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Adsorption of Methylene Blue on Activated Charcoal, Silica Gel and Silica

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Adsorption of methylene blue from aqueous solution has been investigated on activated charcoal, silica gel and silica (clay) by spectrophotometric method. Langmuir and Freudich plots were drawn and their constants were evaluated from the relevant data, which determined the mechanism and the nature of forces involved in adsorbate-adsorbent interactions. Correlation coefficients of the entire data in connection with Langmuir and Freundlich plots for each adsorbent were also calculated. It was found that these regression coefficients approach 99% in most cases, which rather signifies the validity of the data for the straight line. An attempt has also been made to calculate the surface area of the adsorbent.

Key Words: Dye, Freundlich and Langmuir Adsorption Isotherm, Surface area.

INTRODUCTION

Adsorption is an important physical phenomenon, which provides bases for understanding such process as heterogeneous catalysis, chromatographic analyses and dyeing of textiles[1–5]. Since after the discovery of adsorption, a large number of scientists have been working either on adsorption of gases or liquids on different adsorbents. The property possessed by charcoal of removing colouring matter from solutions has been reported and many observations have since been made showing that these finely divided powders are able to take up dyestuff and other substances from solution[6–10].

Adsorption of methylene blue on activated carbon was studied by Potgieter[11] with the illustration of both the Langmuir and Freundlich isotherms. Duff *et al.*[12] studied the adsorption of basic dye malachite green on sand. Khattri *et al.*[13] studied the adsorption of methylene blue and malachite green on sand. Hanson *et al.*[14] worked on adsorption of benzene on silica gel.

The aim of the present work is to study the adsorption of methylene blue on different adsorbents and compare the adsorption capacity of different adsorbents, the effect of change of concentration of methylene blue on the adsorption phenomenon, the effect of change of amount of the adsorbents on the adsorption phenomenon and to select the best adsorbent for the adsorption of methylene blue from aqueous solution.

EXPERIMENTAL

Different adsorbents, *e.g.*, activated charcoal and silica gel (purchased from E. Merck) and ordinary impure dried silica (clay). Methylene blue [3,7-phenothiazine, 3,7-bis(dimethyl amino)chloride] solutions with concentration of 0.5 mg/dm^3 and 0.2 mg/dm^3 were prepared from analytical grade reagent and distilled water. The wavelength of maximum adsorption of methylene blue solution was determined to be 661 nm. Adsorbents were taken in the range of 0.001 and 0.005 g in separate reagent bottles, each containing 50 mL of 0.5 mg/dm^3 methylene blue solution. The flasks were then stoppered and shaken on a mechanical shaker for 20 min in order to reach equilibrium conditions for the adsorption process. The solutions were tested spectrophotometrically before and after the equilibration. Same procedure was followed for 0.2 mg/dm^3 methylene blue solution with different adsorbents.

RESULTS AND DISCUSSION

Experimental data were analyzed by Langmuir and Freundlich isotherm equations (1) and (2) respectively. Langmuir equation[2, 14] is expressed as:

$$\frac{1}{(x/m)} = \frac{1}{(x_m K)} \cdot \frac{1}{C} + \frac{1}{x_m} \qquad (1)$$

where

x/m = the amount of methylene blue adsorbed per mass of adsorbent;

x_m = limiting amount of methylene blue that can be taken up per mass of adsorbent;

C = concentration of methylene blue that is in equilibrium with adsorbent;

K = constant.

Laugmuir plot of 1/(x/m) against 1/C shows a straight line with the gradient of $1/(x_m K)$ and an intercept of $1/x_m$. The values of constants 'K' and 'x_m' were obtained from the slope and intercept respectively (Fig. 1).

