

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

In this present study, the removal of Crystal Violet (CV) dye from an aqueous solution and also from a dyeing industrial effluent were carried out using two adsorbents namely, activated carbon prepared from the pods of *Leucaena leucocephala* (ALL) and Commercial Activated Carbon (CAC) by adsorption technique. Batch experiments were conducted and the parameters which influence the extent of adsorption such as initial concentration of the Crystal Violet dye solution, pH, adsorbent dosage, contact (agitation) time and temperature were investigated. The results were used to evaluate the optimum conditions for the removal of the Crystal Violet dye and to examine the efficiency of the low-cost adsorbent prepared from the pods of *Leucaena leucocephala* for the removal of Crystal Violet dye from an aqueous solution and also from a dyeing industrial effluent containing Crystal Violet dye.

4.1 EFFECT OF VARIATION OF THE INITIAL CONCENTRATION OF CRYSTAL VIOLET DYE SOLUTION ON THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION AND ALSO FROM A DYEING INDUSTRIAL EFFLUENT CONTAINING CRYSTAL VIOLET DYE

The initial concentration of aqueous solution of Crystal Violet dye was varied and batch mode experiments were performed at 32⁰ C to study the effect of initial concentration of Crystal Violet dye solution on Crystal Violet dye removal. The results are shown in the Tables 1 & 2. Figures 10 & 11 clearly depict the effect of initial concentration of Crystal Violet dye solution and agitation time on Crystal Violet dye removal with the adsorbents ALL and CAC. The results indicate that the percentage removal of Crystal Violet dye increases with decrease in the initial concentration of Crystal Violet dye solution. The results obtained shows an increase in the percentage removal of Crystal Violet dye from 42.61 to 72.07 (Table- 1) with the adsorbent ALL and from 59.64 to 94.48 (Table- 2) with the adsorbent CAC in 180 minutes of contact time, when the initial concentration of Crystal Violet dye solution used was varied from 300 to 150 mg/L. This is due to the fact that the amount of adsorbent remains constant the number of adsorption sites is constant, so by increasing the amount of CV dye initial

concentration, the percentage removal decreases due to the limitation of the adsorption sites (**Farooqui *et al.*, 2012**).

The initial concentration of the industrial effluent containing Crystal Violet dye was varied and batch mode experiments were performed at 32⁰ C using 600 mg of the adsorbent ALL and 150 mg of the adsorbent CAC at pH 9.0 ± 0.02 to study the effect of initial concentration of Crystal Violet dye solution on Crystal Violet dye removal. An increase in the percentage removal of Crystal Violet dye from 39.86 to 47.54 (Table 3) with the adsorbent ALL and from 47.11 to 55.74 (Table 4) with the adsorbent CAC in 180 minutes of contact time, when the initial concentration of Crystal Violet dye was varied from 200 to 100 mg/L for the dyeing industrial effluent used in this study. The results are graphically represented in the Figures 12 & 13.

Similar observations have been reported for the adsorption of Crystal Violet dye from an aqueous solution onto *Syzygium cumini* seed and commercial activated carbon as an adsorbent (**Meenakshi Sundaram *et al.*, 2012**), activated Golbasi Lignite as an adsorbent (**Depci *et al.*, 2012**) and rice husk carbon as an adsorbent (**Verma and Mishra, 2010**).

TABLE- 1

EFFECT OF THE INITIAL CONCENTRATION OF CRYSTAL VIOLET DYE SOLUTION FOR THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO ALL

Conditions:

Adsorbent dosage - 200 mg

Temperature - 32⁰ C

Contact time - 10 to 180 minutes

Time (minutes)	% Adsorption of Crystal Violet dye			
	Initial Concentration of Crystal Violet dye solution			
	150 mg/L	200 mg/L	250 mg/L	300 mg/L
10	34.41	31.05	20.56	10.86
20	42.85	36.10	27.60	15.20
30	50.00	43.07	31.28	21.05
40	53.89	50.03	34.96	23.97
50	57.79	54.46	38.03	26.31
60	62.33	58.25	41.87	28.97
90	64.28	60.78	44.78	30.40
120	66.23	63.31	48.76	35.67
150	68.18	66.47	52.73	39.76
180	72.07	69.00	55.34	42.61

TABLE- 2

EFFECT OF THE INITIAL CONCENTRATION OF CRYSTAL VIOLET DYE SOLUTION FOR THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO CAC

Conditions:

Adsorbent dosage - 50 mg

Temperature - 32⁰ C

Contact time - 10 to 180 minutes

Time (minutes)	% Adsorption of Crystal Violet dye			
	Initial Concentration of Crystal Violet dye solution			
	150 mg/L	200 mg/L	250 mg/L	300 mg/L
10	64.13	44.00	34.59	32.73
20	77.94	51.33	40.89	38.18
30	80.69	59.34	44.66	42.53
40	83.45	63.34	48.43	44.63
50	86.21	67.34	49.69	46.67
60	87.59	69.34	50.95	47.90
90	91.72	76.67	59.12	49.70
120	93.10	78.67	67.30	53.49
150	94.48	80.67	67.93	56.36
180	94.48	84.00	70.44	59.64

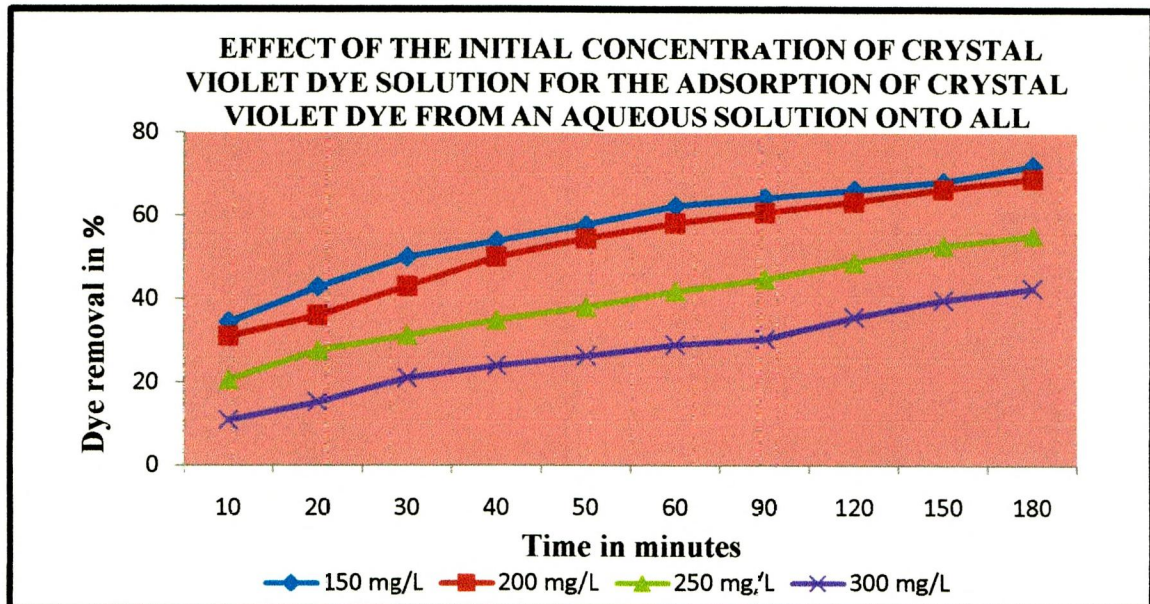


Figure- 10

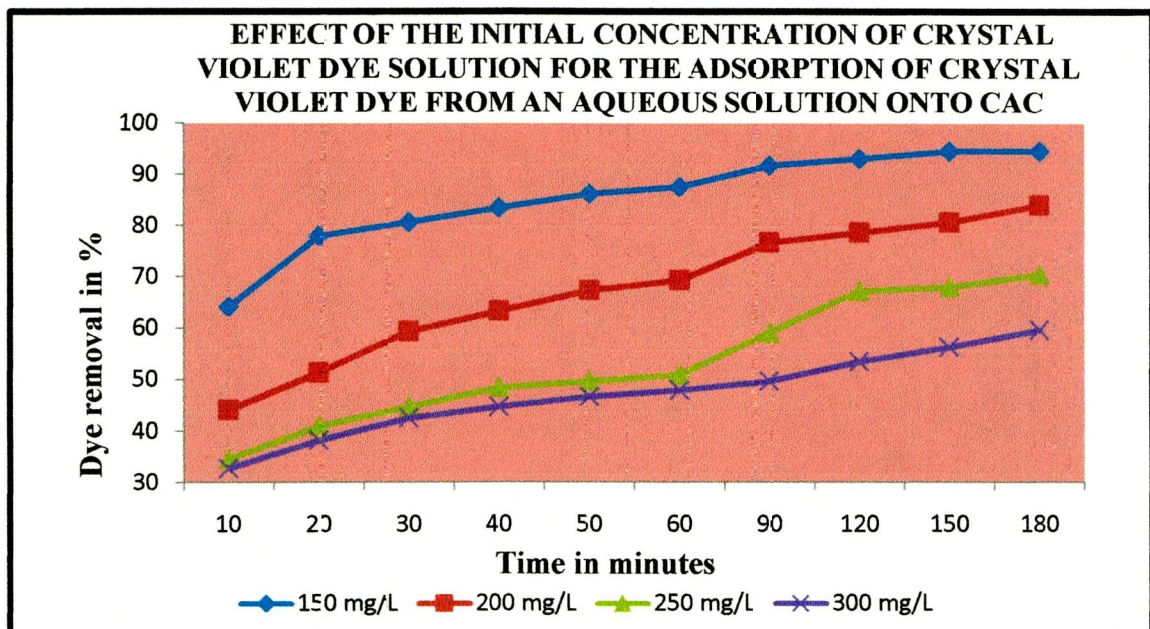


Figure- 11

TABLE- 3

EFFECT OF THE INITIAL CONCENTRATION OF CRYSTAL VIOLET DYE SOLUTION FROM A DYEING INDUSTRIAL EFFLUENT FOR THE ADSORPTION OF CRYSTAL VIOLET DYE ONTO ALL

Conditions:

Adsorbent dosage - 600 mg
pH - 9.0 ± 0.02
Temperature - 32⁰ C
Contact time - 10 to 180 minutes

Time (minutes)	% Adsorption of Crystal Violet dye		
	Initial Concentration of Crystal Violet dye solution		
	100 mg/L	150 mg/L	200 mg/L
10	18.04	15.44	13.78
20	24.59	22.36	20.30
30	30.33	25.43	23.20
40	31.97	26.97	24.65
50	34.43	28.51	26.10
60	37.71	31.58	28.27
90	40.16	34.66	31.89
120	42.62	37.73	34.79
150	45.08	40.81	37.69
180	47.54	43.88	39.86

TABLE- 4

EFFECT OF THE INITIAL CONCENTRATION OF CRYSTAL VIOLET DYE SOLUTION FROM A DYEING INDUSTRIAL EFFLUENT FOR THE ADSORPTION OF CRYSTAL VIOLET DYE ONTO CAC

Conditions:

Adsorbent dosage - 150 mg
pH - 9.0 ± 0.02
Temperature - 32⁰ C
Contact time - 10 to 180 minutes

Time (minutes)	% Adsorption of Crystal Violet dye		
	Initial Concentration of Crystal Violet dye solution		
	100 mg/L	150 mg/L	200 mg/L
10	26.23	25.38	21.02
20	33.61	30.82	27.55
30	36.89	32.35	29.72
40	39.34	36.20	32.62
50	42.62	39.27	35.51
60	45.08	42.35	37.69
90	48.36	45.42	39.86
120	50.82	47.73	42.04
150	53.28	51.57	45.66
180	55.74	53.88	47.11

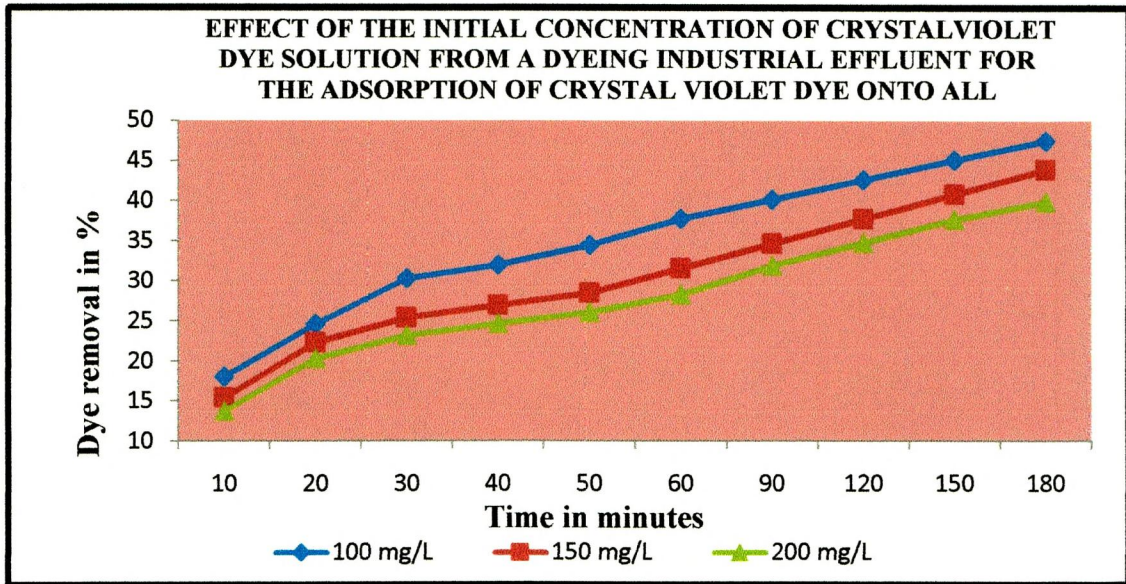


Figure- 12

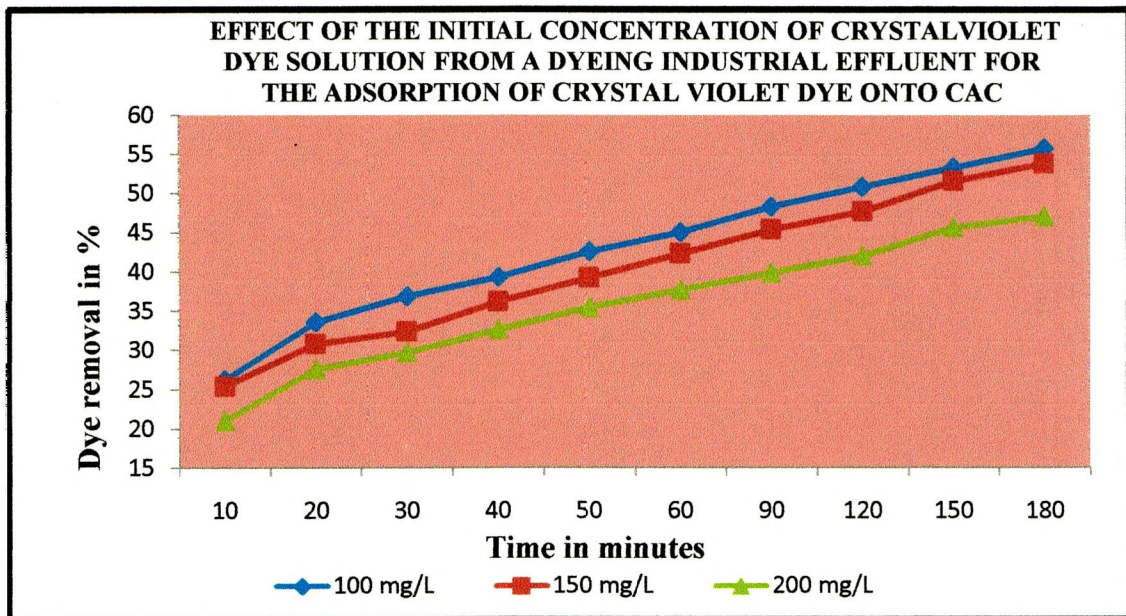


Figure- 13

4.2 EFFECT OF pH ON CRYSTAL VIOLET DYE REMOVAL

The pH of the aqueous solution is an important parameter which controls the adsorption between the adsorbent and aqueous interface. Thus the role of hydrogen ion concentration was studied for the adsorption of Crystal Violet dye at different pH (5.0 to 9.0) using 200 mg of the adsorbent ALL and 50 mg of the adsorbent CAC at 32⁰ C by batch mode adsorption studies. The experimental results obtained for the effect of variation of pH on the percentage removal of Crystal Violet dye from an aqueous solution using the adsorbents ALL and CAC are shown in the Tables 5 & 6. The percentage removal of Crystal Violet dye increased from 37.80 to 46.45 with the adsorbent ALL and from 65.77 to 71.14 with the adsorbent CAC as the pH was varied from 5.0 to 9.0 in 180 minutes of contact time. The graphical representations of variation of pH for the adsorption of Crystal Violet dye in this study are shown in the Figures 14 & 15.

The increase in pH increases the amount of dye adsorption. It depends upon the nature of surface functional group of the adsorbent and the nature of the dye (**Meenakshi Sundaram *et al.*, 2012**). At higher pH, the surface charge density on the adsorbent changes and as a result the adsorbent becomes negatively charged resulting in an enhanced attraction between the positively charged dye molecule and the adsorbent surface (**Gamal O. El- Sayed *et al.*, 2011**).

Similar results have been noticed for the removal of Crystal Violet dye from an aqueous solution using adsorbents such as Fly ash (**Semra Coruh *et al.*, 2012**), Sugarcane stalks (**Gamal O. El- Sayed *et al.*, 2011**) and Ricinus Communis Pericarp Carbon (**Pattabhi *et al.*, 2009**).

