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Adsorption of acid yellow 7 from aqueous solutions by low cost activated carbon

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ABSTRACT

The efficiency of activated carbon prepared from Azadirachta indica stem carbon (AZSC) for the adsorption of acid yellow 7 from aqueous solution has been studied as a function of agitation time, adsorbent dosage, initial dye concentration, temperature and pH of adsorbate solution. The optimal conditions for the adsorption have been arrived and experiments were conducted to find out the Langmuir constants, Freundlich parameters and thermodynamic parameters such as ΔG°, ΔH° and ΔS°. Desorption studies were carried out for the recovery of both adsorbent and the dye.

Key words: Activated carbon (AZSC), yellow 7, Adsorption isotherm, Equilibrium, Kinetic and Thermodynamic parameters, Intraparticle diffusion, Regeneration pattern.

INTRODUCTION

In this paper, the adsorption behavior of acid yellow 7 on *Azadirachta indica stem* carbon (AZSC) prepared from *Azadirachta indica stem*, as the adsorbent has been made. Batch mode experiments were carried out to study the effect of contact time on the removal of dye with the variation of the dose of the adsorbent, variation of the dye concentration of the solution, variation of pH, variation of size of the adsorbent and variation of temperature. Langmuir[1] and Freundlich[2] models were tested and the results are interpreted.

RESULTS AND DISCUSSION

Effect of Dosage of AZSC

Experiments were conducted to find out the effect of the dose of the adsorbent on the removal of dye, namely, 2.0, 4.0, 6.0, 8.0 and 10.0 g/L respectively. Figure-1 represents the plot of acid yellow 7 adsorbed in percentage for various doses of the adsorbent. The result indicates that the uptake of acid yellow 7 per unit mass of the adsorbent increases with the increasing dose of adsorbent[3,4].

Effect of Contact Time

The effect of contact time on the removal of acid yellow 7 by AZSC has been studied and the results are shown in figure-2. There is only a marginal increase in removal of acid yellow 7 after the attainment of equilibrium[5,6]. The maximum amount of acid yellow 7 adsorbed corresponding to the equilibration time is found to be 87.76 % for a weight of 2.0 g/L of the adsorbent.

Effect of Initial Dye Concentration
The results for the effect of concentration of adsorbate solution on removal of acid yellow 7, viz., 10, 20, 30, 40 and 50 mg/L respectively showed that as the concentration of the solution increases, percentage removal of acid yellow 7 decreases[7] (Fig.3).

Effect of Size of the Adsorbent
The experimental results of adsorptions of acid yellow 7 on to the activated carbon with various sizes (75-125, 125-200, 200-250, 250-300 µ) of the adsorbent are presented in figure-4. It is found that the adsorption is much favorable with the 75-125 µ size of the adsorbent[8].

Effect of pH
The effect of pH for the adsorption of acid yellow 7 on to AZSC has been studied and the values are presented in figure-5. The optimum[9,10] pH is found to be 5.5 for the removal of acid yellow 7.

Effect of Temperature
The effect of temperature on the adsorption of acid yellow 7 has been studied and the values are presented in figure-6. The result indicates that the adsorption is maximum at higher temperature and found to be an endothermic process[11,12].

Adsorption Isotherms
The experimental data were analyzed by using linear form of the Langmuir[1] and Freundlich isotherms[2]. The linear plots of C_e/Q_e versus C_e suggest the applicability of the Langmuir isotherms (Fig.7). Values of Q_m and b were determined from slope and intercepts of the plots and are presented in table (Table-1). From the results, it is clear that the values of adsorption efficiency Q_m for AZSC decreases on increasing the temperature[13,14]. But the energy of adsorption shows an increasing trend. From the values, we can conclude that the maximum adsorption corresponds to a saturated monolayer of adsorbate molecules on adsorbent surface with high energy and no transmission of adsorbate in the plane of the adsorbent surface. The separation factor (R_L) was calculated and presented in table (Table-2). The values were found to lie between 0 and 1 and confirmed the adsorption process is favourable[15-17].

