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**Research Article**

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# Study on the adsorption of acid yellow 7 from aqueous solution by low cost activated carbon

**A. Anandan[1*] and T. Janakiram[2]**

[1]*Department of Chemistry, M. A. M. College of Engineering and Technology, Siruganur, Trichy, India*
[2]*Department of Chemistry, Kurinji College of Arts and Science, Trichy, India*

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**ABSTRACT**

*The efficiency of low cost activated carbon prepared from Albizia lebbeck stem carbon[ALSC] for the adsorption of acid yellow 7[Y7] from aqueous solution has been studied as a function of agitation time, dosage of adsorbent, 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 also carried out.*

**Key words:** Acid yellow 7, Activated carbon[ALSC], Adsorption isotherm, Equilibrium, Kinetic and Thermodynamic parameters, Regeneration pattern.

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## INTRODUCTION

In this paper the investigator has made an attempt to make use of activated carbon prepared from *Albizia lebbeck* stem carbon[ALSC], as the adsorbent in order to carry out batch mode of experiments to study the effect of contact time on the removal of acid yellow 7 dye with the variation of the dose of the adsorbent, variation of the initial 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 ALSC

Experiments were conducted to find out the effect of the dose of the adsorbent on the removal of acid yellow 7, namely, 2.0, 4.0, 6.0, 8.0 and 10.0 g/L respectively. The figure.1 represents the plot of acid yellow 7 adsorbed in percentage for various doses of the adsorbent. This shows that as the dose of the adsorbent increases extent of adsorption of acid yellow 7 also increases[3-5].

### Effect of Contact Time

The effect of contact time on the removal of acid yellow 7 by ALSC has been studied and the results are shown in figure.2. The maximum amount of acid yellow 7 adsorbed corresponding to the equilibration time is found to be 89.72 % for a weight of 2 g/L of the adsorbent. Only a marginal increase in removal of acid yellow 7 after the attainment of equilibrium[6,7].

**Effect of Initial Dye Concentration**
The figure-3 represent the result of the effect of concentration of adsorbate solution on removal of acid yellow 7, viz.,10, 20, 30, 40 and 50 mg/L respectively. Results showed that as the concentration of the solution increases, percentage removal of acid yellow 7 decreases[8,9].

**Effect of Size of the Adsorbent**
The experimental results of adsorptions of acid yellow 7 dye on to the activated carbon[ALSC] with various sizes (75-125, 125-200,200-250, 250-300 µ) of the adsorbent are shown in figure-4. It is found that the adsorption is much favorable with the 75- 125µ size of the adsorbent[2,9].

**Effect of pH**
The effect of pH for the adsorption of acid yellow 7 on to ALSC has been studied and the values are presented in figure-5 depicts the optimum pH at which the experiments have been followed. The optimum[10,18,19,20] pH is found to be 5.5 for the removal of acid yellow 7.

**Effect of Temperature**
The figure-6 shows the effect of temperature on the adsorption of acid yellow 7. The results indicate that the adsorption is maximum at higher temperatures and found to be an endothermic process[11-14].

**Adsorption Isotherm**
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 shown in figure-7. Values of $Q_m$ and b were determined from slope and intercepts of the plots and presented in Table-1. From the results, it is clear that the values of adsorption efficiency $Q_m$ for ALSC decreases on increasing the temperature[15,16]. 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-2. The values were found to lie between 0 and 1 and confirmed the adsorption process is favourable[17,18,19].

Linear plot of log $Q_e$ versus log $C_e$ shows that the adsorption of acid yellow 7 follows the Freundlich isotherm shown in figure.8. Values of $K_F$ and n were found and given in Table-1. However, the value of n is greater than one indicating the adsorption is much more favorable[18,19,20].

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 presented in 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 results indicates that $K_o$ values decreases with increase in the concentration of the acid yellow 7 and increases with increase in temperature[21] shown in Table-4.

The $K_p$ values for various concentrations of the solution at 35°C were 0.117, 0.176, 0.235, 0.264, 0.352 and 0.380 $mg/g/min^{1/2}$. The $K_p$ values increased with increase in the acid yellow 7 concentration, which reveal 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 ALSC increased with increase in the temperature of the system from 35-50 °C shown in Table-5. Thermodynamic parameters such as change in free energy (ΔG°), enthalpy (ΔH°) and entropy (ΔS°) were determined and are presented in 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[20,21,22].