TABLE- 5**EFFECT OF pH FOR THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO ALL****Conditions:**

Adsorbent dosage - 200 mg
Temperature - 32⁰ C
Concentration of dye solution - 300mg/L
Contact time - 10 to 180 minutes

Time (minutes)	% Adsorption of Crystal Violet dye				
	pH 5.0	pH 6.0	pH 7.0	pH 8.0	pH 9.0
10	8.33	11.62	13.88	17.15	20.23
20	13.36	17.15	18.92	22.12	26.24
30	17.81	22.67	22.80	25.98	30.06
40	22.25	25.43	25.47	29.30	33.34
50	25.58	27.62	28.19	32.61	36.62
60	28.36	29.30	31.70	34.82	38.26
90	31.13	30.95	34.93	37.03	39.90
120	33.36	33.72	36.72	39.24	41.54
150	36.13	37.03	38.56	40.90	43.18
180	37.80	39.24	41.69	43.10	46.45

TABLE- 6**EFFECT OF pH FOR THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO CAC****Conditions:**

Adsorbent dosage	- 50 mg
Temperature	- 32 ⁰ C
Concentration of dye solution	- 300mg/L
Contact time	- 10 to 180 minutes

Time (minutes)	% Adsorption of Crystal Violet dye				
	pH 5.0	pH 6.0	pH 7.0	pH 8.0	pH 9.0
10	37.58	38.64	39.19	40.95	42.96
20	42.28	45.20	47.97	49.67	50.34
30	44.29	48.63	52.02	53.70	55.04
40	46.30	52.05	54.05	56.38	57.05
50	48.99	54.79	56.75	57.72	59.74
60	51.67	56.85	60.13	61.75	62.42
90	56.37	59.59	62.16	63.76	65.10
120	59.73	63.01	64.18	66.45	67.12
150	63.10	65.75	66.89	67.79	69.13
180	65.77	67.12	68.91	69.80	71.14

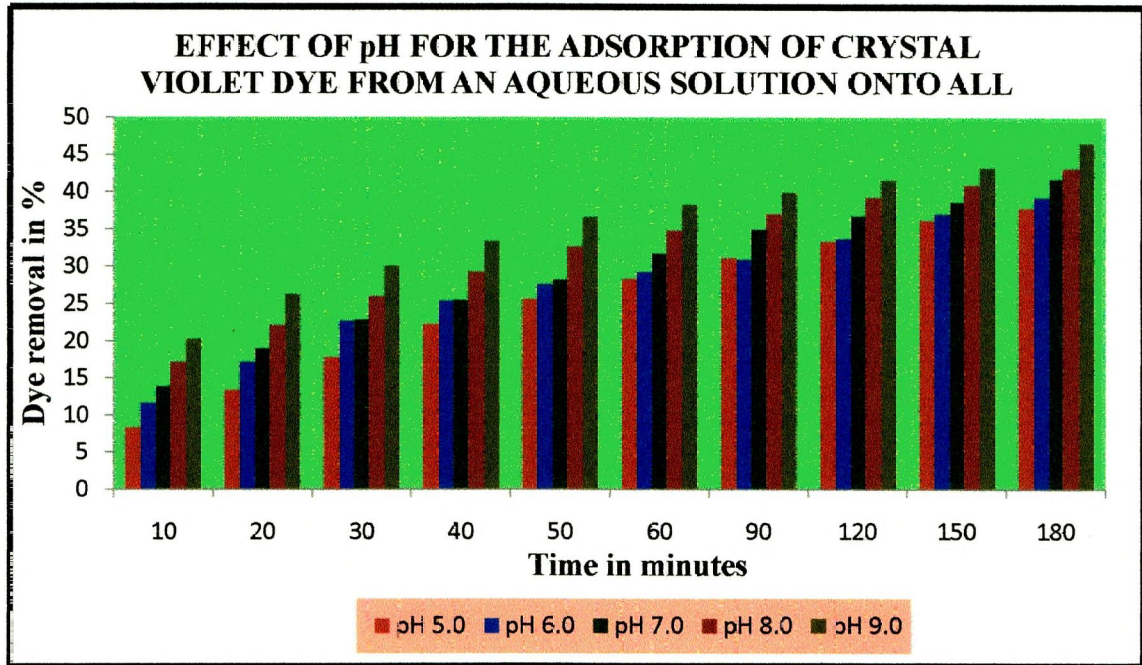


Figure- 14

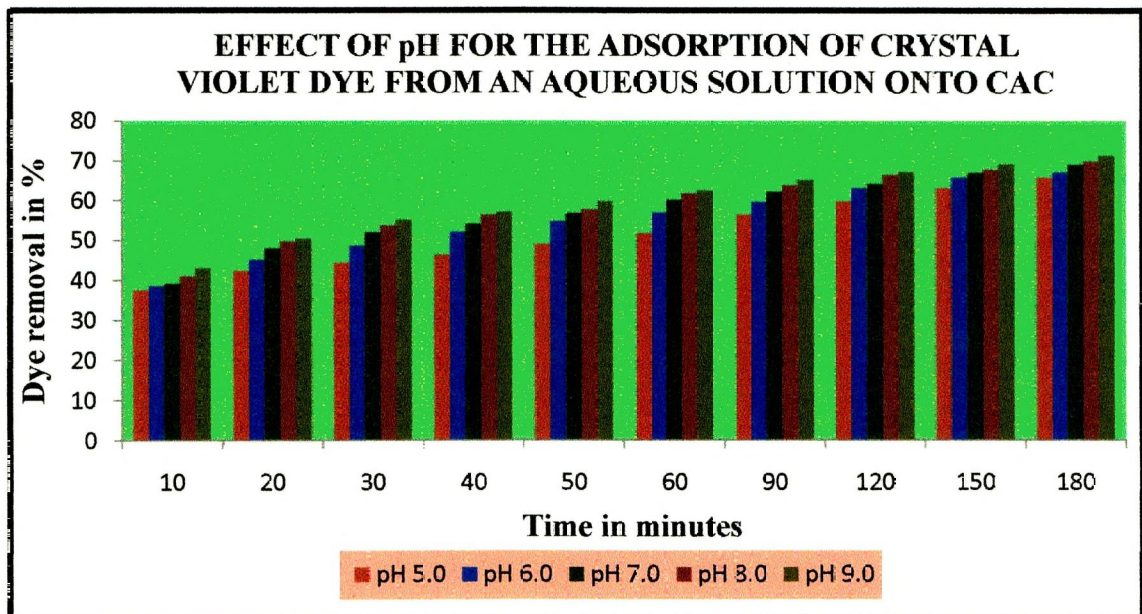


Figure- 15

4.3 EFFECT OF THE ADSORBENT DOSAGE ON CRYSTAL VIOLET DYE REMOVAL

The effect of variation of adsorbent dosage on Crystal Violet dye removal from an aqueous solution was studied by conducting batch experiments at 32⁰ C and at pH 9.0 ± 0.02. It was found that the percentage removal of Crystal Violet dye increased with increase in the adsorbent dosage. The results obtained are shown in the Tables 7 & 8 and graphically represented in the Figures 16 & 17. The percentage removal of Crystal Violet dye increased from 46.45 to 53.70 when the adsorbent, ALL dosage was varied from 200 to 500 mg and similarly the percentage removal of Crystal Violet dye increased from 71.14 to 97.87 when the adsorbent, CAC dosage was varied from 50 to 125 mg using 300 mg/L of the crystal Violet dye solution.

The increase in percentage adsorption of CV dye with increase in the adsorbent dose was due to increased adsorbent surface area and availability of more adsorption sites (**Gamal O. El- Sayed *et al.*, 2011**). Similar results were noticed for the removal of Crystal Violet dye from aqueous solution using low- cost adsorbents namely Cassia siamea, Albizia labbeck, Nerium indicum, Durauta erecta and Potato husk (**Farooqui *et al.*, 2012**) and Phragmites australis as an adsorbent (**Shouman and Rashwan, 2012**).

TABLE- 7**EFFECT OF THE CARBON DOSAGE FOR THE ADSORPTION OF
CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO ALL****Conditions:**

Temperature	- 32 ⁰ C
pH	- 9.0 ± 0.02
Concentration of dye solution	- 300mg/L
Contact time	- 10 to 180 minutes

Time (minutes)	% Adsorption of Crystal Violet dye			
	Adsorbent dosage			
	200 mg	300 mg	400 mg	500 mg
10	20.23	22.83	24.17	26.19
20	26.24	26.86	28.20	28.87
30	30.06	30.88	32.22	32.90
40	33.34	34.24	34.91	35.58
50	36.62	38.26	39.61	41.62
60	38.26	40.95	42.29	42.96
90	39.90	44.30	44.97	46.32
120	41.54	46.99	48.33	49.00
150	43.18	49.67	51.01	51.68
180	46.45	52.35	53.03	53.70

TABLE- 8

**EFFECT OF THE CARBON DOSAGE FOR THE ADSORPTION OF
CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO CAC**

Conditions:

Temperature - 32⁰ C
pH - 9.0 ± 0.02
Concentration of dye solution - 300mg/L
Contact time - 10 to 180 minutes

Time (minutes)	% Adsorption of Crystal Violet dye			
	Adsorbent dosage			
	50 mg	75 mg	100 mg	125 mg
10	42.96	47.53	58.16	71.64
20	50.34	55.33	65.25	78.02
30	55.04	61	69.51	82.27
40	57.05	64.55	72.34	83.69
50	59.74	67.38	74.47	85.82
60	62.42	70.22	77.31	89.36
90	65.1	73.05	79.43	92.2
120	67.12	75.18	82.27	94.32
150	69.13	78.02	85.11	96.45
180	71.14	80.14	86.52	97.87

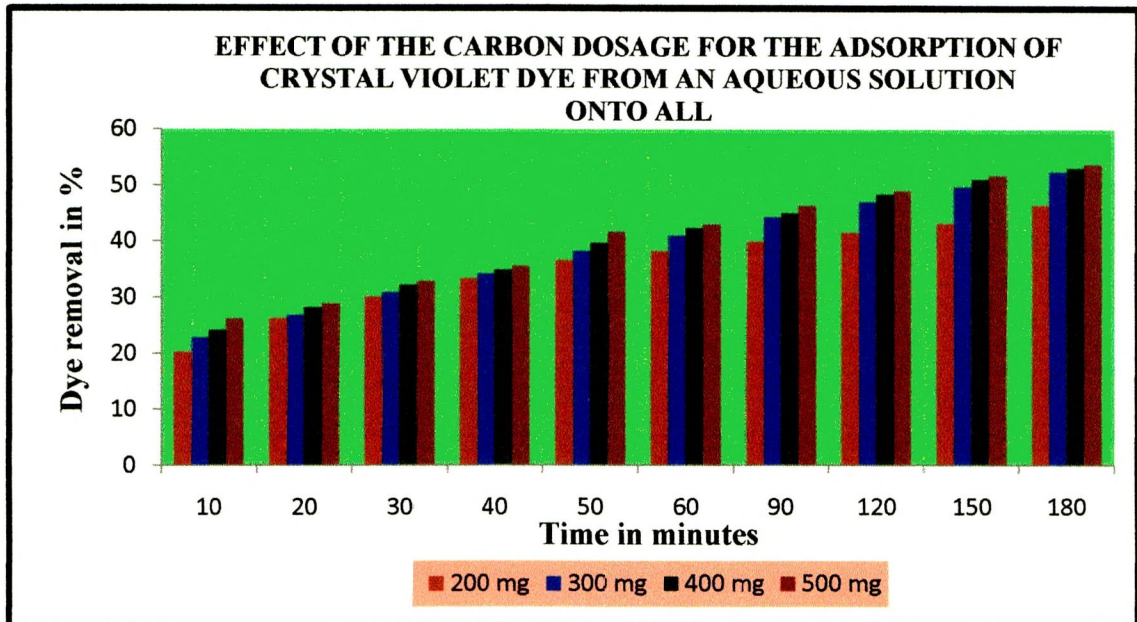


Figure- 16

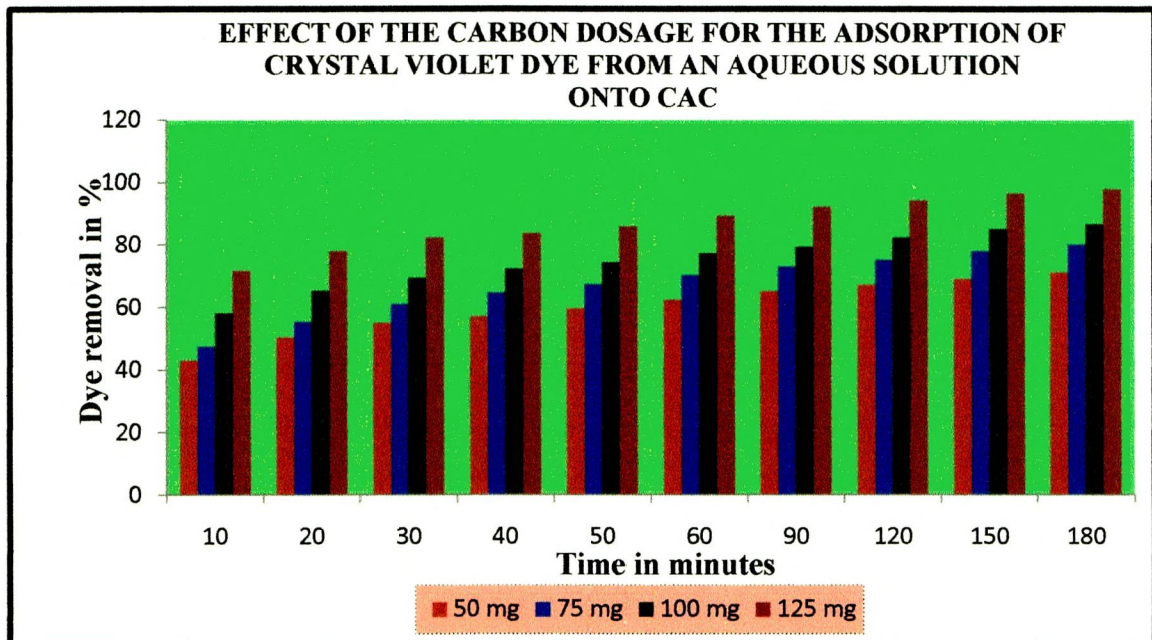


Figure- 17

4.4 EFFECT OF TEMPERATURE ON CRYSTAL VIOLET DYE REMOVAL

Temperature has an important effect on the adsorption process. Batch adsorption studies were carried out at $\text{pH } 9.0 \pm 0.02$ for various temperatures (295, 305 and 315 K) with the 200 mg of adsorbent ALL and 50 mg of adsorbent CAC. The percentage removal of Crystal Violet dye increased from 45.79 to 55.01 as the temperature was varied from 295 to 315 K with 200 mg of the adsorbent ALL and the percentage removal of Crystal Violet dye increased from 69.80 to 78.73 as the temperature was varied from 295 to 315 K with 50 mg of the adsorbent CAC. The results are shown in Tables 9 &10 and the graphical representations are shown in the Figures 18 to 21.

As temperature increased a strong tendency for the formation of monolayer adsorption process occurs. The increase in temperature would increase the mobility of the large dye ions as well as produce a swelling effect within the internal structure of adsorbent, thus enabling the large dye molecules to penetrate further and cause an increase in the diffusion rate of the adsorbate into the pores and decrease in the viscosity of the solution. In addition, changing the temperature will change the equilibrium capacity of the adsorbent for a particular adsorbate (**Mona A. Shouman *et al.*, 2012** and **Satish Patil *et al.*, 2011**).

Similar results were noticed for the removal of Crystal Violet dye from an aqueous solution using Chitosan as an adsorbent (**Mona A. Shouman *et al.*, 2012**), Rice husk as an adsorbent (**Verma and Mishra, 2010**) and Sugarcane stalks as an adsorbent (**Gamal O. El- Sayed *et al.*, 2011**).

TABLE- 9**EFFECT OF TEMPERATURE FOR THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO ALL****Conditions:**

Adsorbent dosage	- 200 mg
pH	- 9.0 ± 0.02
Concentration of dye solution	- 300mg/L
Contact time	- 10 to 180 minutes

Time (minutes)	% Adsorption of Crystal Violet dye		
	Temperature		
	295 K	305 K	315 K
10	16.92	20.23	28.91
20	22.56	26.24	33.36
30	26.08	30.06	36.13
40	29.60	33.34	39.46
50	32.41	36.62	42.80
60	34.52	38.26	45.02
90	37.34	39.90	47.24
120	40.16	41.54	50.02
150	42.97	43.18	52.24
180	45.79	46.45	55.01

TABLE- 10**EFFECT OF TEMPERATURE FOR THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO CAC****Conditions:**

Adsorbent dosage	- 50 mg
pH	- 9.0 ± 0.02
Concentration of dye solution	- 300mg/L
Contact time	- 10 to 180 minutes

Time (minutes)	% Adsorption of Crystal Violet dye		
	Temperature		
	295 K	305 K	315 K
10	36.24	42.96	50.37
20	42.97	50.34	57.46
30	46.32	55.04	60.29
40	52.35	57.05	64.55
50	56.33	59.74	66.67
60	60.41	62.42	69.51
90	63.09	65.10	71.64
120	65.77	67.12	74.47
150	67.79	69.13	76.60
180	69.80	71.14	78.73