Linear plot of log Q_e versus log C_e shows that the adsorption of acid yellow 7 follows the Freundlich isotherm(Fig.8). Values of K_F and n were found and given in the table (Table-1). However, the value of n is greater than one indicating the adsorption is much more favorable[16-18].

The homogeneous equilibrium between the acid yellow 7 solution and the activated carbon has been expressed as:

$$A \underset{k_2}{\overset{k_1}{\rightleftharpoons}} B$$

Where k_1 is the forward rate constant and k_2 is the backward rate constant (Table-3). 'A' represents acid yellow 7 remaining in the aqueous solution and 'B' represents acid yellow 7 adsorbed on the surface of activated carbon. The result indicates that K_o values decreases with increase in the concentration of the acid yellow 7 and increases with increase in temperature[19] (Table-4).

The K_p values obtained from the slope of the linear portions of the curve Q_t vs $t^{0.5}$ for various concentrations of the solution at 35 °C were 0.235, 0.588, 0.705, 0.941, 1.058 and 1.411 mg/g/min. The K_p values increased with increase in the acid yellow 7 concentration, which reveals that the rate of adsorption is governed by the diffusion of adsorbed acid yellow 7 within the pores of the adsorbent.

The percentage of adsorption of AZSC increased with increase in the temperature of the system from 35-50 °C (Table-5). Thermodynamic parameters such as change in free energy (ΔG°), enthalpy (ΔH°) and entropy (ΔS°) were determined and are presented in table (Table.4). The values are within the range of 1 to 93 kJ/mol indicating the favorability of physisorption. From the results we could make out that physisorption is much more favorable for the adsorption of acid yellow 7. The positive values of ΔH° show the endothermic nature of adsorption and it governs the possibility of physical adsorption. However, the low ΔH° value depicts that the dye is physisorbed onto the surface of the adsorbent[18,20].

The negative values of ΔG° (Table-4) show that the adsorption is highly favorable for acid yellow 7. Further it confirms the spontaneous nature and feasibility process. In addition, the positive values of ΔS° show increasing randomness at the solid-liquid interface during the process. From the results, we could make out that the adsorption is purely physisorption rather than chemisorption. Enhancement of adsorption capacity of the activated carbon at higher temperatures is may be due to the enlargement of pore size and activation of the adsorbent surface[17-20].

Desorption Studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the dye. If the adsorbed dye can be desorbed using neutral pH water or by very dilute acids, then the attachment of the dye of the adsorbent is by weak bonds. If sulphuric acid or alkaline water desorb the dye, then the adsorption is by ion exchange. If organic acids, like acetic acid can desorb the dye, then the dye has held by the adsorbent through chemisorptions[19]. The effect of various reagents used for desorption studies reveals that hydrochloric acid is a better reagent for desorption, because we could get more than 80 % removal of adsorbed dye. The reversibility of adsorbed dye in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of dye by dilute mineral acids and alkaline medium indicates that the dye was adsorbed onto the activated carbon through physisorption mechanisms[20].

TABLE-1 LANGMUIR AND FREUNDLICH ISOTHERM CONSTANTS FOR ADSORPTION OF YELLOW 7 ONTO AZSC

S.No.	Temp., °C	Q_m (mg/g)	b (L/mg)	Correlation Coefficient (R^2)	K_F (mg/g)	n (L/mg)	Correlation Coefficient (R^2)
1	35	56.49	0.1267	0.9891	1.7596	1.7695	0.9878
2	40	54.67	0.1492	0.9959	1.7655	1.7599	0.9767
3	45	54.37	0.1650	0.9955	1.6901	1.9054	0.9845
4	50	53.73	0.1782	0.9965	1.6793	1.9290	0.9800

