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Adsorption Studies of Acetic Acid on the Surface of *Alternenthera triandra*

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The adsorption of acetic acid on *Alternenthera triandra* using batch adsorption process has been investigated. The effect of certain parameters on adsorption has been studied. Applicability of Freundlich adsorption isotherm and Langmuir adsorption isotherm has also been tested. Various thermodynamic parameters such as ΔG, ΔH and ΔS are reported.

Key Words: Adsorption, Acetic acid, *Alternenthera triandra*.

INTRODUCTION

Various researchers used plant materials as adsorbents. Plant materials are used as a cheap and low cost material for adsorption, for example, modified corn[1] starch, modified onion skins[2], sawdust[3], phosphate treated sawdust[4], water lettuce[5], etc. Adsorption of different metal ions and organic compounds onto solid surfaces has immersed as a promising field of great application value and has been extensively studied in the recent past.

EXPERIMENTAL

Acetic acid, NaOH, phenolphthalein were supplied by S.D. Fine Chemicals Ltd. and were used without any purification.

The plant material was collected from local fields. It was dried and burned in presence of incomplete oxygen to charcoal powder. Batch experiments were carried out in which solution of acetic acid was treated with 1 g of plant powder and kept shaking at room temperature for a period of 1 h. Finally, the solution was filtered through Whatmann No. 42. The amount of acetic acid was determined volumetrically using phenolphthalein as a reagent[6]. Effect of contact time, temperature and initial concentration was also determined.

RESULTS AND DISCUSSION

On the surface of the substance, there are free valancies. When the adsorbate comes in contact with the surface, each valency is satisfied by a weak bond

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formed. The adsorption of solute from solution takes place due to a decrease in the interfacial tension or due to solid surface acquiring electrostatic charge in solvent. The charged surface of the adsorbent then attains oppositely charged ions from the solution. During the formation of solids such as zeolites, gases are evolved and the solids become porous; such solids can be used as selective adsorbents and can be used for ion exchange[7]. Same logic can be extended to coal formation. During incomplete burning of plant material CO or CO_2 gets evolved and porosity may be formed. Hence, charcoal obtained from the plant materials is a more effective adsorbent.

In the present paper, the adsorption behaviour of acetic acid on the charcoal obtained from the plant *Alternenthera triandra* has been studied. It is important to know the adsorption capacity of various adsorbents, because adsorption can be used effectively in the prevention of environmental pollution. It is used for the catalytic processes. Langmuir suggested that the forces operating between adsorbate and adsorbent are mostly short range forces; these may be dispersion forces, orientation forces and induction forces. Dispersion forces arise from attraction between temporary or instantaneous dipoles. The orientation forces appear upon adsorption of polar molecul carrying constant electrical charges. Polar molecules tend to orient themselves with their positive poles towards the negatively charged surface or negative poles toward the positively charged surface. The induction forces also play an important role in the adsorption process. The electric charge present on the surface of the adsorbent may induce dipoles in the adsorbate molecule thereby attracting them. In addition to these forces, hydrogen bonds may also occur, which form interaction between adsorbate and adsorbent.

Effect of Contact Time

It was observed that *Alternenthera triandra* can be used as a low cost adsorbent effectively. The maximum time required for adsorption is 20 min for 60% adsorption; after that the amount adsorbed remains constant (Table-1).

TABLE-1
EFFECT OF CONTACT TIME

Time (min.)	$\sqrt{t}$	C_e	$q = C_o - C_e$	$Q_e - Q$	$\log Q_e - Q$
5	2.2	3.90	0.66	3.24	0.5105
10	3.1	3.60	0.96	2.64	0.4216
15	3.8	3.48	1.04	2.04	0.3802
20	4.4	3.42	1.14	2.28	0.3579
25	5.0	3.42	1.14	2.28	0.3579
30	5.4	3.42	1.14	2.28	0.3579

The removal curve was found to be smooth and continuous indicating the formation of monolayer coverage of adsorbent on the other surface of adsorbate.