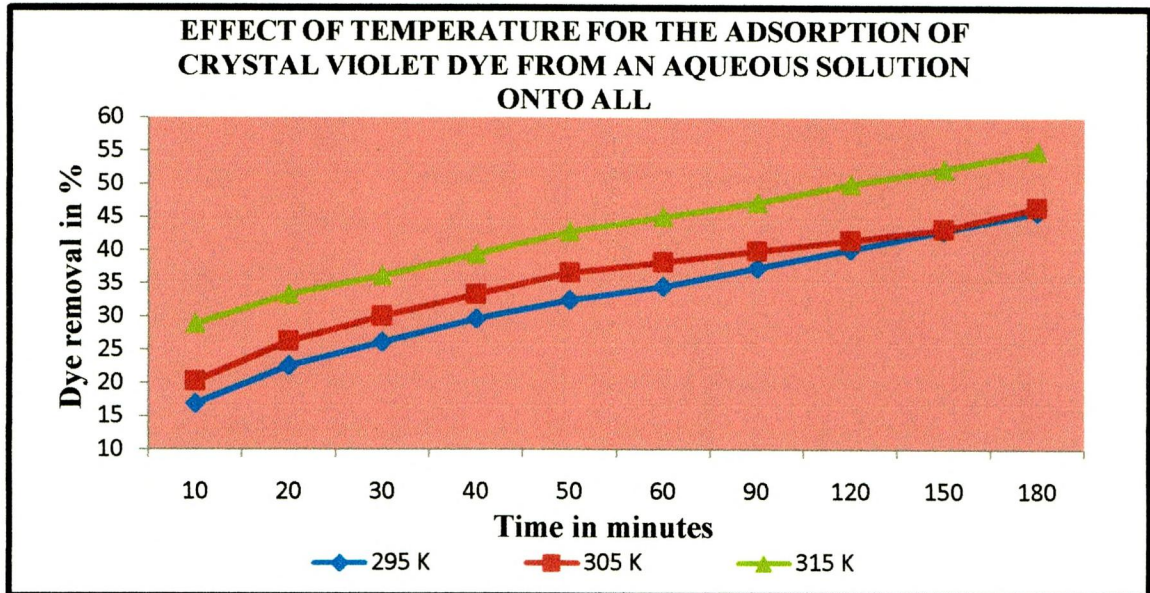


Figure- 18

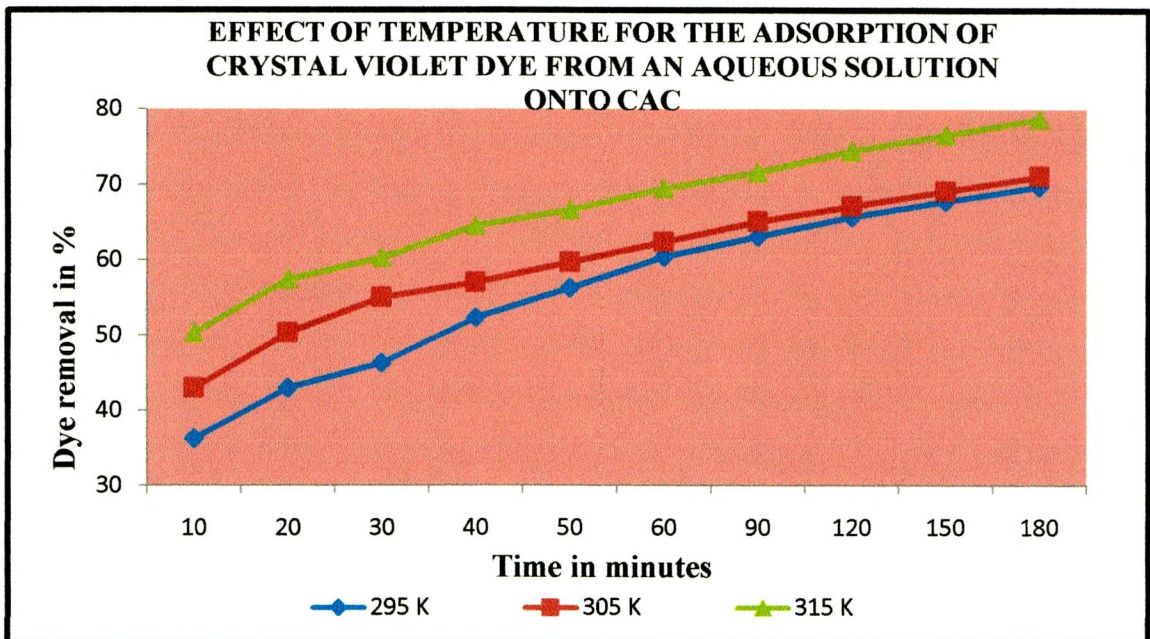


Figure- 19

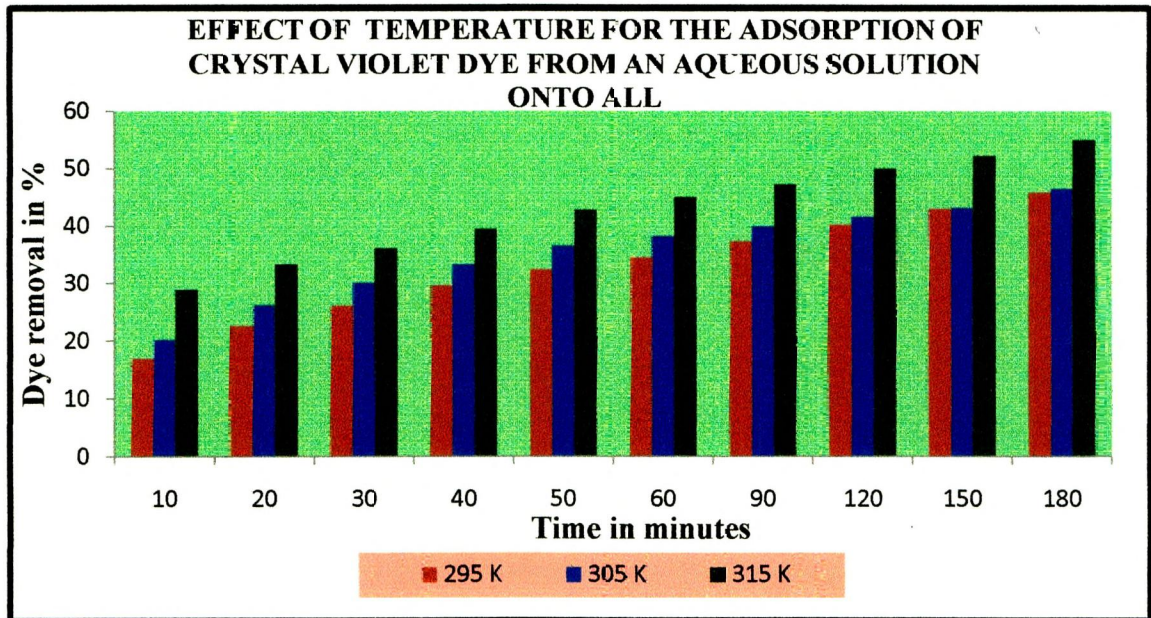


Figure- 20

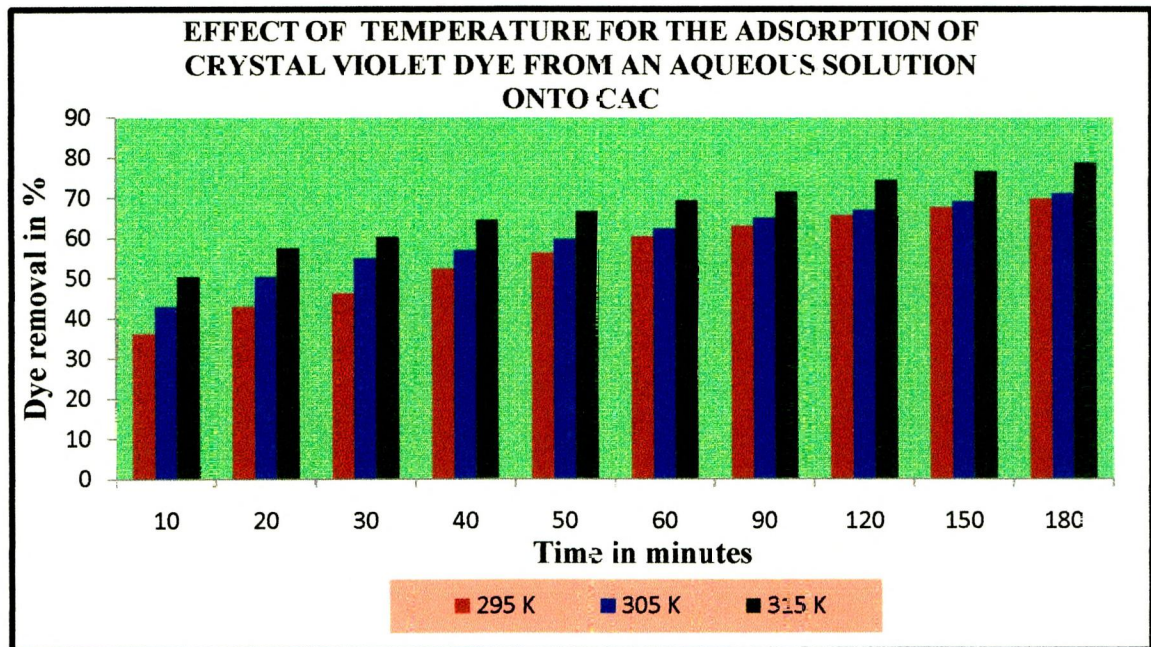


Figure- 21

4.5 KINETIC STUDIES OF ADSORPTION OF CRYSTAL VIOLET DYE

The adsorption kinetics is one of the important characteristics in defining the efficiency of adsorption. It also describes the rate of adsorbate uptake on the activated carbon (Shouman and Rashwan, 2012).

The kinetics for the adsorption of Crystal Violet dye from an aqueous solution and from a dyeing industrial effluent using the adsorbents ALL & CAC were determined using the three kinetic rate equations given below:

- Lagergren rate equation
- Elovich rate equation
- Intraparticle Diffusion rate equation

Any adsorption process is normally controlled by three steps:

1. Transport of the solute from bulk solution to the film, surrounding the adsorbent.
2. From the film to the adsorbent surface.
3. From the surface to the internal sites followed by binding of the adsorbent species into the active sites (Jyothirekha Sarma *et al.*, 2008).

The slowest of these steps determines the overall rate of the adsorption process and usually it is thought that the step 2 leads to surface adsorption and the step 3 leads to intra particle adsorption. Intra particle transport from bulk fluid to the external surface of the porous adsorbent may also have an effect on the overall rate of the adsorption under some circumstances (Srinivasa *et al.*, 2007 and Lalitha *et al.*, 2011).

4.5.1 LAGERGREN RATE EQUATION

The rate constant for the adsorption of Crystal Violet dye from an aqueous solution and also from a dyeing industrial effluent onto the adsorbents ALL and CAC were determined using Lagergren rate equation (Nidheesh *et al.*, 2012).

$$\log (q_e - q) = \log q_e - K_a (t) \quad \text{---} \quad 3.303$$

where, q and q_e - amount of Crystal Violet dye adsorbed at time 't' and at equilibrium time in mg/g.

K_a - rate constant of adsorption in min^{-1} .

t - agitation time in minutes.

Batch mode experiments were carried out by varying the initial concentration of Crystal Violet dye solution at 32°C . The data for Lagergren rate equation for the adsorption of Crystal Violet dye with the adsorbents ALL and CAC are summarized in the Tables 11 & 12. Lagergren plots of $\log(q_e - q)$ Vs 'time' are shown in the Figures 22 & 23. The linear plots show the applicability of Lagergren first order rate equation for the adsorption of Crystal Violet dye. The rate constants K_a calculated from the slope of linear plots are also shown in the Tables 11 & 12.

The rate constant K_a for the adsorption of Crystal Violet dye for various temperatures (295, 305 and 315 K) and at $\text{pH } 9.0 \pm 0.02$ were also calculated. The experimental conditions under which batch adsorption studies were performed and the data obtained were also tabulated in the Tables 13 & 14. The Lagergren plots of $\log(q_e - q)$ Vs 'time' are shown in the Figures 24 & 25 which explain the validity of the equation and consequently the first order nature of the adsorption of Crystal Violet dye from an aqueous solution onto, both the adsorbents used in this study.

Batch mode adsorption experiments were carried out by varying the initial concentration of dyeing industrial effluent containing Crystal Violet dye at 32°C & at $\text{pH } 9.0 \pm 0.02$ with the adsorbents ALL and CAC and the data obtained in this study is fitted with Lagergren rate equation (Tables 15 & 16). Lagergren plots obtained in this study are shown in the Figures 26 & 27. The linear plots show the applicability of Lagergren first order rate equation for the adsorption of Crystal Violet dye. The rate constants K_a calculated from the slope of linear plots are given in the Tables 15 & 16.

TABLE- 11

KINETIC MODELLING FOR THE ADSORPTION OF CRYSTAL VIOLET DYE
FROM AN AQUEOUS SOLUTION ONTO ALL USING LAGERGREN RATE
EQUATION (CONCENTRATION VARIATION)

Conditions:

Adsorbent Dosage - 200 mg

Temperature - 32⁰ C

Time in minutes (t)	Initial concentration of Crystal Violet dye solution							
	150mg/L		200mg/L		250mg/L		300mg/L	
	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)
10	5.16	0.7520	6.21	0.8802	5.14	0.9395	3.25	0.9790
20	6.43	0.6414	7.22	0.8182	6.90	0.8413	4.56	0.9148
30	7.50	0.5198	8.61	0.7151	7.82	0.7795	6.31	0.8109
40	8.08	0.4361	10.00	0.5797	8.74	0.7075	7.19	0.7474
50	8.67	0.3304	10.89	0.4638	9.51	0.6364	7.89	0.6893
60	9.35	0.1643	11.65	0.3324	10.47	0.5276	8.69	0.6117
90	9.64	0.0681	12.16	0.2148	11.19	0.4232	9.12	0.5634
120	9.93	-0.0555	12.66	0.0569	12.19	0.2174	10.70	0.3180
150	10.22	-0.2291	13.29	-0.2924	13.18	-0.1804	11.93	-0.0705
180	10.81	---	13.80	---	3.84	---	12.78	---
Intercept log q _e	0.7195		0.9234		1.0056		1.0426	
Slope (-k _a /2.303)x10 ⁻³	-6.7522		-7.9690		-7.2960		-6.7010	
k _a x 10 ⁻²	1.5550		1.8352		1.6802		1.5432	
Correlation coefficient (r)	-0.9731		-0.9867		-0.9878		-0.9783	

TABLE- 12

KINETIC MODELLING FOR THE ADSORPTION OF CRYSTAL VIOLET DYE
FROM AN AQUEOUS SOLUTION ONTO CAC USING LAGERGREN RATE
EQUATION (CONCENTRATION VARIATION)

Conditions:

Adsorbent Dosage - 50 mg

Temperature - 32⁰ C

Time in minutes (t)	Initial concentration of Crystal Violet dye solution							
	150mg/L		200mg/L		250mg/L		300mg/L	
	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)
10	9.62	0.6580	8.80	0.9030	8.65	0.9523	9.82	0.9068
20	11.69	0.3944	10.27	0.8149	10.22	0.8686	11.45	0.8088
30	12.10	0.3159	11.87	0.6928	11.17	0.8088	12.76	0.7101
40	12.52	0.2174	12.67	0.6159	12.11	0.7403	13.39	0.6532
50	12.93	0.0934	13.47	0.5224	12.42	0.7151	14.00	0.5899
60	13.14	0.0128	13.87	0.4668	12.74	0.6875	14.37	0.5465
90	13.76	-0.3872	15.33	0.1673	14.78	0.4517	14.91	0.4742
120	13.97	-0.6989	15.73	0.0293	16.83	-0.1079	16.05	0.2648
150	14.17	---	16.13	-0.1739	16.98	-0.2006	16.91	-0.0087
180	14.17	---	16.80	---	17.61	---	17.89	---
Intercept log q _e	0.6938		0.9357		1.0948		0.9193	
Slope (-k _a /2.303)x10 ⁻³	-11.7740		-7.6893		-8.6635		-5.8395	
k _a x 10 ⁻²	2.7115		1.7708		1.9952		1.3448	
Correlation coefficient (r)	-0.9950		-0.9943		-0.9759		-0.9859	

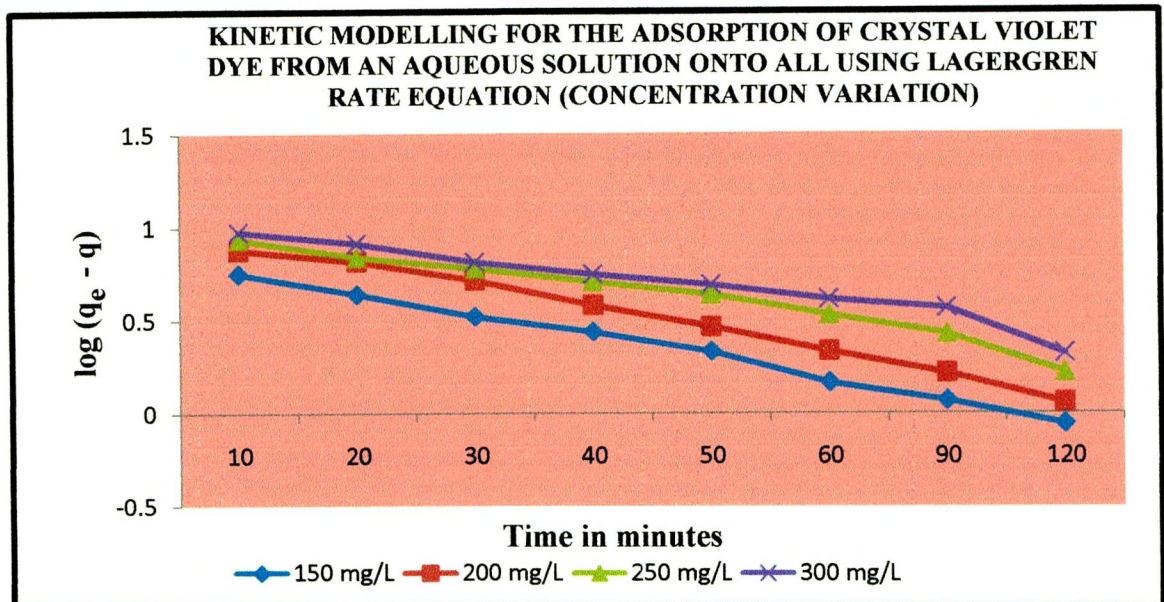


Figure- 22

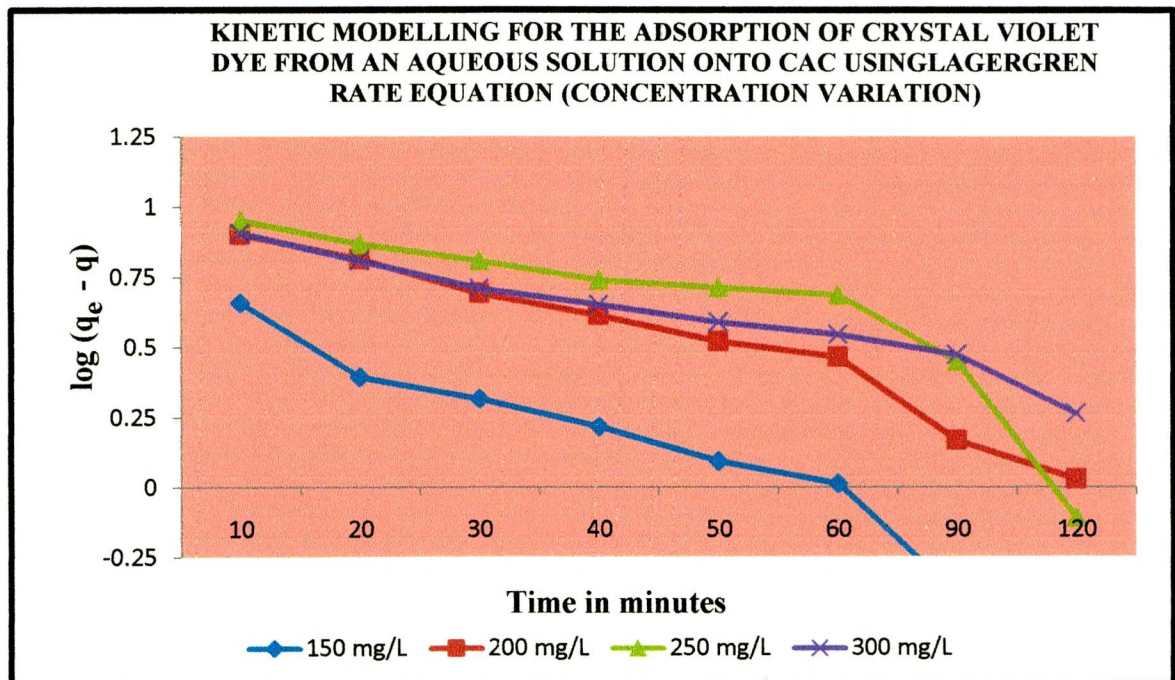


Figure- 23

TABLE- 13

KINETIC MODELLING FOR THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO ALL USING LAGERGREN RATE EQUATION (TEMPERATURE VARIATION)

Conditions:

Adsorbent Dosage - 200 mg
 pH - 9.0 ± 0.02
 Concentration of dye solution - 300mg/L

Time in minutes (t)	Temperature					
	295 K		305 K		315 K	
	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)
10	5.08	0.9375	6.07	0.8959	8.67	0.8937
20	6.77	0.8432	7.87	0.7831	10.00	0.8129
30	7.82	0.7723	9.02	0.6919	10.84	0.7528
40	8.89	0.6857	10.00	0.5954	11.84	0.6683
50	9.72	0.6042	10.99	0.4698	12.84	0.5634
60	10.36	0.5289	11.48	0.3909	13.51	0.4756
90	11.20	0.4048	11.97	0.2944	14.17	0.3673
120	12.05	0.2278	12.46	0.1702	15.00	0.1760
150	12.89	-0.0705	12.95	-0.0043	15.67	-0.0809
180	13.74	---	13.94	---	16.50	----
Intercept log q _e	0.9722		0.8602		0.9362	
Slope (-k _a /2.303)x10 ⁻³	-6.6948		-6.0620		-6.6620	
k _a x 10 ⁻²	1.5418		1.3961		1.5342	
Correlation coefficient (r)	-0.9935		-0.9749		-0.9943	

TABLE- 14

KINETIC MODELLING FOR THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO CAC USING LAGERGREN RATE EQUATION (TEMPERATURE VARIATION)

Conditions:

Adsorbent Dosage - 50 mg
 pH - 9.0 ± 0.02
 Concentration of dye solution - 300mg/L

Time in minutes (t)	Temperature					
	295 K		305 K		315 K	
	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)
10	10.87	1.0030	12.89	0.9268	15.11	0.9299
20	12.89	0.9057	15.10	0.7951	17.24	0.8048
30	13.89	0.8481	16.51	0.6839	18.09	0.7427
40	15.71	0.7185	17.12	0.6253	19.37	0.6283
50	16.89	0.6074	17.92	0.5340	20.00	0.5587
60	18.12	0.4502	18.73	0.4166	20.85	0.4424
90	18.93	0.3031	19.53	0.2576	21.49	0.3283
120	19.73	0.0827	20.14	0.0791	22.34	0.1072
150	20.34	-0.2218	20.74	-0.2218	22.98	-0.1938
180	20.94	---	21.34	---	23.62	---
Intercept log q _e	1.0631		0.9395		0.9573	
Slope (-k _a /2.303)x10 ⁻³	-8.5460		-7.6472		-7.4876	
k _a x 10 ⁻²	1.9681		1.7611		1.7243	
Correlation coefficient (r)	-0.9941		-0.9938		-0.9934	

