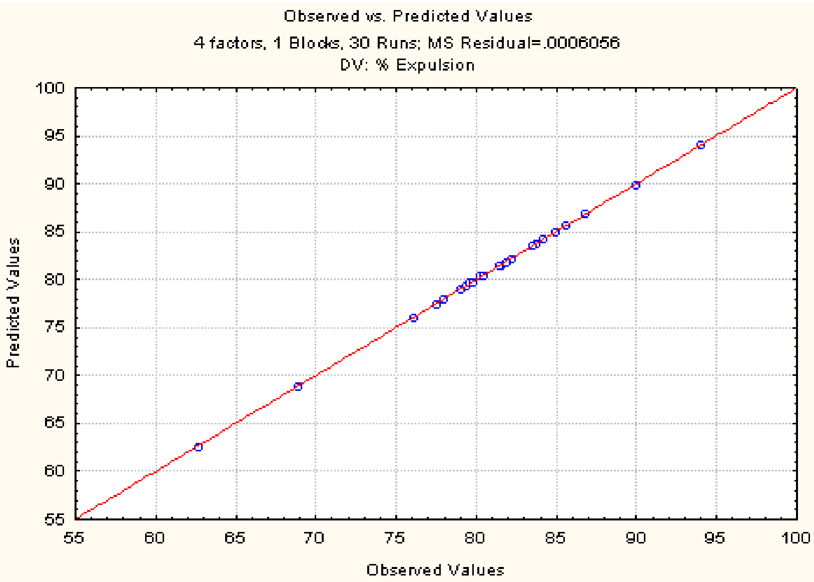

Fig. 3.8. Normal probability plot for AB dye

It is found from the response surface plots that the % Decolorization is maximal at low and high levels of the input variables. However, there exists a region where neither an increasing nor a decreasing trend in % Decolorization is observed. The Decolorization variables should be optimum to maximize the % Decolorization. The % Decolorization of AB dye is strongly influenced by the pH as evident from figs. 3.9 (a) & (b).

The predicted optimal set of conditions for percentage Decolorization of AB dye is

pH of aqueous solution	=	4.1115
Initial AB dye concentration	=	20.8000 mg/L
sorbent dosage	=	30.5298 g/L

Temperature = 306.5157 K

% Decolorization of AB dye = 94.37783

The optimal set of conditions obtained with CCD are shown in table-3.4 along with experimental values. The surface contour plots reveal that maximum % Decolorization was achieved at optimum conditions with dark red color indication.

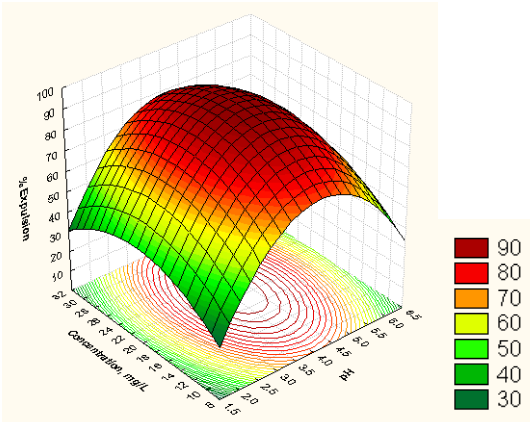

Fig. 3.9 (a) Surface contour plot for the Impacts of pH and initial AB dye concentration on % Decolorization

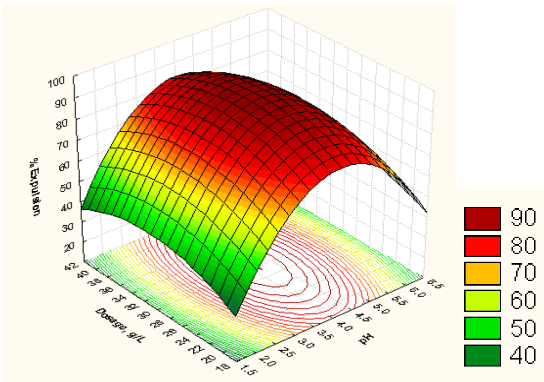

Fig. 3.9 (b) Surface contour plot for the Impacts of pH and dosage on % Decolorizationof AB dye