The negative values of ΔG° shows that the adsorption is highly favorable for acid yellow 7 presented in Table-4. 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[18,20,21,22].

**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 desorp the dye, then the adsorption is by ion exchange. If organic acids, like acetic acid can desorp the dye, then the dye has been held by the adsorbent through chemisorptions[21]. 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 85% 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 by physisorption mechanisms[15,23].

**TABLE-1 LANGMUIR AND FREUNDLICH ISOTHERM CONSTANTS FOR ADSORPTION OF ACID YELLOW 7 ON ALSC**

| 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 | 51.17 | 0.1801 | 0.9965 | 1.6712 | 1.9459 | 0.9923 |
| 2 | 40 | 50.58 | 0.2100 | 0.9969 | 1.6455 | 2.0076 | 0.9853 |
| 3 | 45 | 49.18 | 0.2596 | 0.9967 | 1.6021 | 2.1217 | 0.9838 |
| 4 | 50 | 47.84 | 0.3257 | 0.9990 | 1.5593 | 2.2507 | 0.9797 |

**TABLE-2 VALUES OF $R_L$ FOR ACID YELLOW 7 ADSORPTION ON ALSC**

| S.No. | $[Y7]_{ini.,}$ $C_0$ (mg/L) | Temp., °C | | | |
|---|---|---|---|---|---|
| | | 35° | 40° | 45° | 50° |
| 1 | 10 | 0.357 | 0.322 | 0.277 | 0.238 |
| 2 | 20 | 0.217 | 0.192 | 0.161 | 0.131 |
| 3 | 30 | 0.156 | 0.136 | 0.113 | 0.094 |
| 4 | 40 | 0.121 | 0.106 | 0.087 | 0.072 |
| 5 | 50 | 0.150 | 0.086 | 0.071 | 0.058 |
| 6 | 60 | 0.084 | 0.073 | 0.060 | 0.049 |

**TABLE-3 RATE CONSTANTS FO THE ADSORPTION OF ACID 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**

| Temperature, °C | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S.No. | $[Y7]_{ini.,}$ $C_0$, mg/L | $k_{ad}$ | | | | 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 | 61.09 | 68.33 | 75.68 | 83.27 | 54.82 | 6.27 | 62.03 | 6.30 | 69.36 | 6.32 | 72.51 | 5.76 |
| 2 | 20 | 62.61 | 67.96 | 73.39 | 78.57 | 53.46 | 9.15 | 59.21 | 8.75 | 65.77 | 7.62 | 71.78 | 6.79 |
| 3 | 30 | 66.78 | 71.39 | 76.87 | 82.23 | 55.57 | 11.61 | 60.15 | 11.24 | 65.65 | 11.22 | 71.46 | 10.77 |
| 4 | 40 | 58.49 | 60.10 | 62.52 | 65.29 | 44.54 | 13.95 | 46.45 | 13.65 | 48.81 | 13.71 | 53.00 | 12.29 |
| 5 | 50 | 57.57 | 62.64 | 67.56 | 72.94 | 41.80 | 15.77 | 46.71 | 15.93 | 50.63 | 16.93 | 55.33 | 17.61 |
| 6 | 60 | 59.87 | 62.87 | 65.34 | 67.88 | 40.44 | 19.43 | 42.92 | 19.95 | 45.30 | 20.04 | 46.93 | 20.95 |