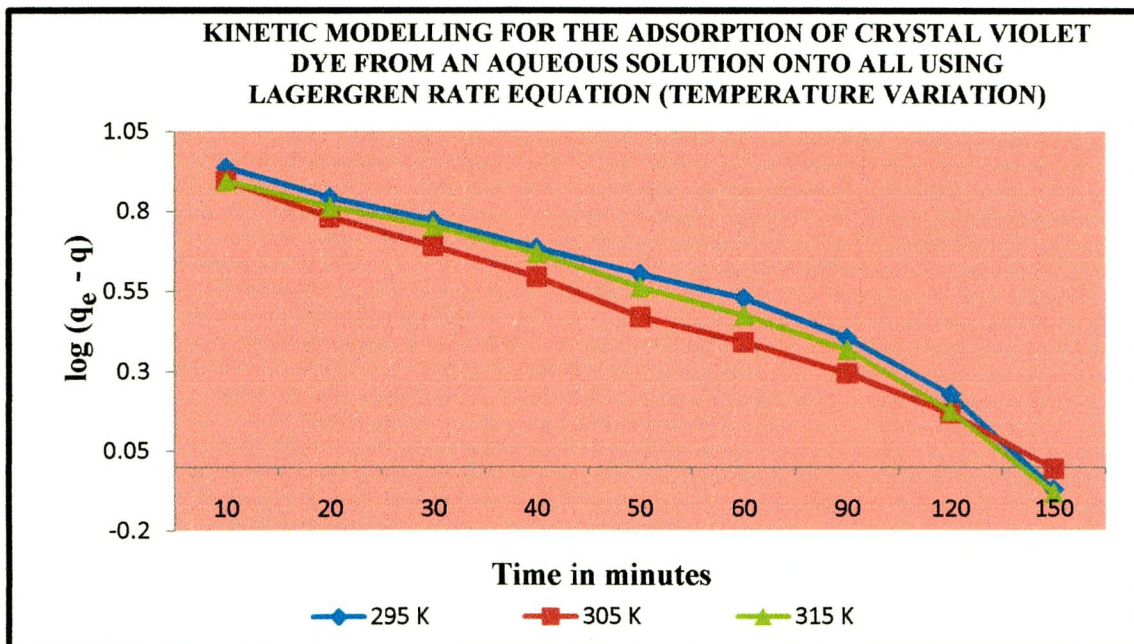


Figure- 24

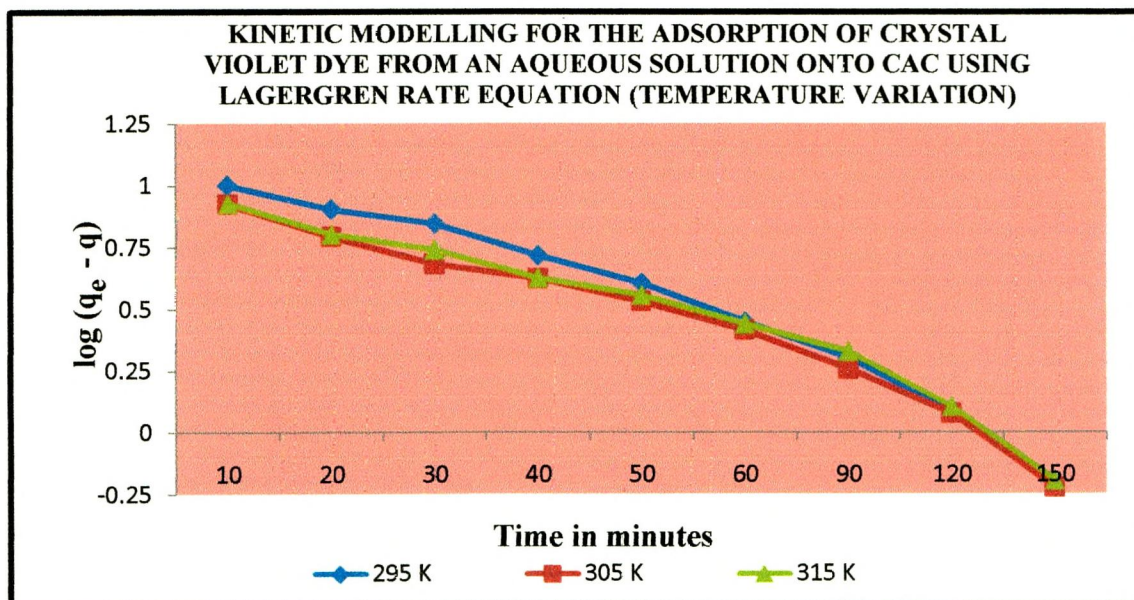


Figure- 25

TABLE- 15

KINETIC MODELLING FOR THE ADSORPTION OF CRYSTAL VIOLET DYE
FROM A DYEING INDUSTRIAL EFFLUENT ONTO ALL USING
LAGERGRN RATE EQUATION (CONCENTRATION VARIATION)

Conditions:

Adsorbent Dosage - 600 mg
pH - 9.0 ± 0.02
Temperature - 32⁰ C

Time in minutes (t)	Initial concentration of Crystal Violet dye solution					
	100 mg/L		150 mg/L		200 mg/L	
	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)
10	1.80	0.4698	2.31	0.6304	2.75	0.7176
20	2.45	0.3617	3.35	0.5092	4.06	0.5921
30	3.03	0.2355	3.81	0.4424	4.64	0.5224
40	3.19	0.1931	4.04	0.4048	4.93	0.4828
50	3.44	0.1172	4.27	0.3636	5.22	0.4393
60	3.77	-0.0087	4.73	0.2671	5.65	0.3654
90	4.01	-0.1307	5.19	0.1430	6.37	0.2041
120	4.26	-0.3098	5.65	-0.0315	6.95	0.0086
150	4.50	-0.6020	6.12	-0.3372	7.53	-0.3565
180	4.75	---	6.58	---	7.97	---
Intercept log q _e	0.4860		0.6626		0.7692	
Slope (-k _a /2.303)x10 ⁻³	-7.1018		-6.2673		-6.9250	
k _a x 10 ⁻²	1.6355		1.4433		1.5948	
Correlation coefficient (r)	-0.9924		-0.9914		-0.9887	

TABLE- 16

**KINETIC MODELLING FOR THE ADSORPTION OF CRYSTAL VIOLET DYE
FROM A DYEING INDUSTRIAL EFFLUENT ONTO CAC USING
LAGERGREN RATE EQUATION (CONCENTRATION VARIATION)**

Conditions:

Adsorbent Dosage - 150 mg
pH - 9.0 ± 0.02
Temperature - 32°C

Time in minutes (t)	Initial concentration of Crystal Violet dye solution					
	100 mg/L		150 mg/L		200 mg/L	
	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)	q (mg/g)	log (q _e - q)
10	2.62	0.4698	3.80	0.6314	4.20	0.7176
20	3.36	0.3443	4.62	0.5390	5.51	0.5921
30	3.68	0.2764	4.85	0.5092	5.94	0.5415
40	3.93	0.2148	5.43	0.4232	6.52	0.4623
50	4.26	0.1172	5.89	0.3404	7.10	0.3654
60	4.50	0.0293	6.35	0.2380	7.53	0.2764
90	4.83	-0.1307	6.81	0.1038	7.97	0.1613
120	5.08	-0.3098	7.15	-0.0315	8.40	0.0086
150	5.32	-0.6020	7.73	-0.4559	9.13	-0.5376
180	5.57	---	8.08		9.42	---
Intercept log q _e	0.4996		0.7047		0.7813	
Slope (-k _a /2.303)x10 ⁻³	-7.1708		-7.0966		-7.7979	
k _a x 10 ⁻²	1.6514		1.6343		1.7958	
Correlation coefficient (r)	-0.9958		-0.9856		-0.9741	

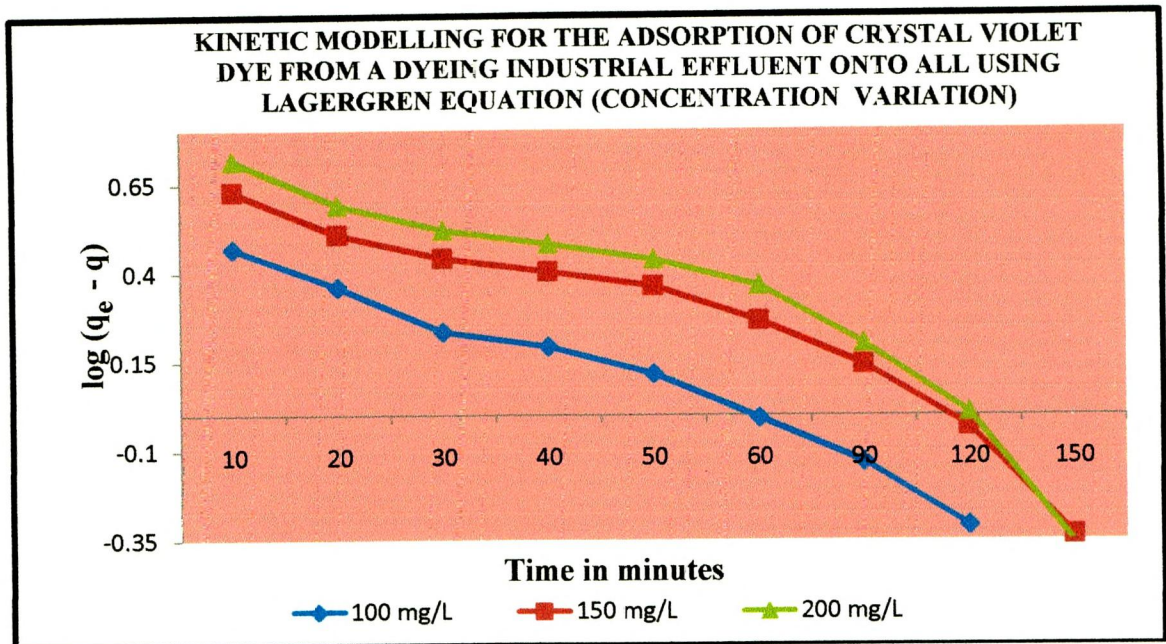


Figure- 26

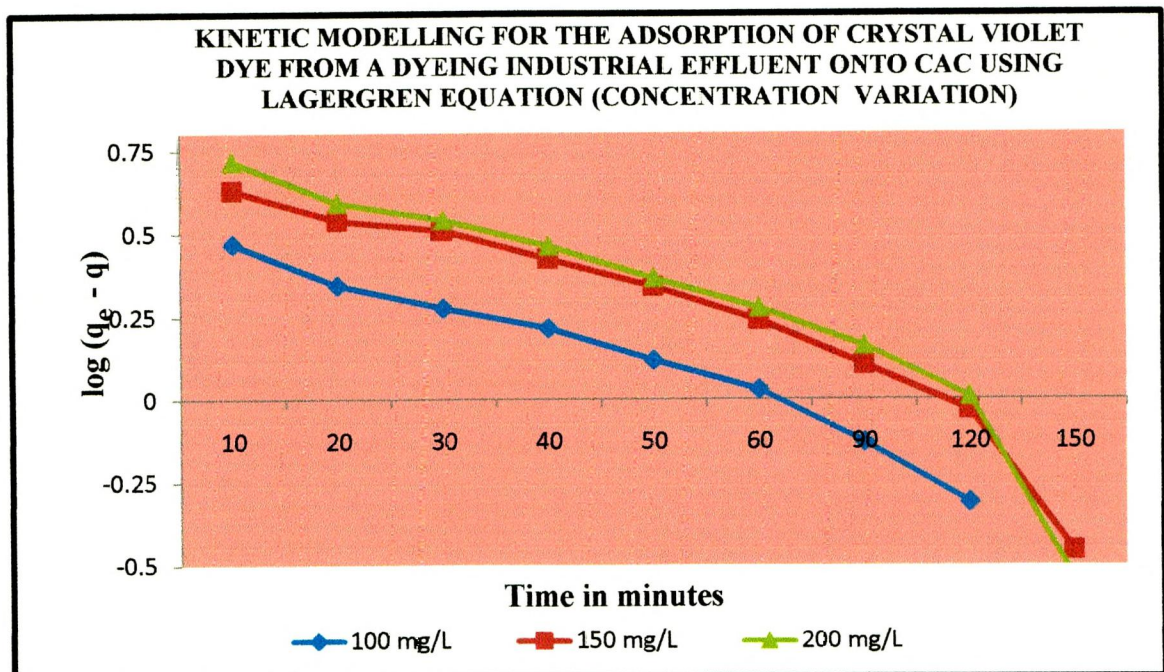


Figure- 27

4.5.2 ELOVICH RATE EQUATION

The Elovich rate equation was developed to describe the kinetics of chemisorption of gas molecules on a solid surface and it is generally expressed as (Dawodu Folasegun Anthony *et al.*, 2012)

$$\frac{dq_t}{dt} = \alpha \exp(-\beta q_t) \quad \longrightarrow \quad (1)$$

where, q_t - amount of Crystal Violet dye adsorbed at time 't' in mg/g

α - initial adsorption rate in mg/g/min

β - Desorption constant in g/mg

Assuming the initial boundary condition, $q=0$ and $t=0$, equation (1) on integration becomes,

$$\frac{1}{q_t} = \frac{1}{\beta} \ln(1 + \alpha\beta t) \quad \longrightarrow \quad (2)$$

To simplify the Elovich rate equation, Chien and Clayton (1980) assumed $\alpha\beta \gg 1$ and applying the boundary conditions $q_t = 0$ at $t = 0$ and $q_t = q_t$ at $t = t$, equation (2) becomes

$$q_t = \frac{\ln(\alpha\beta)}{\beta} + \frac{\ln t}{\beta} \quad \longrightarrow \quad (3)$$

Equation (3) was commonly used in the kinetics of chemisorption of gases on solids. Taylor *et al* (1995) successfully used the Elovich rate equation for the sorption of zinc ions onto soils and Juang and Chen (1997) studied the sorption kinetics of metal ions from sulphate solutions onto solvent impregnated resins.

The Elovich rate equation data obtained in this study for Crystal Violet dye adsorption with the adsorbents ALL and CAC are summarized in the Tables 17 & 18. Elovich plots of ' $\ln t$ ' Vs ' q_t ' (amount of CV dye adsorbed) gives a linear relationship. The graphical representations of the Elovich plots are shown in the Figures 28 & 29. The higher Correlation coefficient (r) shows the successfulness of the Elovich model.

Elovich rate equation was also applied for the removal of Crystal Violet dye from a dyeing industrial effluent and the data obtained are shown in the Tables 19 & 20 and graphically represented in the Figures 30 & 31.

TABLE- 17

ELOVICH RATE EQUATION FOR THE ADSORPTION OF CRYSTAL VIOLET
DYE FROM AN AQUEOUS SOLUTION ONTO ALL
(CONCENTRATION VARIATION)

Conditions:

Adsorbent Dosage - 200 mg

Temperature - 32⁰ C

Time in minutes (t)	ln (t)	Amount of Crystal Violet dye adsorbed at time 't' (q _t)			
		150mg/L	200mg/L	250mg/L	300mg/L
10	2.3025	5.16	6.21	5.14	3.25
20	2.9957	6.43	7.22	6.90	4.56
30	3.4011	7.50	8.61	7.82	6.31
40	3.6888	8.08	10.00	8.74	7.19
50	3.9120	8.67	10.89	9.51	7.89
60	4.0943	9.35	11.65	10.47	8.69
90	4.4998	9.64	12.16	11.19	9.12
120	4.7874	9.93	12.66	12.19	10.70
150	5.0106	10.22	13.29	13.18	11.93
180	5.1929	10.81	13.80	13.84	12.78
Intercept : $1/\beta \ln \alpha\beta$		0.9180	-0.3896	-2.1844	-4.8766
Slope : $1/\beta$		1.9207	2.7676	3.0293	3.2891
Initial adsorption rate : α		3.0976	2.4042	1.4728	0.7467
Desorption constant : β		0.5206	0.3613	0.3301	0.3040
Correlation coefficient (r)		0.9890	0.9871	0.9960	0.9903

TABLE- 18

**ELOVICH RATE EQUATION FOR THE ADSORPTION OF CRYSTAL VIOLET
DYE FROM AN AQUEOUS SOLUTION ONTO CAC
(CONCENTRATION VARIATION)**

Conditions:

Adsorbent Dosage - 50 mg

Temperature - 32⁰ C

Time in minutes (t)	ln (t)	Amount of Crystal Violet dye adsorbed at time 't' (q _t)			
		150mg/L	200mg/L	250mg/L	300mg/L
10	2.3025	9.62	8.80	8.65	9.82
20	2.9957	11.69	10.27	10.22	11.45
30	3.4011	12.10	11.87	11.17	12.76
40	3.6888	12.52	12.67	12.11	13.39
50	3.9120	12.93	13.47	12.42	14.00
60	4.0943	13.14	13.87	12.74	14.37
90	4.4998	13.76	15.33	14.78	14.91
120	4.7874	13.97	15.73	16.83	16.05
150	5.0106	14.17	16.13	16.98	16.91
180	5.1929	14.17	16.80	17.61	17.89
Intercept : $1/\beta \ln \alpha\beta$		6.8513	2.1867	0.3370	3.6099
Slope : $1/\beta$		1.4932	2.8349	3.2628	2.6438
Initial adsorption rate : α		4.9892	6.1314	3.6185	10.3573
Desorption constant : β		0.6697	0.3527	0.3064	0.3782
Correlation coefficient (r)		0.9726	0.9963	0.9810	0.9929