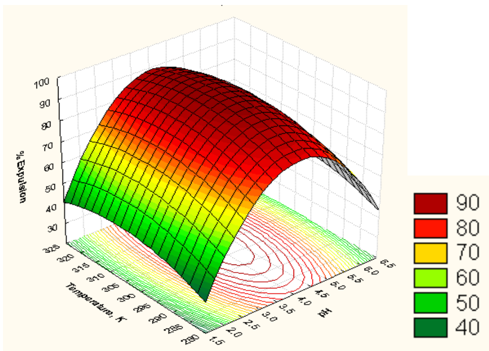

Fig. 3.9 (c) Surface contour plot for the Impacts of pH and Temperature on % Decolorization of AB dye

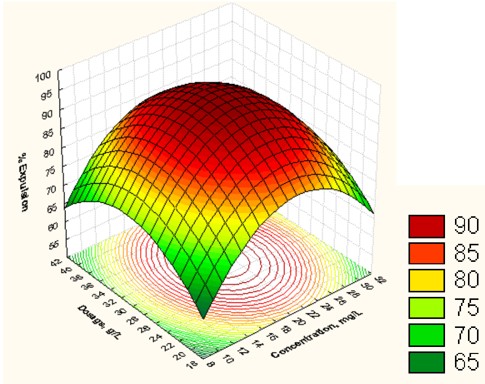

Fig. 3.9 (d) Surface contour plot for the Impacts of initial concentration and dosage on % Decolorization of AB dye

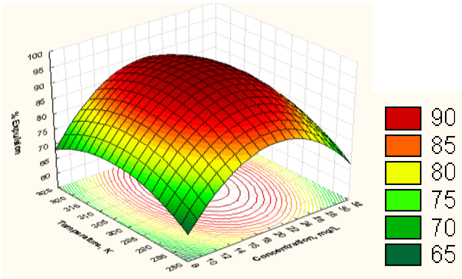

Fig. 3.9 (e) Surface contour plot for the Impacts of initial concentration and Temperature on % Decolorization of AB dye

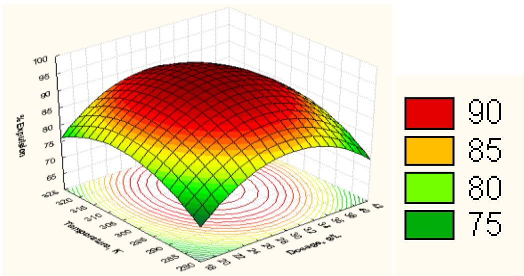

Fig. 3.9 (f) Surface contour plot for the Impacts of Dosage and Temperature on % Decolorizationof AB dye

Table – 3.5Comparison between optimum values from CCD and experimentation

Variable	CCD	Experimental value
pH of aqueous solution	4.1115	4
Initial Aniline blue concentration, mg/L	20.8000	20
Decolorization dosage, w, g/L	30.5298	30
Temperature, K	306.1201	303
% Decolorization	94.37783	94

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Conclusions

The equilibrium agitation time for AB dye Decolorizationis 20 minutes (65%).The optimum dosage for Decolorization is 30 g/L (0.626 mg/g).Maximum extent of Decolorization is noted at pH = 4 (86%). The maximum uptake capacity of 0.626 mg/g is obtained at 303 K.With an increase in the initial concentration of RB dye (20 to 200 mg/L) in the aqueous solution, the percentage Decolorization of RB dye from the aqueous solution is decreased (86 to 75 %). From the predicted values of RSM results, maximum Decolorization of AB dye (94.37783 %) is observed when the processing parameters are set as pH = 4.1115, w = 30.5298 g/L, Co = 20.8000 mg/L and T = 306.1201 K.

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