TABLE-2 VALUES OF R_L FOR YELLOW 7 ADSORPTION ONTO AZSC

[Yellow 7]$_{ini.}$, C_0, (mg/L)	R_L values at different temperatures			
	35°	40°	45°	50°
50	0.442	0.409	0.377	0.359
100	0.284	0.251	0.232	0.217
150	0.209	0.182	0.168	0.153
200	0.165	0.143	0.132	0.123
250	0.136	0.118	0.108	0.100
300	0.116	0.101	0.091	0.085

TABLE-3 RATE CONSTANTS FOR THE ADSORPTION OF YELLOW 7 (10^3 k_{ad}, min $^{-1}$) AND THE CONSTANTS FOR FORWARD (10^3 k_1, min $^{-1}$) AND REVERSE (10^3 k_2, min^{-1}) PROCESS

S.No	[Yellow 7]$_{ini.}$, C_0, mg/L	Temperature, °C											
		k_{ad}				35		40		45		50	
		35	40	45	50	k_1	k_2	k_1	k_2	k_1	k_2	k_1	k_2
1	10	15.17	17.96	19.85	22.07	13.32	1.85	16.12	1.84	17.69	2.16	19.96	2.11
2	20	12.73	14.32	15.94	17.52	10.87	1.86	12.47	1.85	14.09	1.85	15.70	1.82
3	30	9.21	11.97	13.45	15.98	7.63	1.58	10.09	1.88	11.51	1.94	13.78	2.20
4	40	8.52	8.75	9.02	9.33	6.60	1.92	6.81	1.94	7.15	1.88	7.48	1.85
5	50	7.28	7.47	7.88	8.32	5.37	1.91	5.54	1.93	5.91	1.97	6.31	2.01
6	60	5.27	5.52	5.84	6.27	3.65	1.62	3.24	2.28	4.18	1.66	4.52	1.75

TABLE-4 EQUILIBRIUM CONSTANT AND THERMODYNAMIC PARAMETERS FOR THE ADSORPTION OF YELLOW 7 ONTO AZSC

$W_{adsorbent}$, m,g/L, = 2.0; Adsorbent Size = 75-125 µ ; pH = 5.5 ; Contact time =180 min

S.No.	[Yellow 7]$_{ini.}$, C_0, mg/L	Temperature, °C									
		K_0				ΔG°				ΔH°	ΔS°
		35	40	45	50	35	40	45	50		
1	10	7.17	8.72	9.17	9.47	-4.96	-5.54	-5.76	-6.04	20.78	83.72
2	20	5.86	6.74	7.61	8.62	-4.45	-4.88	-5.28	-5.78	21.69	84.98
3	30	4.85	5.35	5.93	6.26	-3.98	-4.29	-4.63	-4.92	16.65	67.09
4	40	3.43	3.50	3.81	4.05	-3.10	-3.21	-3.53	-3.75	12.58	52.46
5	50	2.81	2.86	2.99	3.12	-2.61	-2.69	-2.89	-3.04	5.07	25.03
6	60	2.24	2.42	2.51	2.57	-2.03	-2.26	-2.43	-2.54	9.51	37.52

BLE-5 EQUILIBRIUM PARAMETERS FOR THE ADSORPTION OF YELLOW 7 ONTO AZSC

S.No	[Yellow]$_{ini.}$, C_0, mg/L	Temperature, °C											
		C_e (mg / L)				q_e (mg/g)				Yellow 7 removed (%)			
		35	40	45	50	35	40	45	50	35	40	45	50
1	10	1.2232	1.0281	0.9825	0.9542	8.7768	8.97.19	9.0175	9.0458	87.76	89.71	90.19	90.45
2	20	2.9128	2.5824	2.3215	2.0810	17.0872	17.4176	17.6785	17.9190	85.43	87.08	88.39	89.59
3	30	5.1230	4.7217	4.3270	4.1270	24.8770	25.2783	25.6730	25.8730	82.92	84.26	85.57	86.24
4	40	9.0214	8.8751	8.3219	7.9215	30.9760	31.1249	31.6781	32.0785	77.44	77.81	79.19	80.19
5	50	13.1081	13.9272	12.5238	12.1271	36.8919	37.0728	37.4762	37.8729	73.78	74.14	74.95	75.74
6	60	18.5121	17.5248	17.0810	16.7812	41.4879	42.4752	42.9190	43.2188	69.14	70.79	71.53	72.03