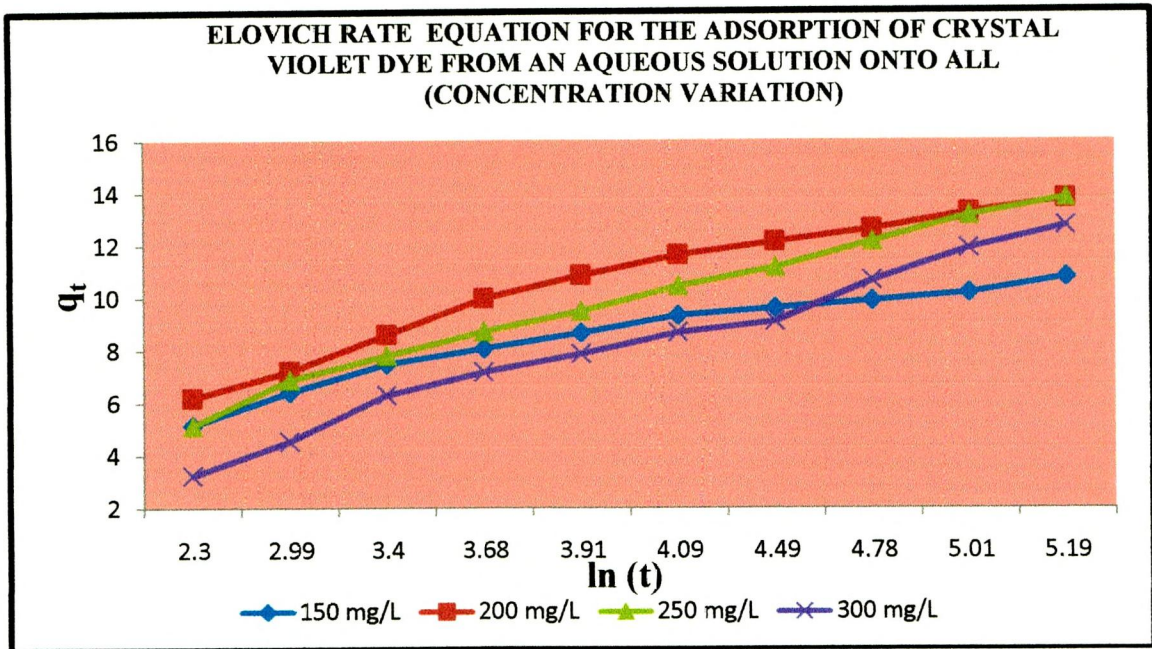


Figure- 28

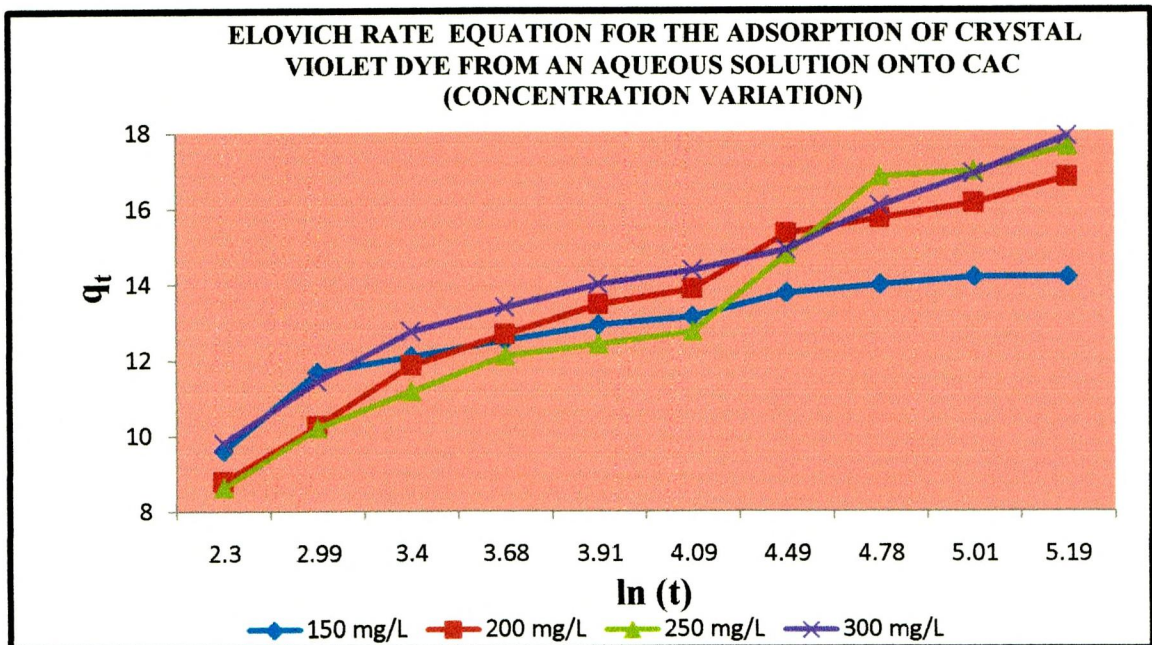


Figure- 29

TABLE- 19

**ELOVICH RATE EQUATION FOR THE ADSORPTION OF CRYSTAL VIOLET
DYE FROM A DYEING INDUSTRIAL EFFLUENT ONTO ALL
(CONCENTRATION VARIATION)**

Conditions:

Adsorbent Dosage - 600 mg
pH - 9.0 ± 0.02
Temperature - 32° C

Time in minutes (t)	ln (t)	Amount of Crystal Violet dye adsorbed at time 't' (q _t)		
		100 mg/L	150 mg/L	200 mg/L
10	2.3025	1.80	2.31	2.75
20	2.9957	2.45	3.35	4.06
30	3.4011	3.03	3.81	4.64
40	3.6888	3.19	4.04	4.93
50	3.9120	3.44	4.27	5.22
60	4.0943	3.77	4.73	5.65
90	4.4998	4.01	5.19	6.37
120	4.7874	4.26	5.65	6.95
150	5.0106	4.50	6.12	7.53
180	5.1929	4.75	6.58	7.97
Intercept : 1/β ln αβ		-0.4847	-1.0342	-1.3733
Slope : 1/β		1.0040	1.4138	1.7501
Initial adsorption rate : α		0.6195	0.6802	0.7985
Desorption constant : β		0.9960	0.7073	0.5713
Correlation coefficient (r)		0.9971	0.9932	0.9945

TABLE- 20

**ELOVICH RATE EQUATION FOR THE ADSORPTION OF CRYSTAL VIOLET
DYE FROM A DYEING INDUSTRIAL EFFLUENT ONTO CAC
(CONCENTRATION VARIATION)**

Conditions:

Adsorbent Dosage - 150 mg
pH - 9.0 ± 0.02
Temperature - 32⁰ C

Time in minutes (t)	ln (t)	Amount of Crystal Violet dye adsorbed at time 't' (q _t)		
		100 mg/L	150 mg/L	200 mg/L
10	2.3025	2.62	3.80	4.20
20	2.9957	3.36	4.62	5.51
30	3.4011	3.68	4.85	5.94
40	3.6888	3.93	5.43	6.52
50	3.9120	4.26	5.89	7.10
60	4.0943	4.50	6.35	7.53
90	4.4998	4.83	6.81	7.97
120	4.7874	5.08	7.15	8.40
150	5.0106	5.32	7.73	9.13
180	5.1929	5.57	8.08	9.42
Intercept : 1/β ln αβ		0.2972	0.0546	0.0415
Slope : 1/β		1.0073	1.5084	1.7877
Initial adsorption rate : α		0.7499	1.5641	1.8299
Desorption constant : β		0.9927	0.6629	0.5593
Correlation coefficient (r)		0.9986	0.9912	0.9964

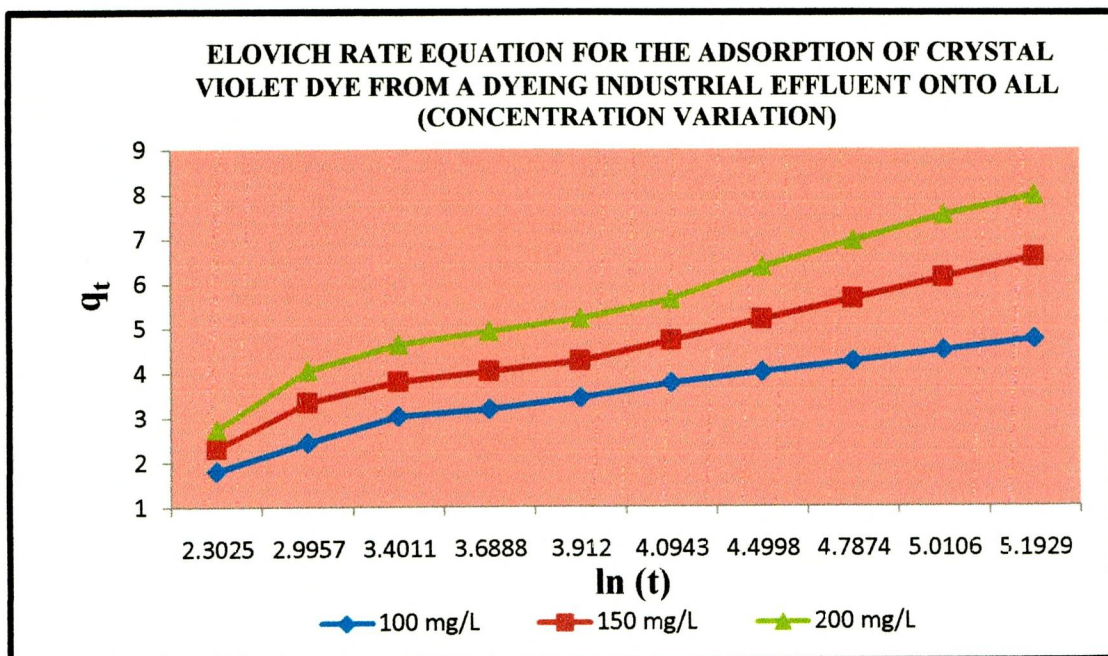


Figure- 30

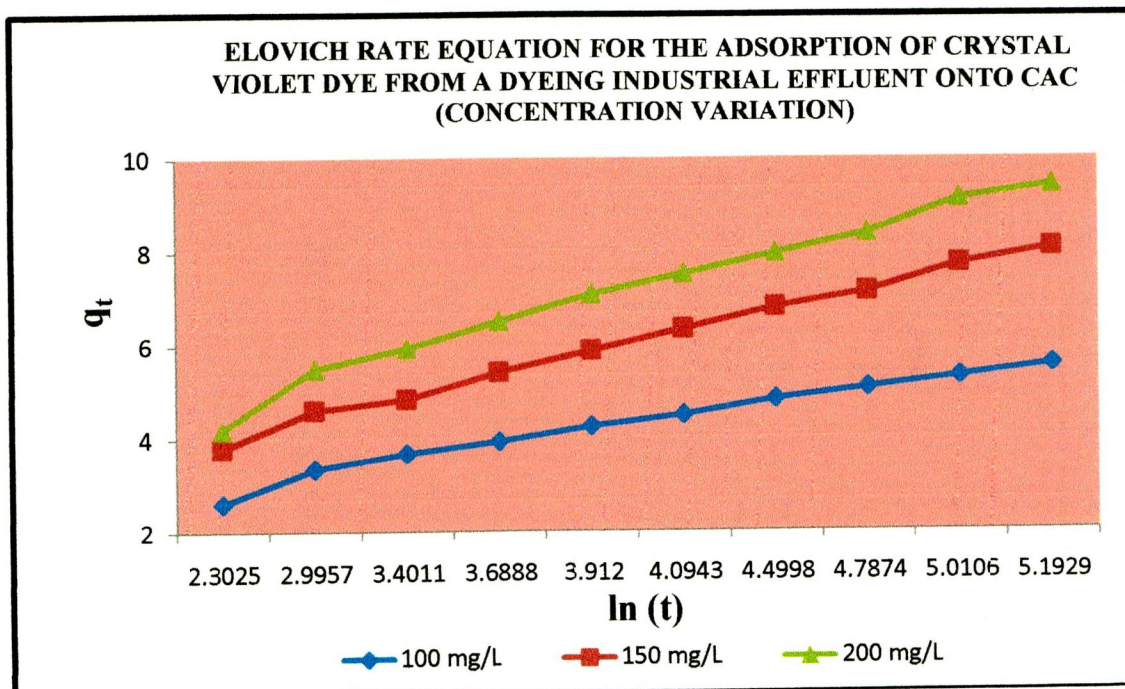


Figure- 31

4.5.3 INTRAPARTICLE DIFFUSION RATE EQUATION FOR THE ADSORPTION OF CRYSTAL VIOLET DYE

Due to rapid stirring in batch reactors there is a possibility of transport of Crystal Violet dye species from the bulk into pores of the adsorbent as well as adsorption at the outer surface of the adsorbent. The rate- limiting step may be either film diffusion or intraparticle diffusion. As they act in series, the slowest of the two steps will be the rate determining step. The possibility of Crystal Violet dye species to diffuse into the interior sites of the particles of adsorbent was tested with Weber- Morris equation given as follows (Yunjin Yao *et al.*, 2010).

$$q_t = K_p t^{1/2} + C$$

where, q_t - amount of Crystal Violet dye adsorbed at time 't' in mg/g

K_p - intraparticle diffusion rate constant

t - agitation time in minutes

In order to study the diffusion process, batch adsorption experiments were carried out with the adsorbents ALL and CAC used in this study at 32⁰ C by varying the initial concentration of Crystal Violet dye solution. The data obtained in this study are given in the Tables 21 & 22 and graphically represented in the Figures 32 & 33. Similar batch adsorption experiments were carried out with the adsorbents ALL and CAC at 32⁰ C by varying the initial concentration of Crystal Violet dye rich effluent obtained from a dyeing industry.. The results are given in the Tables 23 & 24 and graphically represented in the Figures 34 & 35.

The plots are straight lines (for both the adsorbents) but not passing through the origin and this indicates some degree of boundary layer control and further shows that the intraparticle diffusion is not the only rate- limiting step, but also other kinetic models may control the rate of adsorption, all of which may be operating simultaneously. The values of intercept give an idea about the boundary layer thickness such as the larger the intercept, the greater the boundary layer effect (Gandhimathi *et al.*, 2012).

Similar results have been observed for the removal of Crystal Violet dye from wastewater using adsorbents such as Mangrove plant leaf powder, Mangrove plant fruit powder, Mango leaf powder, Tamarind fruit shell powder, Teak tree bark powder and Almond tree bark powder (Satish Patil *et al.*, 2011).

TABLE- 21

INTRAPARTICLE DIFFUSION RATE EQUATION FOR THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO ALL (CONCENTRATION VARIATION)

Conditions:

Adsorbent Dosage - 200 mg

Temperature - 32⁰ C

Time in minutes (t)	t ^{1/2}	Amount of Crystal Violet dye adsorbed at time 't' (q _t)			
		150mg/L	200mg/L	250mg/L	300mg/L
10	3.1622	5.16	6.21	5.14	3.25
20	4.4721	6.43	7.22	6.90	4.56
30	5.4772	7.50	8.61	7.82	6.31
40	6.3245	8.08	10.00	8.74	7.19
50	7.0710	8.67	10.89	9.51	7.89
60	7.7459	9.35	11.65	10.47	8.69
90	9.4868	9.64	12.16	11.19	9.12
120	10.9544	9.93	12.66	12.19	10.70
150	12.2474	10.22	13.29	13.18	11.93
180	13.4164	10.81	13.80	3.84	12.78
Intercept		4.5691	4.8065	6.4954	1.0889
Slope K_p		0.4989	0.7270	0.2989	0.8901
Correlation coefficient (r)		0.9470	0.9557	0.3368	0.9878

TABLE- 22

INTRAPARTICLE DIFFUSION RATE EQUATION FOR THE ADSORPTION OF CRYSTAL VIOLET DYE FROM AN AQUEOUS SOLUTION ONTO CAC (CONCENTRATION VARIATION)

Conditions:

Adsorbent Dosage - 50 mg

Temperature - 32⁰ C

Time in minutes (t)	$t^{1/2}$	Amount of Crystal Violet dye adsorbed at time 't' (q _t)			
		150mg/L	200mg/L	250mg/L	300mg/L
10	3.1622	9.62	8.80	8.65	9.82
20	4.4721	11.69	10.27	10.22	11.45
30	5.4772	12.10	11.87	11.17	12.76
40	6.3245	12.52	12.67	12.11	13.39
50	7.0710	12.93	13.47	12.42	14.00
60	7.7459	13.14	13.87	12.74	14.37
90	9.4868	13.76	15.33	14.78	14.91
120	10.9544	13.97	15.73	16.83	16.05
150	12.2474	14.17	16.13	16.98	16.91
180	13.4164	14.17	16.80	17.61	17.89
Intercept		9.7663	7.4875	6.1614	8.4466
Slope Kp		0.3783	0.7474	0.8946	0.7103
Correlation coefficient (r)		0.9084	0.9682	0.9914	0.9832

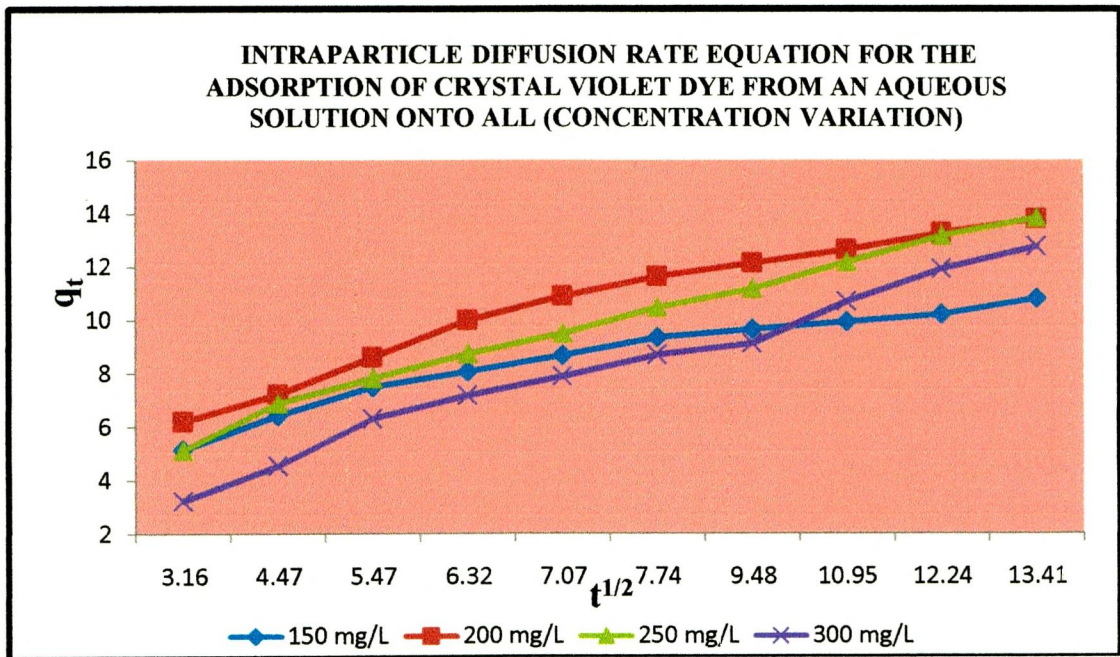


Figure- 32



Figure- 33

TABLE- 23

**INTRAPARTICLE DIFFUSION RATE EQUATION FOR THE ADSORPTION
OF CRYSTAL VIOLET DYE FROM A DYEING INDUSTRIAL EFFLUENT
ONTO ALL (CONCENTRATION VARIATION)**

Conditions:

Adsorbent Dosage - 600 mg

pH - 9.0 ± 0.02

Temperature - 32⁰ C

Time in minutes (t)	t ^{1/2}	Amount of Crystal Violet dye adsorbed at time 't' (q _t)		
		100 mg/L	150 mg/L	200 mg/L
10	3.1622	1.80	2.31	2.75
20	4.4721	2.45	3.35	4.06
30	5.4772	3.03	3.81	4.64
40	6.3245	3.19	4.04	4.93
50	7.0710	3.44	4.27	5.22
60	7.7459	3.77	4.73	5.65
90	9.4868	4.01	5.19	6.37
120	10.9544	4.26	5.65	6.95
150	12.2474	4.50	6.12	7.53
180	13.4164	4.75	6.58	7.97
Intercept		1.3899	1.5332	1.8092
Slope Kp		0.2650	0.3822	0.4726
Correlation coefficient (r)		0.9702	0.9897	0.9897

TABLE- 24

**INTRAPARTICLE DIFFUSION RATE EQUATION FOR THE ADSORPTION
OF CRYSTAL VIOLET DYE FROM A DYEING INDUSTRIAL EFFLUENT
ONTO CAC (CONCENTRATION VARIATION)**

Conditions:

Adsorbent Dosage - 150 mg
pH - 9.0 ± 0.02
Temperature - 32⁰ C

Time in minutes (t)	$t^{1/2}$	Amount of Crystal Violet dye adsorbed at time 't' (q _t)		
		100 mg/L	150 mg/L	200 mg/L
10	3.1622	2.62	3.80	4.20
20	4.4721	3.36	4.62	5.51
30	5.4772	3.68	4.85	5.94
40	6.3245	3.93	5.43	6.52
50	7.0710	4.26	5.89	7.10
60	7.7459	4.50	6.35	7.53
90	9.4868	4.83	6.81	7.97
120	10.9544	5.08	7.15	8.40
150	12.2474	5.32	7.73	9.13
180	13.4164	5.57	8.08	9.42
Intercept		2.1635	2.7896	3.3392
Slope Kp		0.2677	0.4083	0.4769
Correlation coefficient (r)		0.9782	0.9889	0.9798