Freundlich equation[13] is expressed as:

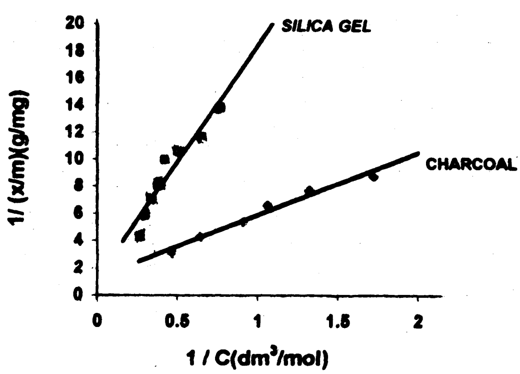

Fig. 1. Plot of 1/(x/m) *vs.* 1/C for adsorption of methyl blue on charcoal and silica gel

$$\log \frac{x}{m} = \log K + \frac{1}{n} \log C$$

where all the terms have their usual meanings and 1/n is a constant known as Freundlich isotherm. The plot of log x/m vs. log C shows linear plot and values of 1/n and K constants were evaluated from the slope and intercept of plot (Fig. 2).

Experimental data showing the effect of concentration of adsorbent and adsorbate are shown in Tables 1 and 2 respectively. Results show that the extent of adsorption increases with the increase in concentration of adsorbent and

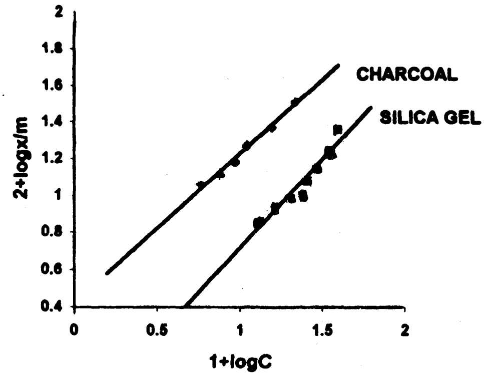

Fig. 2. Plot of (2 + log x/m) vs. (1 + log C) for adsorption of methylene blue on charcoal and silica gel

TABLE-1
ADSORPTION OF METHYLENE BLUE AT DIFFERENT ADSORBENTS

Adsorbate = Methylene blue; Mass of adsorbate before adsorption = 0.32 mg

S. No.	Amount of adsorbent (mg)	Mass of MB after adsorption (mg)	MB mass adsorbed/ mass of adsorbent, x/m (mg/g)	[MB] after adsorption, C (mg/dm^3)
		CHARCOAL		
1.	1.0	0.058	0:262	1.16
2.	2.0	0.042	0.140	0.84
3.	3.0	0.026	0.098	0.52
4.	4.0	0.009	0.078	0.18
5.	5.0	0.003	0.064	0.05
		SILICA GEL		
1.	1.0	0.160	0.165	3.10
2.	2.0	0.110	0.104	2.24
3.	3.0	0.084	0.079	1.69
4.	4.0	0.067	0.063	1.34
5.	5.0	0.053	0.053	1.06
		SILICA (CLAY)		
1.	1.0	0.064	0.260	1.28
2.	2.0	0.056	0.130	1.12
3.	3.0	0.040	0.093	0.80
4.	4.0	0.016	0.076	0.32
5.	5.0	0.012	0.062	0.24

adsorbate. The high value for adsorption was observed in case of charcoal. Laugmuir and Freundlich constants for the adsorbents at 2.4 and 0.5 mg/dm^3 methylene blue solutions are tabulated in Table-3. The experimental data points fitted to the two isotherms are graphically represented in Figs. 1and 2 respectively.

TABLE-2
EFFECT OF ADSORBATE ON ADSORPTION OF METHYLENE BLUE
AT DIFFERENT ADSORBENTS

Adsorbate = Methylene blue; Mass of adsorbate before adsorption = 3.0 mg

S. No.	Amount of adsorbent (mg)	Mass of MB after adsorption (mg)	MB mass adsorbed/ mass of adsorbent, x/m (mg/g)	[MB] after adsorption, C (mg/dm^3)
		CHARCOAL		
1.	0.427	0.380	0.130	0.76
2.	0.320	0.026	0.098	0.52
3.	0.210	0.012	0.066	0.23
4.	0.170	0.008	0.054	0.16
5.	0.140	0.003	0.046	0.05
		SILICA GEL		
1.	0.427	0.120	0.100	2.40
2.	0.320	0.084	0.079	1.69
3.	0.210	0.073	0.046	1.46
4.	0.170	0.053	0.039	1.06
5.	0.140	0.014	0.042	0.29
		SILICA (CLAY)		
1.	0.427	0.045	0.130	0.91
2.	0.320	0.040	0.093	0.80
3.	0.210	0.029	0.060	0.58
4.	0.170	0.014	0.052	0.28
5.	0.140	0.004	0.047	0.07