Adsorption Isotherm

To study the validity of Freundlich adsorption isotherm the following equation was used:

$$x/m = Kc^{1/n}$$

The linear plot of log x/m *vs.* log C indicates the applicability of Freundlich adsorption isotherm (Table-2). This shows a system in which exists a monolayer coverage of the adsorbent on the other surface of adsorbate. To verify Langmuir adsorption isotherm $1/C_e$ is plotted against $1/q$; the value of 'b' is calculated graphically which is used to calculate the equilibrium parameter R_L.

TABLE-2
ADSORPTION CAPACITIES
(Initial concentration $C_0 = 4.56$ g/L)

Adsorbent mass (mg)	quilibrium concentration C_e (g/L)	log C_e	$X = C_0 - C_e$	$Y = \frac{(C_0 - C_e)v}{M}$	$Fr = \frac{C_0 - C}{C_0}$	x/m	log x/m	$\frac{C_e}{x/m}$
250	4.44	0.6473	0.12	24.0	0.02630	0.48	0.3184	9.25
300	4.20	0.6232	0.36	60.0	0.07890	1.20	0.0791	3.50
400	3.90	0.5910	0.66	82.5	0.21052	1.92	0.2833	2.36
500	3.60	0.5563	0.96	96.0	0.21052	1.92	0.2833	1.87
600	3.60	0.5563	0.96	96.0	0.21052	1.92	0.2833	1.87

$$R_L = \frac{1}{1 + bC_0}$$

The range $0 < R_L < 1$ reflects favourable adsorption.

The value of R_L was found to be less than 1 (one). The Langmuir adsorption parameters are very useful for predicting adsorption capacities and also for incorporating into mass transfer relationship. The isotherm can be written as

$$\frac{C_e}{Q_e} = \frac{1}{K_L} + \frac{Q_L}{K_L} C_e$$

C_e is the concentration of the adsorbate at equilibrium, Q_e is the amount of metal ions adsorbed per unit weight of the adsorbent, a_L and K_L are Langmuir constants, Q_L indicates the intensity of adsorption and $K_L = Q_L b_L$ where b_L is the adsorption capacity. For the present study we obtain $a_L = 2.025$ L/mg, $b_L = 0.041$ mg/g.

The rate of acid adsorption (removal) falls off to give a smooth curve; this part of the plot is due to intra-particle diffusion. The initial portion of the plot can be interpreted by supposing a three step model as follows:

(1) Mass transfer of acid from the bulk solution to the particle surface, (2) Intraparticle diffusion, (3) Adsorption at an interior side.

It is assumed that step three is rapid with respect to the first two steps[8].

The mathematical theory of diffusion is based on Fick's first law. Mainly molecular adsorption processes involve diffusive mass transport and the interpretation of the overall behaviour in terms of the diffusivity and intrinsic equilibrium sorption properties is difficult. Intraparticle diffusion is an important rate controlling step during adsorption process. The following equations were used to find out the adsorption capacity of the plant *Alternenthera triandra*:

$$Y = \frac{(C_0 - C)v}{M} \quad \text{and} \quad F_r = \frac{C_0 - C}{C_0}$$

Thermodynamic Study

The experiments were carried out at different temperatures to study the effect of temperature on adsorption. Thermodynamic parameters such as ΔG, ΔH and ΔS were determined using the following equations (Table-3):

$$K_c = \frac{C_{ad}}{C_e}; \quad \Delta G = -RT \ln K_c$$

$$\log K_c = \frac{1}{2.303R}\left[\Delta S - \frac{\Delta H}{T}\right]$$

where K_c = equilibrium constant, C_{ad} = amount of metal ion adsorbed per litre of the solution at equilibrium, C_e = equilibrium concentration (mg/L) of the metal in the solution.

TABLE-3
VARIOUS VALUES OF THERMODYNAMIC PARAMETERS

Temp. (K)	$1/T \times 10^{-3}$	K_c	log K_c	ΔG (J/mol)
303	3.30	0.2042	–0.6899	–4002.48
308	3.24	0.1692	–0.7715	–4556.79
313	3.19	0.1176	–0.9295	–5570.50
318	3.14	0.2063	–0.6855	–4173.83
323	3.09	0.0857	–1.0670	–414.36
328	3.04	0.0857	–1.0670	–414.36

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