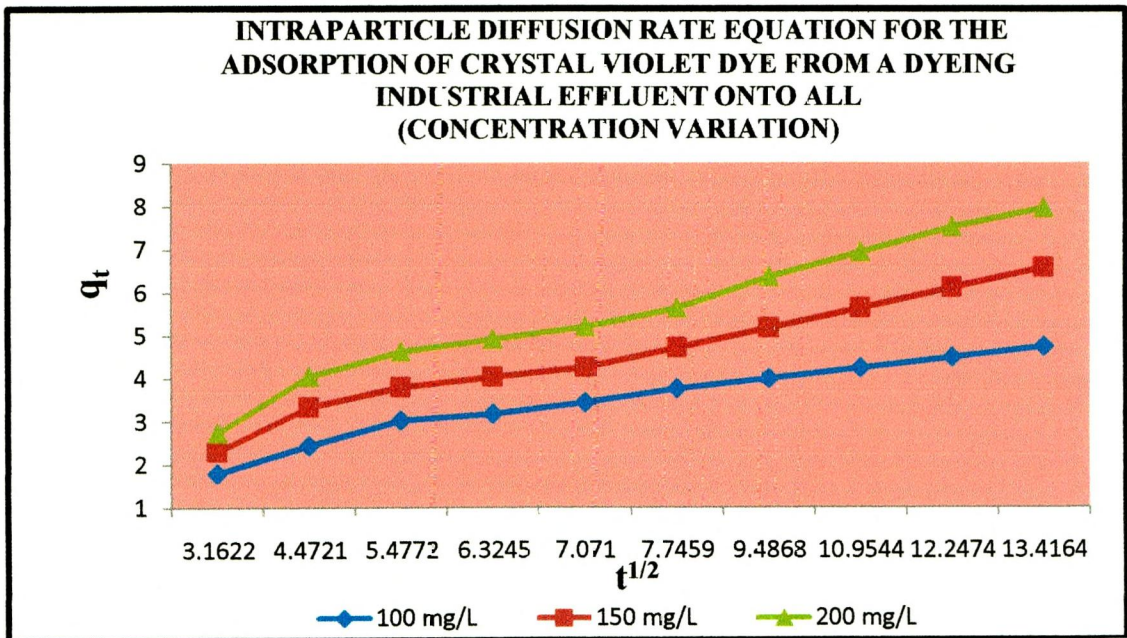


Figure- 34

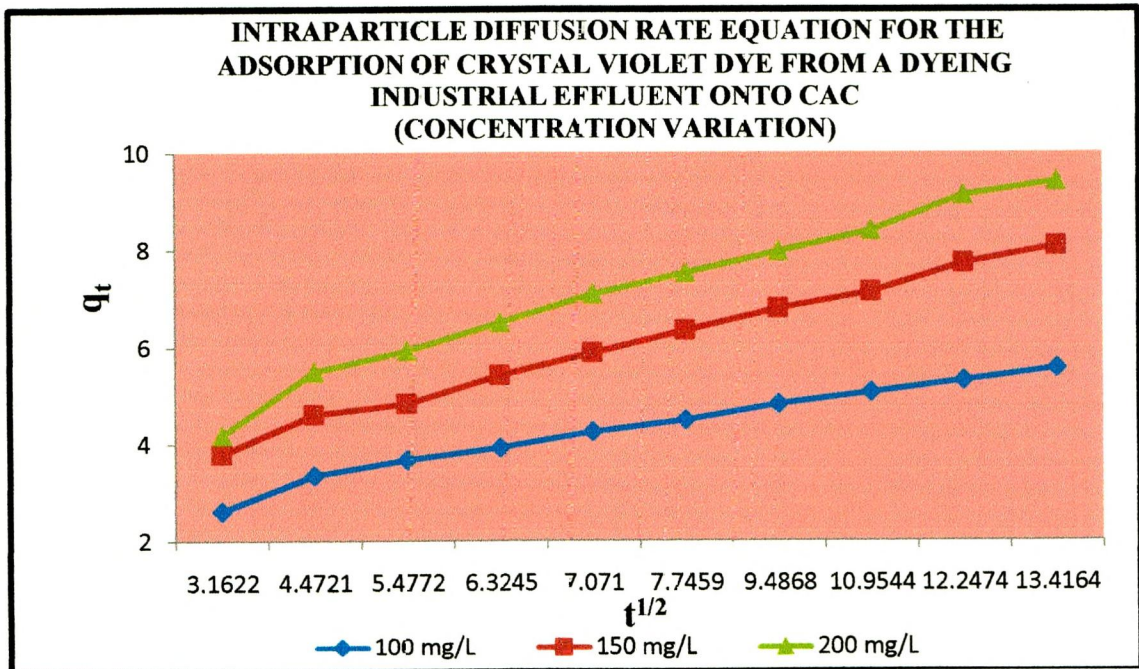


Figure- 35

4.6 ADSORPTION ISOTHERM

The adsorption isotherm indicates how the adsorption molecules distribute between the liquid phase and the solid phase when the adsorption process reaches an equilibrium state (**Gamal O. El- Sayed *et al.*, 2011**). For solid–liquid adsorption system, adsorption isotherm is an important model in the description of adsorption behavior. At equilibrium, a saturation point is reached where no further adsorption can occur. Adsorption equilibrium information helps to understand how much adsorbate can be accommodated by a solid adsorbent (**Dalia Khalid Mahmoud *et al.*, 2012**).

There are several adsorption isotherm equations, which can be used to describe equilibrium nature of adsorption. Most of the adsorption isotherms are used to explain the adsorption in solution based on semi empirical equations (**Mehmet Dogan *et al.*, 2008**).

In the present study, two of the most commonly used models, namely Langmuir and Freundlich adsorption isotherms are studied for the adsorption of Crystal Violet dye. The distribution of adsorbate (Crystal Violet dye) between the adsorbent and the bulk solution when the system is in equilibrium is important to establish the capacity of the adsorbent for adsorbing the adsorbate. An analysis of the adsorption isotherm is important to develop and represent the results accurately for design purposes.

Batch mode adsorption studies were carried out at 32⁰ C by varying the initial concentration of an aqueous solution of Crystal Violet dye. Similar adsorption studies were carried out at 32⁰ C and at pH 9.0 ± 0.02 by varying the initial concentration of the industrial effluent containing Crystal Violet dye.

4.6.1 LANGMUIR ADSORPTION ISOTHERM

The Langmuir adsorption isotherm was developed by Irving Langmuir in 1916 to describe the monomolecular adsorption on energetically homogeneous surfaces. The Langmuir model is probably the most popular one due to its simplicity (**Dalia Khalid Mahmoud *et al.*, 2012**). The Langmuir adsorption isotherm gives the following hypotheses:

- ⊗ Monolayer adsorption (the adsorbed layer is one molecule thick).
- ⊗ Adsorption takes place at specific homogeneous sites within the adsorbent.

- ⊗ Once a dye molecule occupies a site, no further adsorption can take place at that site.
- ⊗ Adsorption energy is constant and does not depend on the degree of occupation of an adsorbent's active centers.
- ⊗ The strength of the intermolecular attractive forces is believed to fall off rapidly with distance.
- ⊗ The adsorbent has a finite capacity for the adsorbate (at equilibrium, a saturation point is reached where no further adsorption can occur).
- ⊗ All sites are identical and energetically equivalent.
- ⊗ The adsorbent is structurally homogeneous.
- ⊗ There is no interaction between molecules adsorbed on neighboring sites.

Langmuir adsorption isotherm plays an important role in the determination of the maximum capacity of adsorbent (**Dalia Khalid Mahmoud *et al.*, 2012**). The Langmuir adsorption isotherm is commonly given by,

$$\frac{x}{m} = \frac{k_1^1 C_e}{1 + k_1 C_e}$$

where, x - amount of Crystal Violet dye adsorbed (mg/L)

m - weight of adsorbent (mg)

C_e - Concentration of Crystal Violet dye at equilibrium

k₁¹ and k₁ are the Langmuir constants which are the measure of adsorption capacity and energy of adsorption respectively.

On rearranging, the above equation becomes

$$\frac{1}{x/m} = \frac{1}{k_1^1 / k_1} + \frac{1}{k_1^1 C_e}$$

The Langmuir adsorption isotherm data for Crystal Violet dye adsorption from an aqueous solution on the adsorbents ALL and CAC are shown in the Tables 25 & 26 and graphically represented in the Figures 36 & 37. Similarly the Langmuir adsorption isotherm data for Crystal Violet dye adsorption from a dyeing industrial effluent on the

adsorbents ALL and CAC are shown in the Tables 27 & 28 and graphically represented in the Figures 38 & 39.

The Langmuir plots obtained by plotting $1/C_e$ Vs m/x are linear showing the applicability of Langmuir adsorption isotherm for Crystal Violet dye adsorption with both the adsorbents (ALL and CAC) used in this study. The essential characteristics of Langmuir adsorption isotherm can be expressed in terms of a dimensionless constant, separation factor or equilibrium parameter ' R_L ' which is defined by,

$$R_L = \frac{1}{1+bC_i}$$

where, C_i - initial concentration of the Crystal Violet dye solution in mg/L

b - Langmuir constant (k^1_1)

The parameter R_L indicates the shape of the isotherm as follows:

R_L Value	Type of isotherm
$R_L > 1$	Unfavourable
$R_L = 1$	Linear
$0 < R_L < 1$	Favourable
$R_L = 0$	Irreversible

The values of the dimensionless equilibrium parameter R_L , reveal that the Langmuir adsorption isotherm is favourable for the adsorption of Crystal Violet dye with both the adsorbents (ALL and CAC) throughout the 180 minutes of adsorption study time. The R_L values obtained are given in the Tables 25 & 26 for the adsorbents ALL and CAC respectively. The results of this study are similar with the results reported for the removal of basic dyes using saw- dust of sagaun (Khattri and Singh, 1999), rice husk carbon (Singh and Srivastava, 2001) and removal of Cr (VI) using a low- cost and commercial activated carbon (Renugadevi *et al.*, 2009).

TABLE- 25

**INTERPRETATION OF RESULTS OF LANGMUIR ADSORPTION ISOTHERM
FOR CRYSTAL VIOLET DYE ADSORPTION FROM AN
AQUEOUS SOLUTION ONTO ALL**

Time in minutes	Initial Conc. of dye in mg/L	1/Ce	m/x	Separation factor R_L	Intercept k_1/k_1^1	Slope $1/k_1^1$	Correlation coefficient (r)
10	150	0.1016	0.0387	-0.00192	0.0616	-0.2878	-0.6363
	200	0.0725	0.0322	-0.00144			
	250	0.0503	0.0389	-0.00115			
	300	0.0373	0.0613	-0.00096			
20	150	0.1166	0.0311	-0.00079	0.0414	-0.1189	-0.5378
	200	0.0782	0.0277	-0.00059			
	250	0.0552	0.0289	-0.00047			
	300	0.0393	0.0438	-0.00039			
30	150	0.1333	0.0266	-0.00026	0.0299	-0.0399	-0.4504
	200	0.0878	0.0232	-0.00019			
	250	0.0582	0.0255	-0.00015			
	300	0.0422	0.0316	-0.00013			
40	150	0.1445	0.0247	-0.00034	0.0293	-0.0521	-0.4679
	200	0.1000	0.0199	-0.00026			
	250	0.0615	0.0228	-0.00020			
	300	0.0438	0.0316	-0.00017			
50	150	0.1579	0.0230	-0.000110	0.0234	-0.0165	-0.2800
	200	0.1097	0.0183	-0.000082			
	250	0.0645	0.0210	-0.000066			
	300	0.0452	0.0253	-0.000055			

TABLE- 25

**INTERPRETATION OF RESULTS OF LANGMUIR ADSORPTION ISOTHERM
FOR CRYSTAL VIOLET DYE ADSORPTION FROM AN
AQUEOUS SOLUTION ONTO ALL**

Time in minutes	Initial Conc. of dye in mg/L	1/Ce	m/x	Separation factor R_L	Intercept k_1/k_1^1	Slope $1/k_1^1$	Correlation coefficient (r)
60	150	0.1769	0.0213	-0.000059	0.0210	-0.0089	-0.2012
	200	0.1197	0.0171	-0.000044			
	250	0.0688	0.0191	-0.000035			
	300	0.0469	0.0230	-0.000029			
90	150	0.1866	0.0207	-0.000028	0.0196	-0.0042	-0.1044
	200	0.1274	0.0164	-0.000021			
	250	0.0724	0.0178	-0.000016			
	300	0.0478	0.0219	-0.000014			
120	150	0.1974	0.0201	0.000077	0.0163	0.0116	0.3729
	200	0.1362	0.0157	0.000057			
	250	0.0780	0.0164	0.000046			
	300	0.0518	0.0186	0.000038			
150	150	0.2095	0.0195	0.000121	0.0142	0.0183	0.5998
	200	0.1491	0.0150	0.000091			
	250	0.0846	0.0151	0.000073			
	300	0.0553	0.0167	0.000060			
180	150	0.2386	0.0185	0.000111	0.0134	0.0167	0.7046
	200	0.1612	0.0145	0.000083			
	250	0.0895	0.0144	0.000066			
	300	0.0580	0.0156	0.000055			

TABLE- 26

INTERPRETATION OF RESULTS OF LANGMUIR ADSORPTION ISOTHERM
FOR CRYSTAL VIOLET DYE ADSORPTION FROM AN
AQUEOUS SOLUTION ONTO CAC

Time in minutes	Initial Conc. of dye in mg/L	1/Ce	m/x	Separation factor R_L	Intercept k_1/k_1^1	Slope $1/k_1^1$	Correlation coefficient (r)
10	150	0.1858	0.0051	-0.000011	0.0056	-0.0017	-0.3065
	200	0.0892	0.0056	-0.000008			
	250	0.0611	0.0057	-0.000007			
	300	0.0495	0.0051	-0.000006			
20	150	0.3022	0.0042	-0.000011	0.0048	-0.0016	-0.5622
	200	0.1027	0.0048	-0.000008			
	250	0.0676	0.0049	-0.000006			
	300	0.0539	0.0043	-0.000005			
30	150	0.3452	0.0041	-0.0000010	0.0042	-0.00016	-0.0896
	200	0.1229	0.0042	-0.0000008			
	250	0.0722	0.0044	-0.0000006			
	300	0.0580	0.0039	-0.0000005			
40	150	0.4028	0.0040	0.0000023	0.0038	0.00035	0.3290
	200	0.1363	0.0039	0.0000017			
	250	0.0775	0.0041	0.0000013			
	300	0.0602	0.0037	0.0000011			
50	150	0.4834	0.0038	0.00000113	0.0037	0.00017	0.1692
	200	0.1530	0.0037	0.00000084			
	250	0.0795	0.0040	0.00000067			
	300	0.0625	0.0035	0.00000056			

TABLE- 26

INTERPRETATION OF RESULTS OF LANGMUIR ADSORPTION ISOTHERM
FOR CRYSTAL VIOLET DYE ADSORPTION FROM AN
AQUEOUS SOLUTION ONTO CAC

Time in minutes	Initial Conc. of dye in mg/L	1/Ce	m/x	Separation factor R_L	Intercept k_1/k_1^1	Slope $1/k_1^1$	Correlation coefficient (r)
60	150	0.5372	0.0038	0.0000024	0.0035	0.00037	0.3780
	200	0.1630	0.0036	0.0000018			
	250	0.0815	0.0039	0.0000014			
	300	0.0639	0.0034	0.0000012			
90	150	0.8051	0.0036	0.0000025	0.0032	0.00039	0.7974
	200	0.2143	0.0032	0.0000019			
	250	0.0978	0.0034	0.0000015			
	300	0.0662	0.0033	0.0000012			
120	150	0.9661	0.0035	0.0000037	0.00295	0.00056	0.9277
	200	0.2344	0.0031	0.0000027			
	250	0.1223	0.0029	0.0000022			
	300	0.0716	0.0031	0.0000018			
150	150	1.2077	0.0035	0.0000031	0.0029	0.00048	0.9724
	200	0.2586	0.0031	0.0000023			
	250	0.1247	0.0029	0.0000019			
	300	0.0763	0.0030	0.0000015			
180	150	1.2077	0.0035	0.0000045	0.0026	0.00068	0.9972
	200	0.3125	0.0029	0.0000033			
	250	0.1353	0.0028	0.0000027			
	300	0.0825	0.0027	0.0000022			

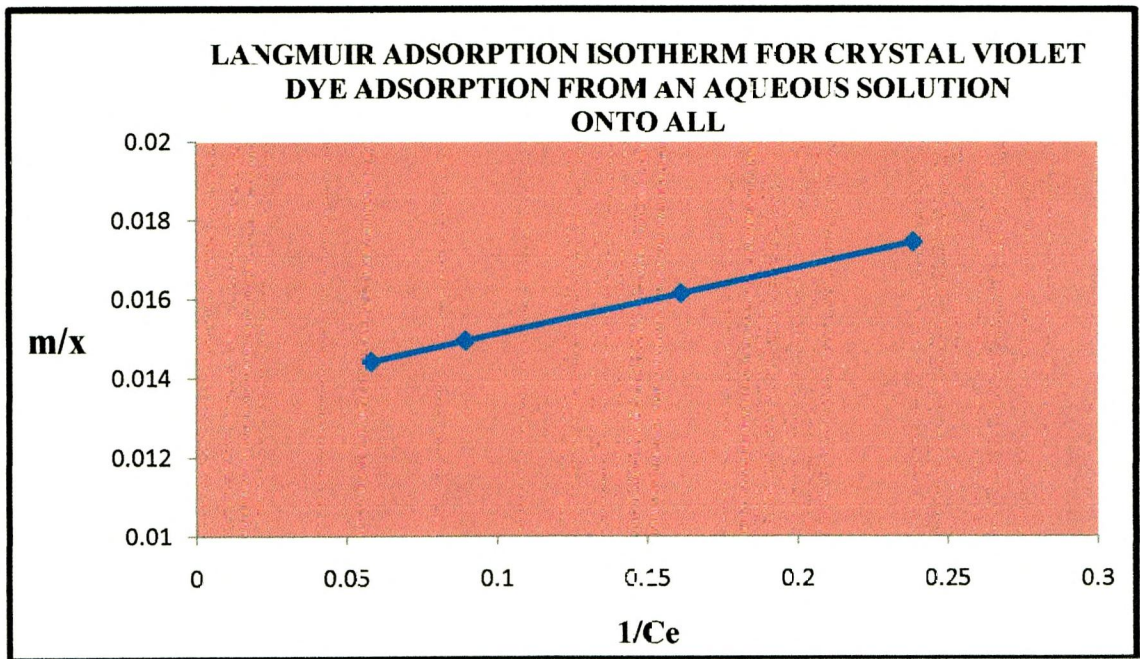


Figure- 36

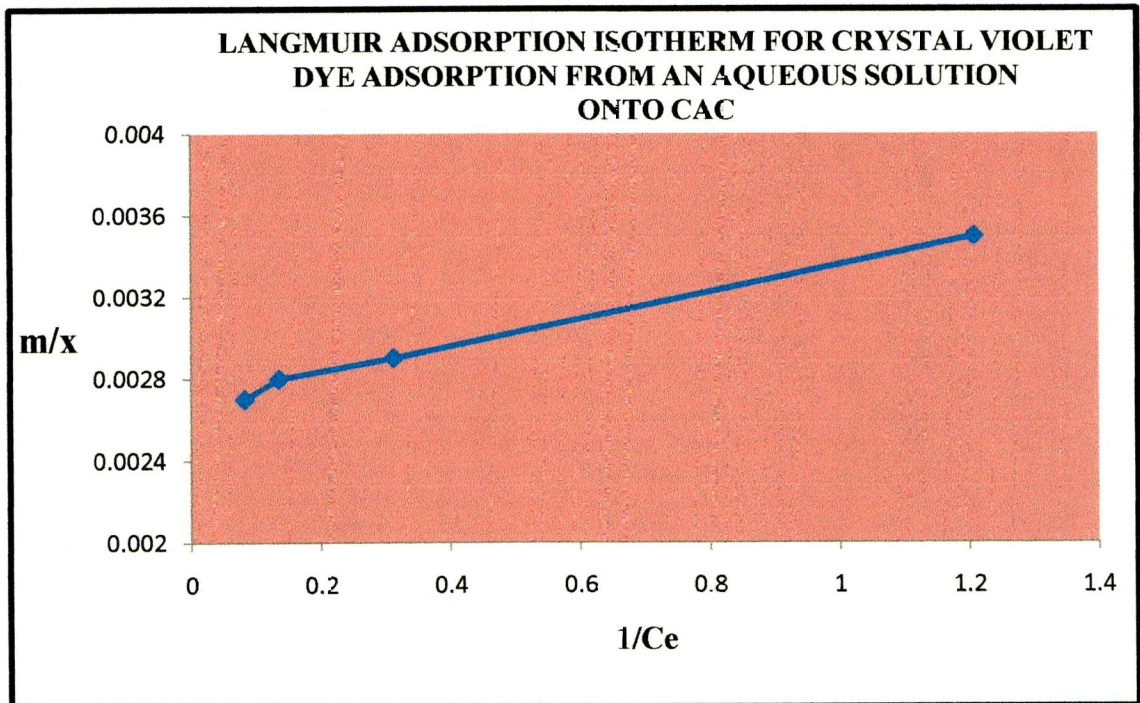


Figure- 37

TABLE- 27

**INTERPRETATION OF RESULTS OF LANGMUIR ADSORPTION ISOTHERM
FOR CRYSTAL VIOLET DYE ADSORPTION FROM A
DYEING INDUSTRIAL EFFLUENT ONTO ALL**