**TABLE-4 EQUILIBRIUM CONSTANT AND THERMODYNAMIC PARAMETERS FOR THE ADSORPTION OF ACID YELLOW 7 ONTO ALSC**

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

| Temperature, °C | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S.No. | $[Y7]_{ini.,}$ $C_0$, mg/L | $K_0$ | | | | $\Delta G^o$ | | | | $\Delta H^o$ | $\Delta S^o$ |
| | | 35 | 40 | 45 | 50 | 35 | 40 | 45 | 50 | | |
| 1 | 10 | 8.73 | 9.85 | 10.97 | 13.45 | -5.55 | -5.95 | -6.33 | -6.98 | 33.92 | 126.42 |
| 2 | 20 | 5.84 | 6.76 | 8.62 | 10.56 | -4.52 | -4.97 | -5.69 | -6.33 | 33.59 | 123.35 |
| 3 | 30 | 4.75 | 5.35 | 5.85 | 6.63 | -3.99 | -4.36 | -4.67 | -5.08 | 18.45 | 72.71 |
| 4 | 40 | 3.19 | 3.40 | 3.56 | 4.31 | -2.97 | -3.18 | -3.36 | -3.92 | 15.69 | 60.31 |
| 5 | 50 | 2.65 | 2.93 | 2.99 | 3.14 | -2.49 | -2.79 | -2.89 | -3.07 | 8.86 | 36.96 |
| 6 | 60 | 2.08 | 2.15 | 2.22 | 2.24 | -1.88 | -1.99 | -2.10 | -2.16 | 4.03 | 19.18 |