Fig.1 Effect of dose of adsorbent on removal of Yellow 7

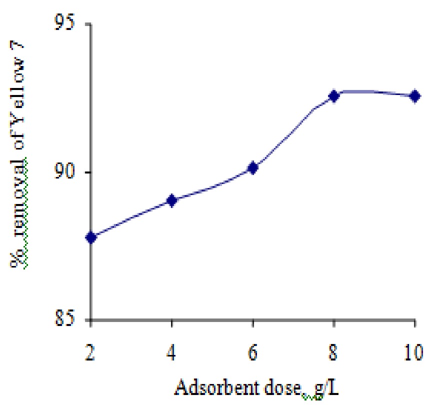


Fig. 2 Effect of contact time on removal of Yellow 7

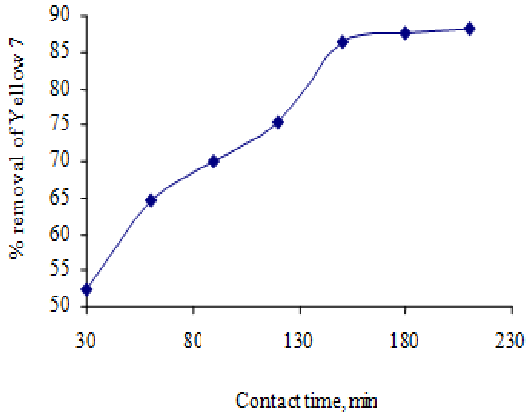


Fig. 3 Effect of concentration on removal of Yellow 7

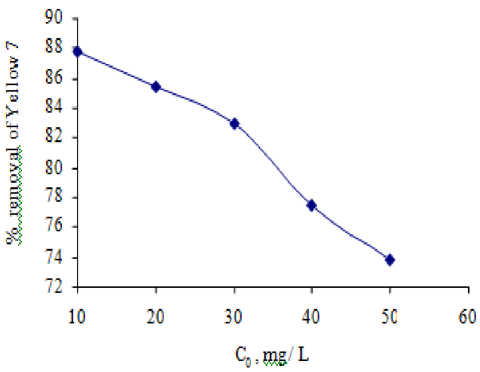


Fig. 4 Effect of size of adsorbent on removal of Yellow 7

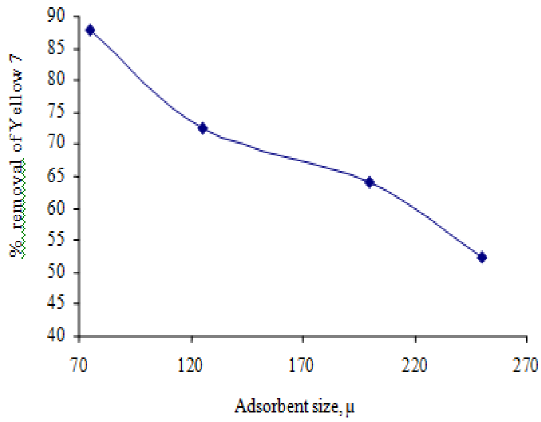


Fig. 5 Effect of pH on removal of yellow 7

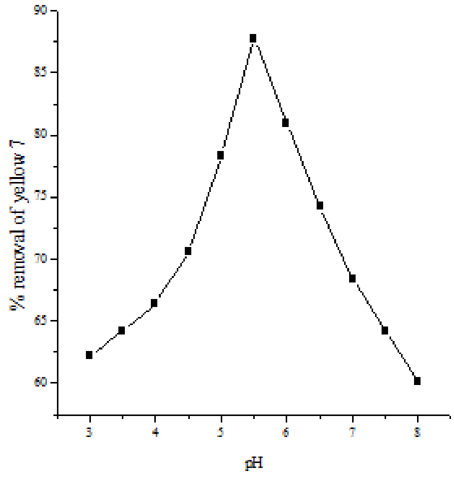


Fig. 6 Effect of temperature on removal of Yellow 7

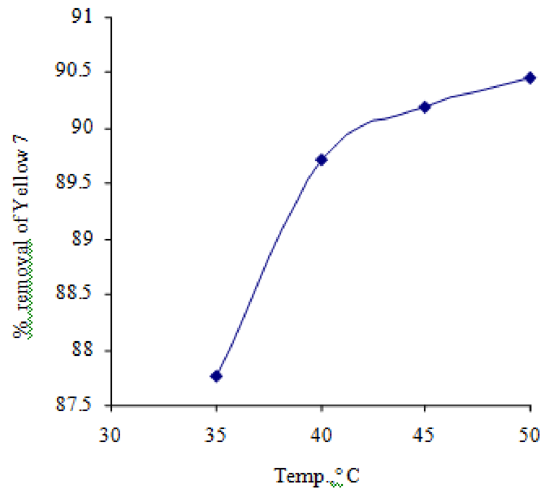


Fig.7 Langmuir isotherm for adsorption of Yellow 7 on AZSC

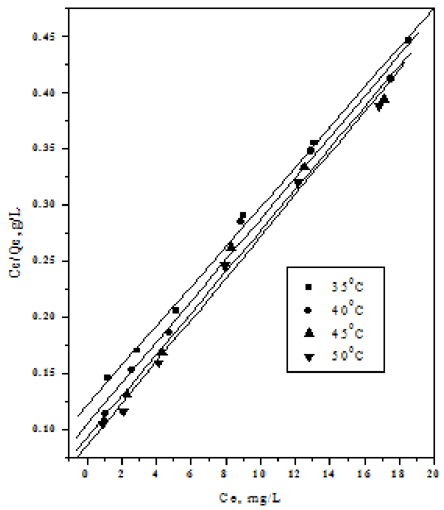
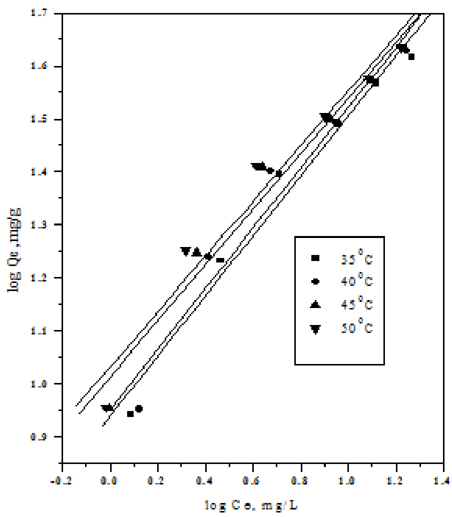


Fig.8 Freundlich isotherm for adsorption of Yellow 7 on AZSC



CONCLUSION

1. The equilibrium time, 180 min appears to be sufficient for the maximum adsorption of acid yellow 7 by AZSC, under the given set of experimental conditions and the maximum amount of acid yellow 7 adsorbed is found to be 87.76 %, for a concentration of 10 mg/L with the dose of AZSC 2 g/L, at 35 °C with the optimum pH 5.5.
2. The percentage removal of acid yellow 7 increases with the increase of the dose of the adsorbent and decreases with the increase of the concentration of adsorbate solution. Similarly, the minimum time required to achieve maximum adsorption also increases with the increase of the dose of the adsorbent.
3. The optimal pH to be fixed for further experimental work is 5.5.
4. The equilibrium data were found to be well represented by Langmuir and Freundlich isotherms and the results of thermodynamic studies have confirmed the adsorption is found to be an endothermic process.

5. The R_L values have confirmed the favorability of adsorption process.
6. All the above information reveals that the selected AZSC may be used as an adsorbent for the removal of acid yellow 7 from waste waters.

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