Time in minutes	Initial Conc. of dye in mg/L	1/Ce	m/x	Separation factor R_L	Intercept k_1/k_1^1	Slope $1/k_1^1$	Correlation coefficient (r)
10	100	0.1220	0.3325	0.017463	0.1164	1.7774	0.9992
	150	0.0788	0.2590	0.011710			
	200	0.0579	0.2177	0.008808			
20	100	0.1326	0.2440	0.013611	0.0608	1.3799	0.9999
	150	0.0858	0.1788	0.009115			
	200	0.0627	0.1477	0.006852			
30	100	0.1435	0.1978	0.008458	0.0766	0.8531	0.9940
	150	0.0894	0.1572	0.005655			
	200	0.0651	0.1293	0.004247			
40	100	0.1469	0.1876	0.007924	0.0714	0.7988	0.9943
	150	0.0912	0.1483	0.005297			
	200	0.0663	0.1217	0.003978			
50	100	0.1525	0.1742	0.006716	0.0725	0.6762	0.9898
	150	0.0932	0.1403	0.004487			
	200	0.0676	0.1149	0.003369			

TABLE- 27

**INTERPRETATION OF RESULTS OF LANGMUIR ADSORPTION ISOTHERM
FOR CRYSTAL VIOLET DYE ADSORPTION FROM A
DYEING INDUSTRIAL EFFLUENT ONTO ALL**

Time in minutes	Initial Conc. of dye in mg/L	1/Ce	m/x	Separation factor R_L	Intercept k_1/k_1^1	Slope $1/k_1^1$	Correlation coefficient (r)
60	100	0.1605	0.1591	0.005686	0.0681	0.5719	0.9958
	150	0.0974	0.1266	0.003798			
	200	0.0697	0.1061	0.002851			
90	100	0.1671	0.1494	0.005760	0.0534	0.5794	0.9958
	150	0.1020	0.1154	0.003847			
	200	0.0734	0.0940	0.002888			
120	100	0.1742	0.1407	0.005483	0.0451	0.5514	0.9983
	150	0.1070	0.1060	0.003662			
	200	0.0766	0.0862	0.002749			
150	100	0.1820	0.1330	0.005193	0.0382	0.5221	0.9995
	150	0.1126	0.0980	0.003468			
	200	0.0802	0.0795	0.002603			
180	100	0.1906	0.1262	0.004741	0.0351	0.4764	0.9997
	150	0.1187	0.0911	0.003165			
	200	0.0831	0.0752	0.002376			

TABLE- 28

**INTERPRETATION OF RESULTS OF LANGMUIR ADSORPTION ISOTHERM
FOR CRYSTAL VIOLET DYE ADSORPTION FROM A
DYEING INDUSTRIAL EFFLUENT ONTO CAC**

Time in minutes	Initial Conc. of dye in mg/L	1/Ce	m/x	Separation factor R_L	Intercept k_1/k_1^1	Slope $1/k_1^1$	Correlation coefficient (r)
10	100	0.1355	0.0571	0.003067	0.0144	0.3077	0.9806
	150	0.0893	0.0394	0.002047			
	200	0.0633	0.0356	0.001536			
20	100	0.1506	0.0446	0.002143	0.0121	0.2148	0.9992
	150	0.0963	0.0324	0.001429			
	200	0.0690	0.0272	0.001072			
30	100	0.1584	0.0406	0.001736	0.0132	0.1740	0.9980
	150	0.0985	0.0309	0.001158			
	200	0.0711	0.0252	0.000869			
40	100	0.1648	0.0381	0.001683	0.0102	0.1686	0.9996
	150	0.1044	0.0276	0.001122			
	200	0.0742	0.0229	0.000842			
50	100	0.1742	0.0351	0.001452	0.0096	0.1455	0.9995
	150	0.1097	0.0254	0.000969			
	200	0.0775	0.0211	0.000726			

TABLE- 28

**INTERPRETATION OF RESULTS OF LANGMUIR ADSORPTION ISOTHERM
FOR CRYSTAL VIOLET DYE ADSORPTION FROM A
DYEING INDUSTRIAL EFFLUENT ONTO CAC**

Time in minutes	Initial Conc. of dye in mg/L	1/Ce	m/x	Separation factor R_L	Intercept k_1/k_1^1	Slope $1/k_1^1$	Correlation coefficient (r)
60	100	0.1820	0.0332	0.001330	0.0087	0.1332	0.9974
	150	0.1156	0.0236	0.000887			
	200	0.0802	0.0198	0.000665			
90	100	0.1936	0.0310	0.001121	0.0090	0.1123	0.9950
	150	0.1221	0.0220	0.000748			
	200	0.0831	0.0188	0.000561			
120	100	0.2033	0.0295	0.001013	0.0086	0.1015	0.9953
	150	0.1275	0.0209	0.000676			
	200	0.0862	0.0178	0.000507			
150	100	0.2140	0.0281	0.000977	0.0067	0.0978	0.9904
	150	0.1376	0.0193	0.000651			
	200	0.0920	0.0164	0.000488			
180	100	0.2259	0.0269	0.000855	0.0071	0.0856	0.9874
	150	0.1445	0.0185	0.000570			
	200	0.0945	0.0159	0.000427			

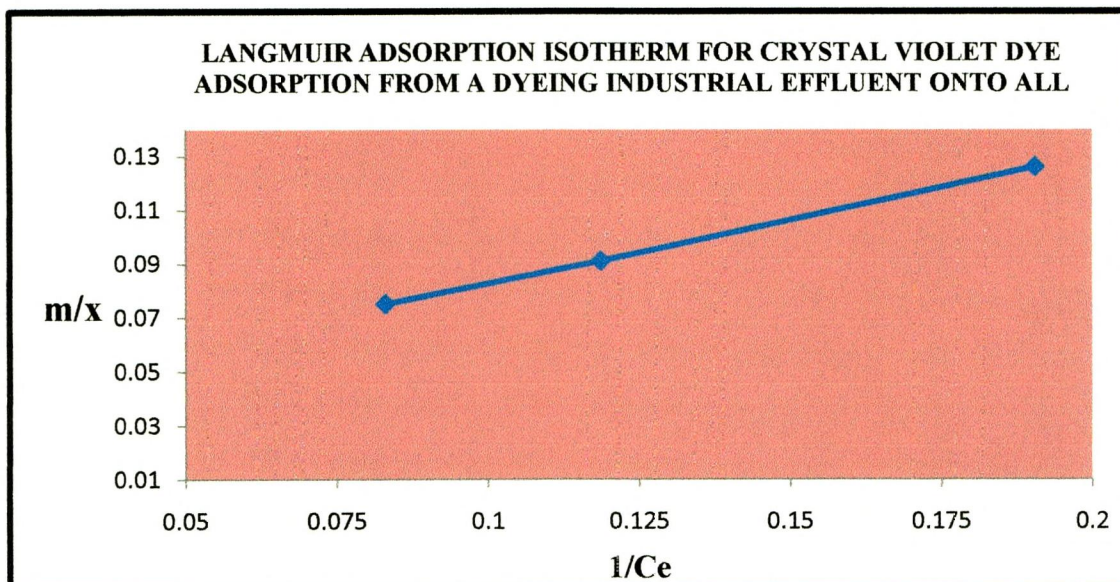


Figure- 38

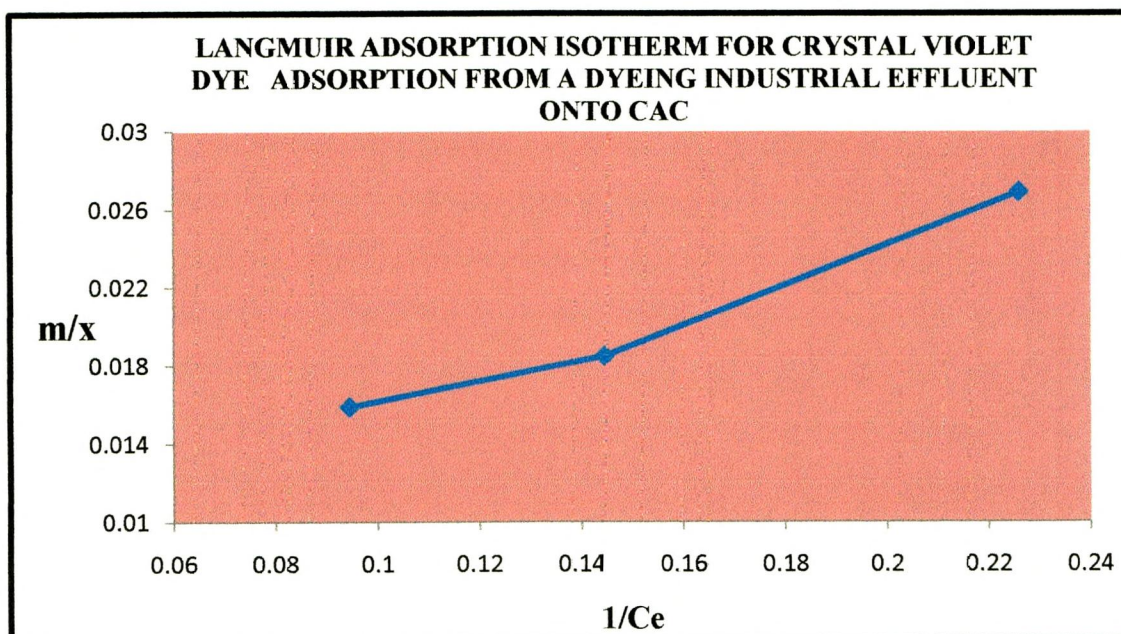


Figure- 39

4.6.2 FREUNDLICH ADSORPTION ISOTHERM

The Freundlich adsorption isotherm equation is used for determining the applicability of heterogeneous surface energy in the adsorption process. The empirical Freundlich adsorption isotherm equation is as follows (Jayaraj *et al.*, 2012)

$$x/m = K_F C_e^{1/n}$$

The linear form of Freundlich adsorption isotherm equation is

$$\log x/m = \log K_F + 1/n \log C_e$$

where,

x - amount of Crystal Violet dye adsorbed (mg/L)

m - weight of adsorbent (mg)

C_e - Concentration of Crystal Violet dye at equilibrium

K_F and 1/n are the Freundlich constants related to the adsorption capacity and intensity of adsorption respectively.

The Freundlich adsorption isotherm data for Crystal Violet dye adsorption from an aqueous solution onto the adsorbents ALL and CAC are summarized in the Tables 29 & 30. The value of 1/n (less than 1 obtained in this study) indicates the applicability of Freundlich adsorption isotherm for Crystal Violet dye adsorption. The corresponding isotherms drawn are given in the Figures 40 & 41.

The Freundlich adsorption isotherm data for Crystal Violet dye adsorption from a dyeing industrial effluent onto the adsorbents ALL and CAC are summarized in the Tables 31 & 32. The value of 1/n (less than 1 obtained in this study) indicates the applicability of Freundlich adsorption isotherm for Crystal Violet dye adsorption. The corresponding isotherms drawn are given in the Figures 42 & 43.

TABLE- 29

**INTERPRETATION OF RESULTS OF FREUNDLICH ADSORPTION
ISOTHERM FOR CRYSTAL VIOLET DYE ADSORPTION FROM AN
AQUEOUS SOLUTION ONTO ALL**

Time in minutes	Initial Conc. of dye in mg/L	log Ce	log x/m	Intercept	Slope 1/n	n	Correlation coefficient (r)
10	150	0.9931	1.4122	1.9340	-0.45463	-02.19	-0.7220
	200	1.1396	1.4921				
	250	1.2984	1.4101				
	300	1.4282	1.2125				
20	150	0.9333	1.5072	1.8248	-0.28429	-03.51	-0.6367
	200	1.1067	1.5575				
	250	1.2581	1.5391				
	300	1.4056	1.3585				
30	150	0.8752	1.5751	1.7428	-0.14710	-06.79	-0.5682
	200	1.0565	1.6345				
	250	1.2351	1.5934				
	300	1.3746	1.5003				
40	150	0.8401	1.6073	1.8464	-0.21205	-04.71	-0.5745
	200	1.0000	1.7011				
	250	1.2111	1.6421				
	300	1.3585	1.5003				
50	150	0.8016	1.6382	1.7734	-0.10322	-09.68	-0.4152
	200	0.9597	1.7375				
	250	1.1904	1.6777				
	300	1.3448	1.5968				

TABLE- 29

**INTERPRETATION OF RESULTS OF FREUNDLICH ADSORPTION
ISOTHERM FOR CRYSTAL VIOLET DYE ADSORPTION FROM AN
AQUEOUS SOLUTION ONTO ALL**

Time in minutes	Initial Conc. of dye in mg/L	log Ce	log x/m	Intercept	Slope 1/n	n	Correlation coefficient (r)
60	150	0.7522	1.6716	1.7803	-0.07823	-12.78	-0.3552
	200	0.9219	1.7670				
	250	1.1624	1.7189				
	300	1.3288	1.6382				
90	150	0.7291	1.6840	1.7808	-0.06004	-16.65	-0.2710
	200	0.8948	1.7851				
	250	1.1402	1.7495				
	300	1.3205	1.6595				
120	150	0.7046	1.6968	1.7200	0.03433	29.12	0.1787
	200	0.8658	1.8041				
	250	1.1079	1.7852				
	300	1.2856	1.7304				
150	150	0.6788	1.7099	1.6974	0.08919	11.21	0.4305
	200	0.8265	1.8239				
	250	1.0726	1.8210				
	300	1.2572	1.7772				
180	150	0.6223	1.7328	1.7110	0.10152	09.85	0.5448
	200	0.7926	1.8386				
	250	1.0481	1.8416				
	300	1.2365	1.8068				

TABLE- 30

**INTERPRETATION OF RESULTS OF FREUNDLICH ADSORPTION
ISOTHERM FOR CRYSTAL VIOLET DYE ADSORPTION FROM AN
AQUEOUS SOLUTION ONTO CAC**

Time in minutes	Initial Conc. of dye in mg/L	log Ce	log x/m	Intercept	Slope 1/n	n	Correlation coefficient (r)
10	150	0.7309	2.2924	2.3021	-0.02970	-33.67	-0.2901
	200	1.0496	2.2518				
	250	1.2139	2.2441				
	300	1.3053	2.2924				
20	150	0.5197	2.3767	2.3883	-0.04606	-21.71	-0.4557
	200	0.9884	2.3187				
	250	1.1701	2.3098				
	300	1.2684	2.3665				
30	150	0.4619	2.3872	2.3809	0.00143	69.93	0.0227
	200	0.9104	2.3767				
	250	1.1414	2.3565				
	300	1.2365	2.4089				
40	150	0.3949	2.3979	2.3880	0.02050	48.78	0.3949
	200	0.8655	2.4089				
	250	1.1106	2.3872				
	300	1.2204	2.4317				
50	150	0.3156	2.4202	2.4147	0.01362	73.42	0.2243
	200	0.8153	2.4317				
	250	1.0996	2.3979				
	300	1.2041	2.4559				

TABLE- 30

**INTERPRETATION OF RESULTS OF FREUNDLICH ADSORPTION
ISOTHERM FOR CRYSTAL VIOLET DYE ADSORPTION FROM AN
AQUEOUS SOLUTION ONTO CAC**

Time in minutes	Initial Conc. of dye in mg/L	log Ce	log x/m	Intercept	Slope 1/n	n	Correlation coefficient (r)
60	150	0.2698	2.4202	2.4136	0.02595	38.53	0.4069
	200	0.7878	2.4436				
	250	1.0888	2.4089				
	300	1.1944	2.4685				
90	150	0.0941	2.4436	2.4507	0.02894	34.55	0.6354
	200	0.6689	2.4948				
	250	1.0096	2.4685				
	300	1.1791	2.4814				
120	150	0.0149	2.4559	2.4632	0.05830	17.15	0.8359
	200	0.6300	2.5086				
	250	0.9125	2.5376				
	300	1.1450	2.5086				
150	150	---	---	2.4953	0.03176	31.48	0.5842
	200	0.5873	2.5086				
	250	0.9041	2.5376				
	300	1.1174	2.5228				
180	150	---	---	2.5101	0.05235	19.10	0.9874
	200	0.5051	2.5376				
	250	0.8687	2.5528				
	300	1.0835	2.5686				