**Fig. 1 Effect of dose of adsorbent on removal of acid yellow 7**

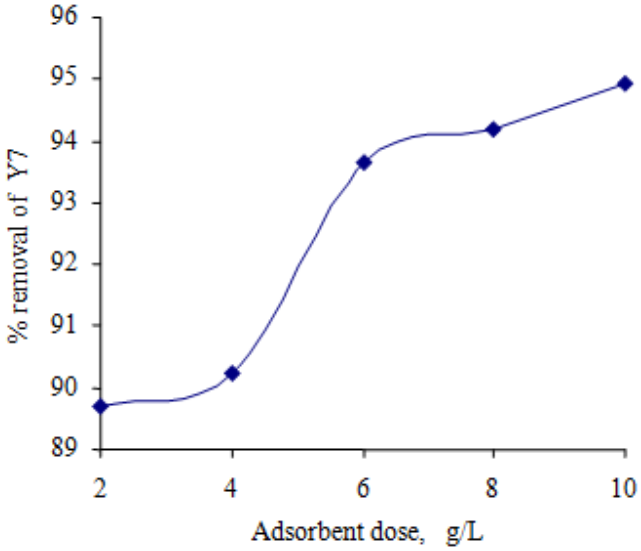



**Fig. 2 Effect of contact time on removal of acid yellow 7**

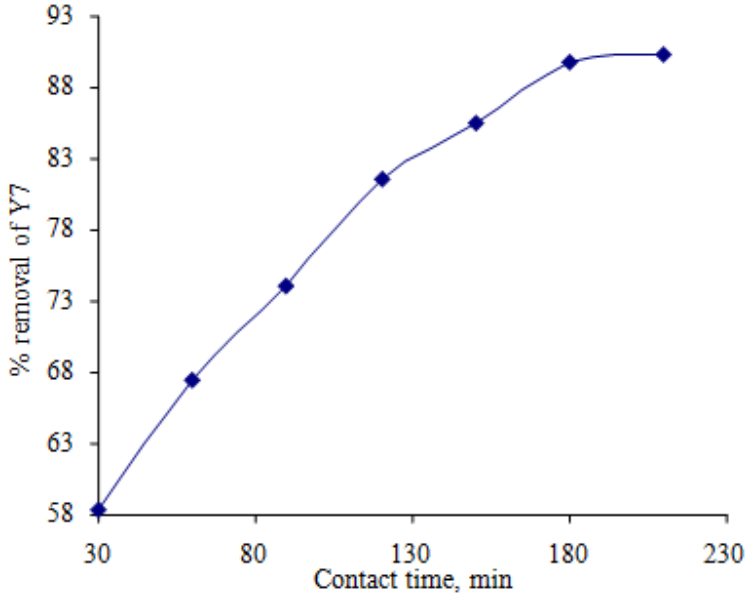



**TABLE-5 EQUILIBRIUM PARAMETERS FOR THE ADSORPTION OF ACID YELLOW 7 ONTO ALSC**

| S.No. | $[Y7]_{ini.,}$ $C_{0,}$ mg/L | Temperature, °C | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $C_e$ (mg / L) | | | | $q_e$ (mg/g) | | | | Y7 removed (%) | | | |
| | | 35 | 40 | 45 | 50 | 35 | 40 | 45 | 50 | 35 | 40 | 45 | 50 |
| 1 | 10 | 1.0271 | 0.9213 | 0.8351 | 0.6917 | 8.9729 | 9.0787 | 9.1649 | 9.3083 | 89.72 | 90.78 | 91.65 | 93.08 |
| 2 | 20 | 2.9227 | 2.5743 | 2.0783 | 1.7289 | 17.0773 | 17.4257 | 17.9217 | 18.2711 | 85.38 | 87.12 | 89.60 | 91.35 |
| 3 | 30 | 5.2157 | 4.7215 | 4.3789 | 3.9281 | 24.7843 | 25.2785 | 25.6211 | 26.0719 | 82.61 | 84.26 | 85.40 | 86.90 |
| 4 | 40 | 9.5254 | 9.0829 | 8.7528 | 7.5293 | 30.4746 | 30.9171 | 31.2472 | 32.4707 | 76.18 | 77.29 | 78.11 | 81.17 |
| 5 | 50 | 13.6923 | 12.7216 | 12.5271 | 12.0578 | 36.3077 | 37.2784 | 37.4729 | 37.9422 | 72.61 | 74.56 | 74.94 | 75.88 |
| 6 | 60 | 19.4227 | 19.0279 | 18.6527 | 18.5025 | 40.5773 | 40.9721 | 41.3473 | 41.4975 | 67.62 | 68.26 | 69.91 | 69.16 |