TABLE-3
LANGMUIR AND FREUNDLICH PARAMETERS AND REGRESSION COEFFICIENT VALUES FOR THE ADSORPTION OF METHYLENE BLUE

$[MB] \cdot 10^5$ (mol/dm^3)	Langmuir parameters		Regression coefficient	Freundlich parameters		Regression coefficient
	$1/x_m$	$1/(x_m K)$		log K	1/n	
			CHARCOAL			
2.4	3.48	2.27	0.88	–0.71	0.20	0.40
1.2	6.31	1.02	0.88	–0.66	0.60	0.92
0.8	6.37	0.81	0.88	–0.57	0.65	0.91
			SILICA GEL			
2.4	11.63	17.35	0.95	–1.30	0.96	0.96
1.2	10.75	14.23	0.96	–1.40	0.50	0.97
0.8	11.82	3.50	0.94	–1.13	0.39	0.95
			SILICA (CLAY)			
2.4	2.37	3.97	0.90	–0.77	0.91	0.87
1.2	10.64	2.03	0.85	–1.02	0.50	0.88
0.8	7.19	1.16	0.89	–0.64	0.70	0.96

The linear plots of log x/m vs. log C indicate the applicability of Freundlich adsorption isotherm and Langmuir isotherm for the present system, which exhibits monolayer coverage of the adsorbate on the outer surface of the adsorbent. Both equations show the validity for adsorption of methylene blue on different adsorbents such as charcoal, silica gel and silica (clay).

The value of x_m obtained from Langmuir equation and the hypothesized area covered by dye molecule can be used to estimate the specific surface area of dispersed solid by using the following relation[2]:

$$S = x_n N_A \cdot \frac{a}{n} \tag{3}$$

where 'S' is specific surface area of solid, 'N_A' is Avogadro number, 'a' is the area of dye molecule and 'n' is aggregation number. The monomeric species of dye (methylene blue) prevails below concentration[11] 4.0×10^{-5} mol/dm^3; so the selected concentration[15] range is 10^{-6} to 10^{-5} and the value of 'n' is taken as 1.0. The values of specific surface areas of adsorbents are shown in Table-4.

TABLE-4
SPECIFIC SURFACE AREA OF DIFFERENT ADSORBENTS OBTAINED FROM LANGMUIR ISOTHERM

[MB] $\cdot 10^5$ (mol/dm^3)	Specific surface area (m^2/gm)		
	Charcoal	Silica Gel	Silica (Clay)
2.4	168	621	186

In Langmuir equation, x_m is the measure of the surface area of solid and K is the strength of adsorption. Results tabulated in Table-1 reveal that as the concentration of methylene blue is decreased the value of $1/x_m$ is increased which shows that less surface area is utilized with decrease in concentration of methylene blue. The values of $1/Kx_m$ is decreasing with decrease in concentration of methylene blue which shows that the value of 'K' is increasing remarkably, which in turn shows that the intensity of adsorption is increasing with the decrease in concentration of methylene blue.

In Freundlich adsorption isotherm equation, K is the measure of the intensity of adsorption while the value of 1/n shows the extent of adsorption. Results tabulated in Table-3 show that the value of log K increases with decrease in concentration of methylene blue in presence of different adsorbents such as charcoal, silica gel and silica (clay).

Conclusion

Results show that at higher concentration of methylene blue Langmuir and Freundlich equations give good results for silica (clay), silica gel and charcoal. Further, at higher concentration of methylene blue, more surface area is utilized by charcoal, silica gel and silica (clay). It was concluded that adsorption of methylene blue gives validity for Langmuir and Freundlich isotherms at higher concentration with silica gel, charcoal and silica (clay) and the extent of adsorption is high by using charcoal as compared to silica (clay) and silica gel.

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