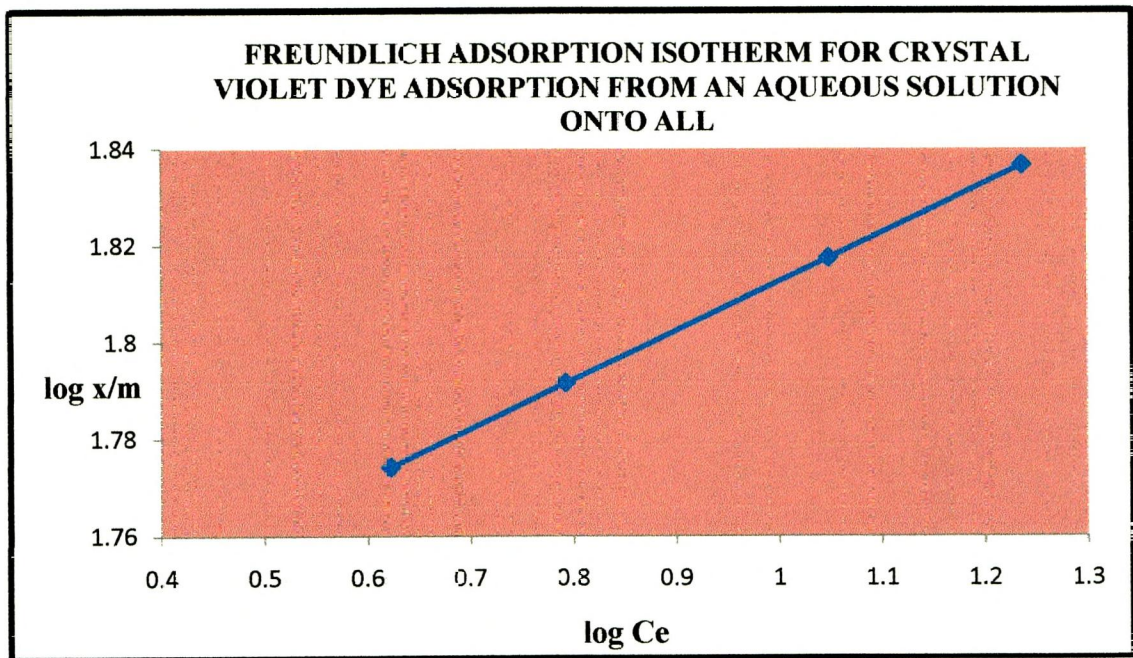


Figure- 40

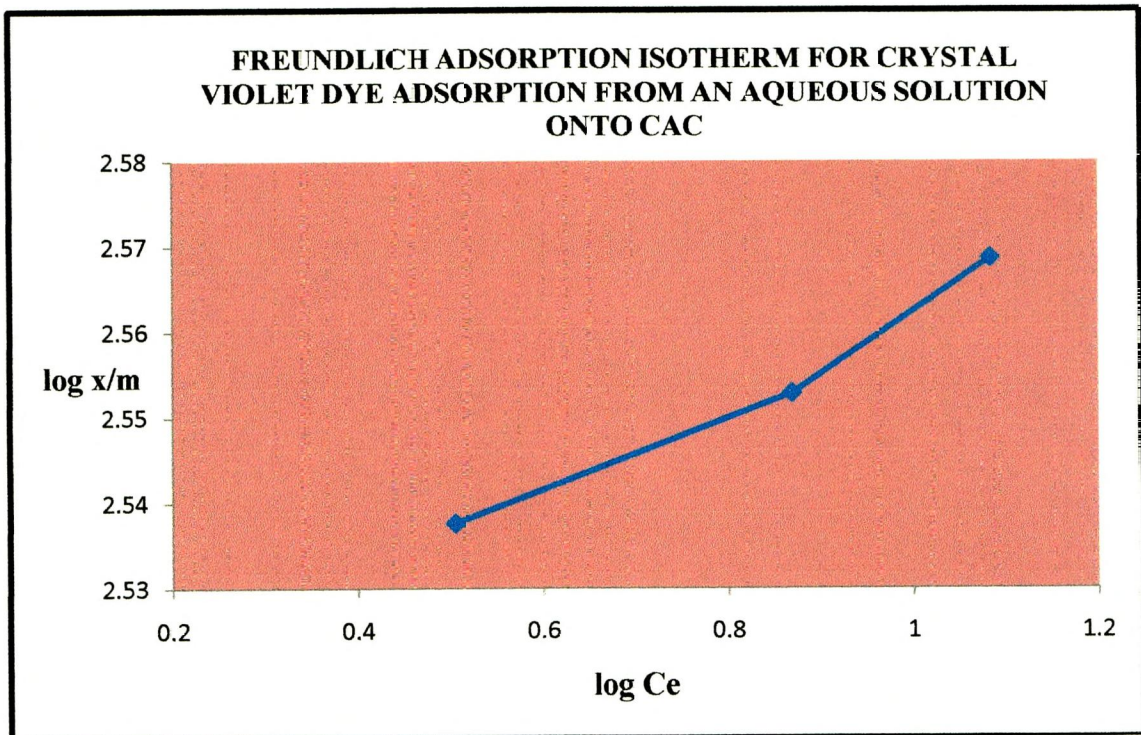


Figure- 41

TABLE- 31

**INTERPRETATION OF RESULTS OF FREUNDLICH ADSORPTION
ISOTHERM FOR CRYSTAL VIOLET DYE ADSORPTION FROM A
DYEING INDUSTRIAL EFFLUENT ONTO ALL**

Time in minutes	Initial Conc. of dye in mg/L	log Ce	log x/m	Intercept	Slope 1/n	n	Correlation coefficient (r)
10	100	0.9136	0.4782	-0.0408	0.56835	1.7594	0.9999
	150	1.1034	0.5867				
	200	1.2373	0.6621				
20	100	0.8774	0.6126	0.0245	0.67288	1.4861	0.9990
	150	1.0665	0.7476				
	200	1.2027	0.8306				
30	100	0.8431	0.7037	0.2506	0.53394	1.8728	0.9977
	150	1.0486	0.8035				
	200	1.1864	0.8884				
40	100	0.8329	0.7267	0.2740	0.54012	1.8514	0.9979
	150	1.0400	0.8288				
	200	1.1784	0.9147				
50	100	0.8167	0.7589	0.3421	0.50546	1.9783	0.9952
	150	1.0305	0.8529				
	200	1.1700	0.9396				

TABLE- 31

**INTERPRETATION OF RESULTS OF FREUNDLICH ADSORPTION
ISOTHERM FOR CRYSTAL VIOLET DYE ADSORPTION FROM A
DYEING INDUSTRIAL EFFLUENT ONTO ALL**

Time in minutes	Initial Conc. of dye in mg/L	log Ce	log x/m	Intercept	Slope 1/n	n	Correlation coefficient (r)
60	100	0.7945	0.7983	0.4125	0.48343	2.0685	0.9992
	150	1.0114	0.8975				
	200	1.1567	0.9742				
90	100	0.7770	0.8256	0.3882	0.55996	1.7858	0.9988
	150	0.9913	0.9377				
	200	1.1343	1.0268				
120	100	0.7589	0.8517	0.3992	0.59499	1.6807	0.9998
	150	0.9706	0.9746				
	200	1.1157	1.0644				
150	100	0.7399	0.8761	0.4115	0.62851	1.5910	0.9999
	150	0.9484	1.0087				
	200	1.0958	1.0996				
180	100	0.7198	0.8989	0.4513	0.62701	1.5948	0.9977
	150	0.9255	1.0404				
	200	1.0803	1.1237				

TABLE- 32

INTERPRETATION OF RESULTS OF FREUNDLICH ADSORPTION
ISOTHERM FOR CRYSTAL VIOLET DYE ADSORPTION FROM A
DYEING INDUSTRIAL EFFLUENT ONTO CAC

Time in minutes	Initial Conc. of dye in mg/L	log Ce	log x/m	Intercept	Slope 1/n	n	Correlation coefficient (r)
10	100	0.8680	1.2433	0.7108	0.63028	1.5865	0.9655
	150	1.0491	1.4045				
	200	1.1985	1.4485				
20	100	0.8221	1.3506	0.8304	0.63811	1.5671	0.9965
	150	1.0163	1.4894				
	200	1.1611	1.5654				
30	100	0.8002	1.3914	0.9151	0.59380	1.6840	0.9997
	150	1.0065	1.5100				
	200	1.1481	1.5985				
40	100	0.7830	1.4190	0.9202	0.64181	1.5580	0.9975
	150	0.9812	1.5590				
	200	1.1295	1.6401				
50	100	0.7589	1.4546	0.9786	0.63247	1.5812	0.9973
	150	0.9597	1.5951				
	200	1.1106	1.6757				

TABLE- 32

INTERPRETATION OF RESULTS OF FREUNDLICH ADSORPTION
ISOTHERM FOR CRYSTAL VIOLET DYE ADSORPTION FROM A
DYEING INDUSTRIAL EFFLUENT ONTO CAC

Time in minutes	Initial Conc. of dye in mg/L	log Ce	log x/m	Intercept	Slope 1/n	n	Correlation coefficient (r)
60	100	0.7399	1.4788	1.0156	0.63558	1.5733	0.9927
	150	0.9370	1.6270				
	200	1.0958	1.7033				
90	100	0.7130	1.5086	1.0926	0.59632	1.6769	0.9873
	150	0.9132	1.6575				
	200	1.0803	1.7258				
120	100	0.6918	1.5301	1.1286	0.59358	1.6846	0.9876
	150	0.8944	1.6798				
	200	1.0644	1.7495				
150	100	0.6695	1.5512	1.1348	0.64127	1.5594	0.9804
	150	0.8613	1.7144				
	200	1.0362	1.7851				
180	100	0.6460	1.5702	1.1938	0.60548	1.6515	0.9747
	150	0.8401	1.7328				
	200	1.0245	1.7986				

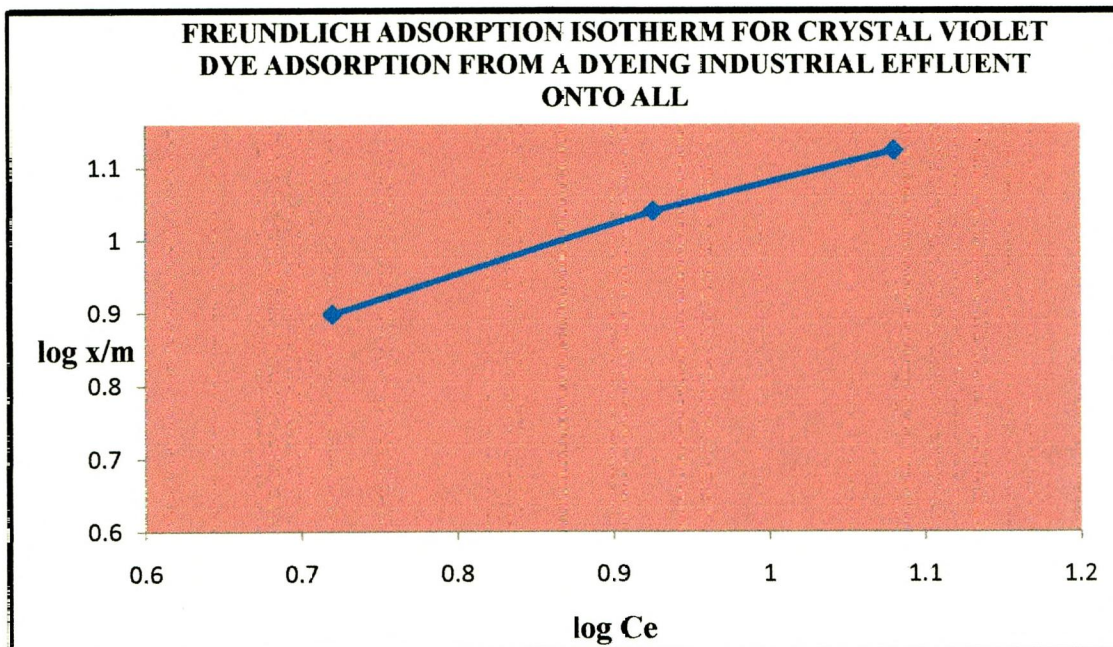


Figure- 42

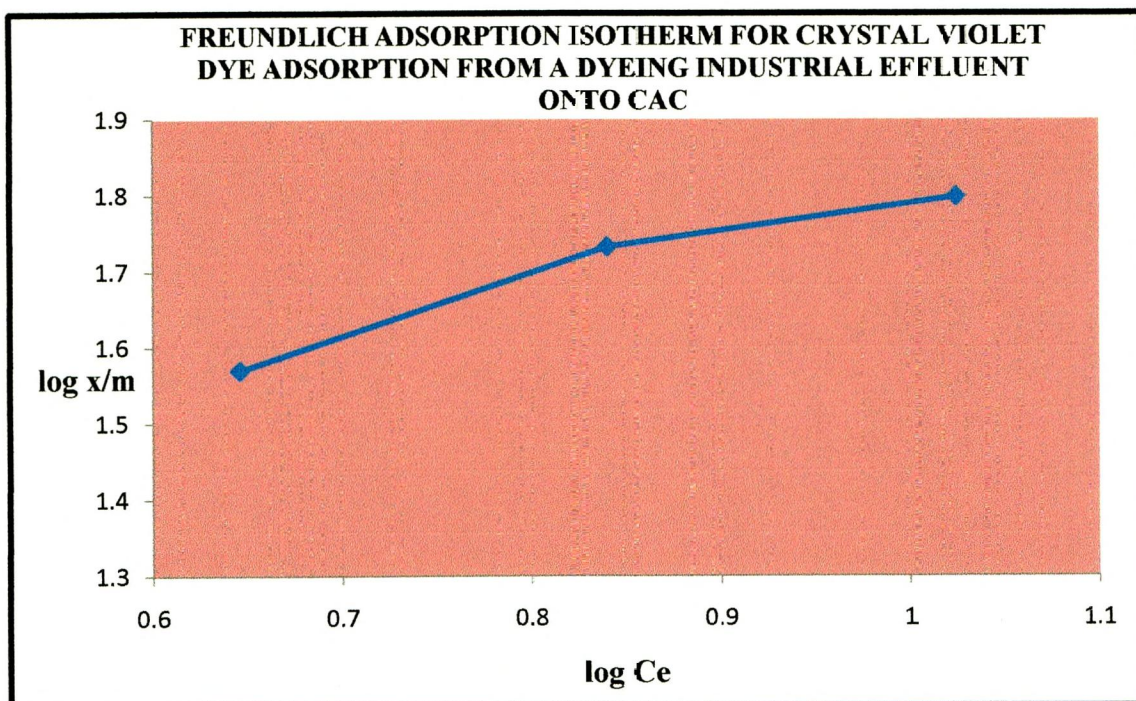


Figure- 43

4.7 SCANNING ELECTRON MICROSCOPE (SEM) ANALYSIS

Scanning Electron Microscope (SEM) photographs of the adsorbents ALL & CAC and these adsorbents with the adsorbed Crystal Violet dye species from an aqueous solution and as well as from a dyeing industrial effluent obtained using Nikon- Epiphot SEM analyzer made in Japan are given below

- * Plate IA - Adsorbent ALL prepared from the pods of *Leucaena leucocephala*.
- * Plate IB - Adsorbent ALL with adsorbed Crystal Violet dye species from an aqueous solution.
- * Plate IC - Adsorbent ALL with adsorbed Crystal Violet dye species from a dyeing industrial effluent.
- * Plate IIA - Commercial Activated Carbon adsorbent (CAC).
- * Plate IIB - Adsorbent CAC with adsorbed Crystal Violet dye species from an aqueous solution.
- * Plate IIC - Adsorbent CAC with adsorbed Crystal Violet dye species from a dyeing industrial effluent.

Photographs (Plates IB, IC, IIB and IIC) shows the adsorbed Crystal Violet dye species on the surface of both the adsorbents used in this study.

Adsorbent ALL prepared from the pods of *Leucaene leucocephala*

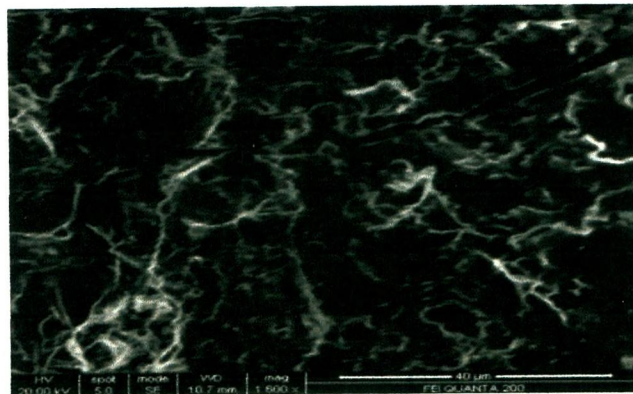


Plate - IA

Adsorbent ALL with adsorbed Crystal Violet dye species from an aqueous solution

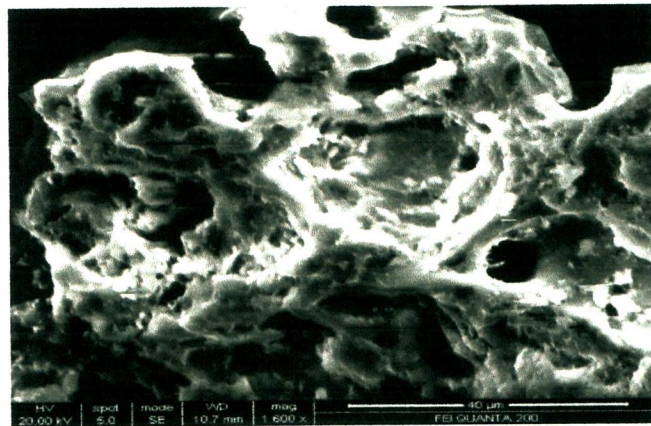


Plate - IB

Adsorbent ALL with adsorbed Crystal Violet dye species from a dyeing industrial effluent

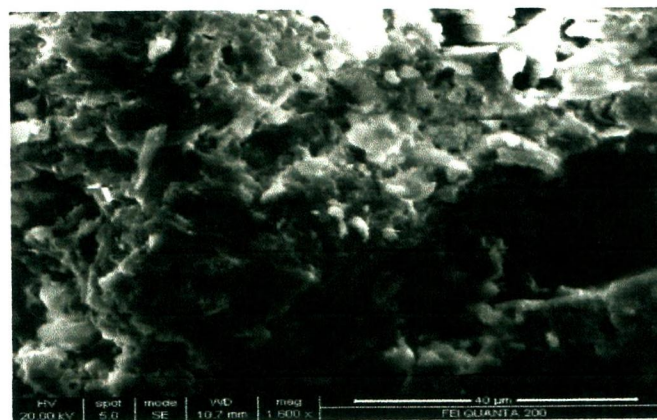


Plate - IC

Commercial Activated Carbon adsorbent (CAC)

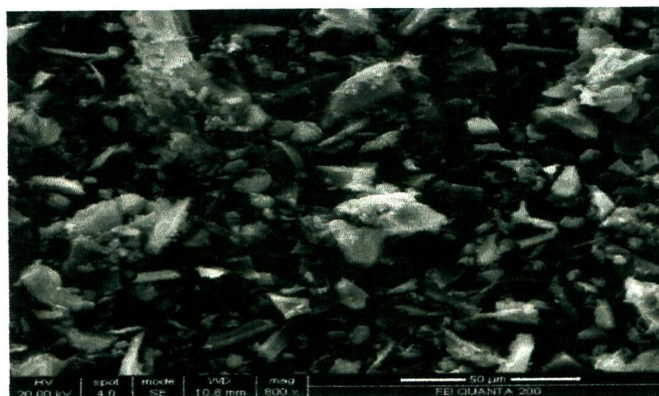


Plate - IIA

Adsorbent CAC with adsorbed Crystal Violet dye species from an aqueous solution

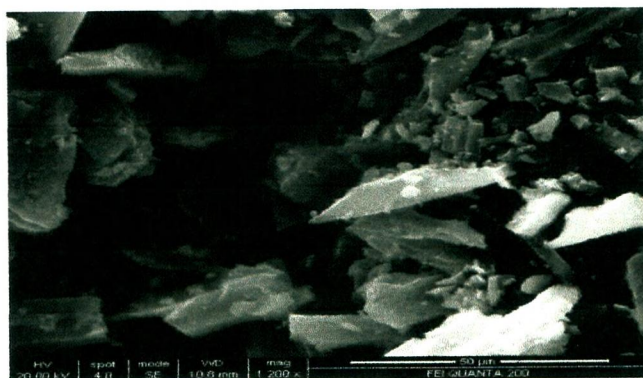


Plate - IIB

Adsorbent CAC with adsorbed Crystal Violet dye species from a dyeing industrial effluent

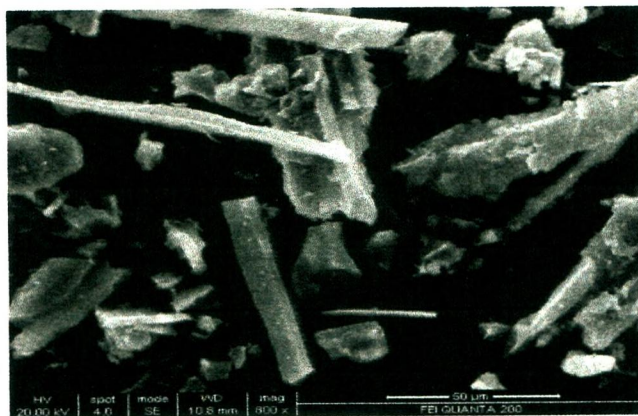


Plate - IIC