**Fig. 3 Effect of concentration on removal of acid yellow 7**

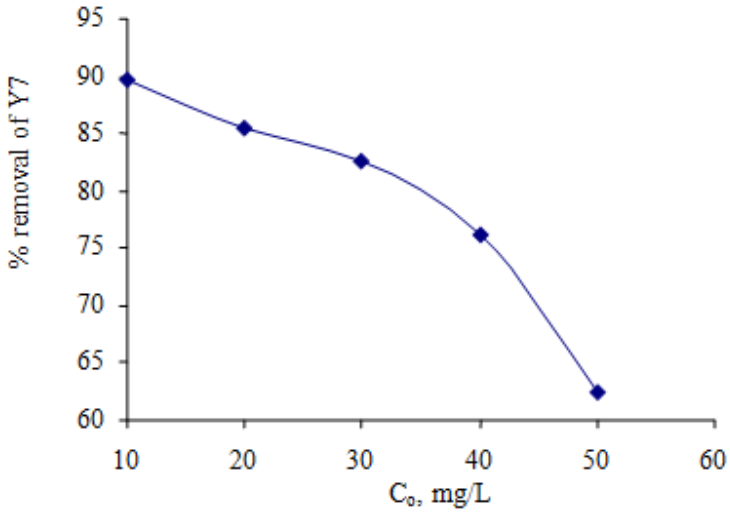



**Fig. 4 Effect of size of adsorbent on removal of acid yellow 7**

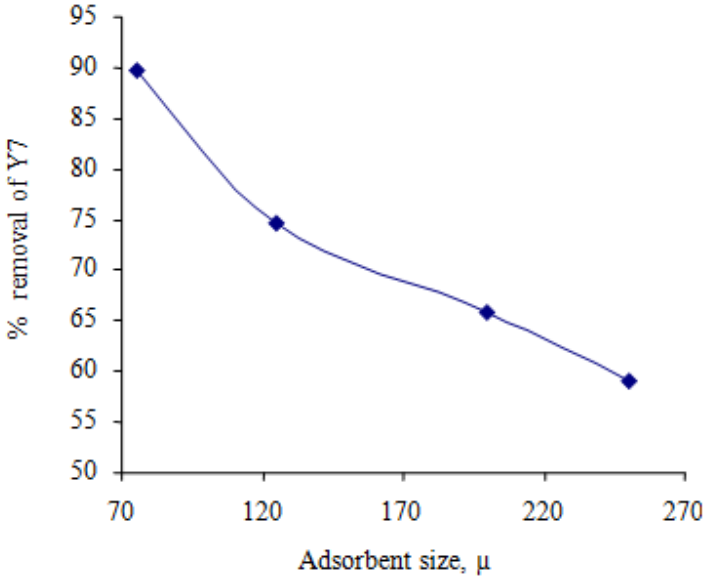


**Fig. 5 Effect of pH on removal of acid yellow 7**

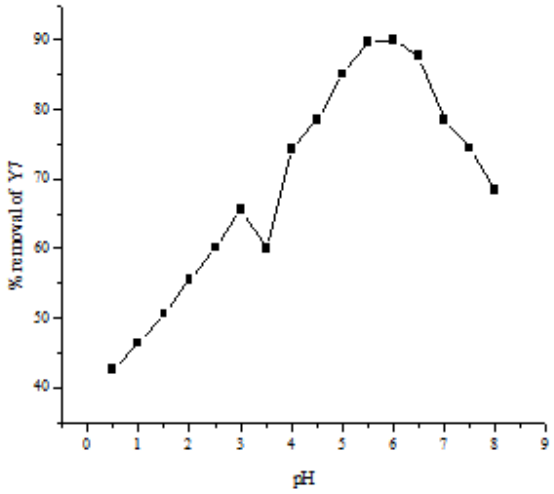



**Fig. 6 Effect of temperature on removal of acid yellow 7**

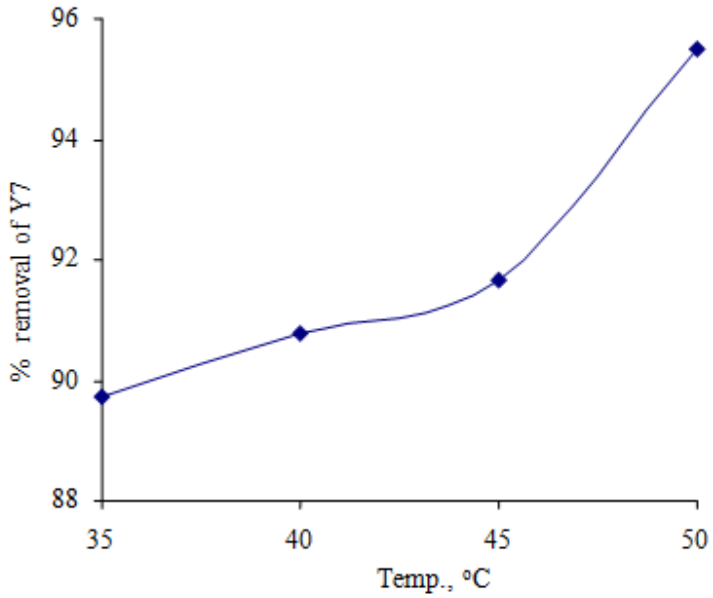



**Fig. 7 Langmuir isotherm for adsorption of acid yellow 7 on ALSC**

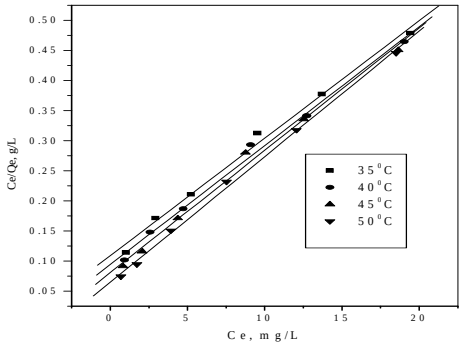
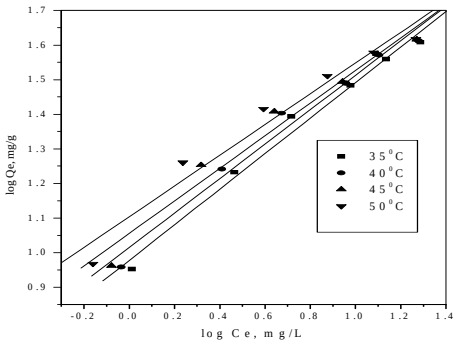


**Fig. 8 Freundlich isotherm for adsorption of acid yellow 7 on ALSC**




## CONCLUSION

1. The equilibrium time, 180 min appears to be sufficient for the maximum adsorption of acid yellow 7 species by ALSC, under the given set of experimental conditions and the maximum amount of acid yellow 7 adsorbed is found to be 89.72 %, for a concentration of 10 mg/L with the dose of ALSC 2 g/L, at 35 $^{o}$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 solutions. 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 has been found to be 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 ALSC may be used as an adsorbent for the removal of acid yellow 7 from waste waters.

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