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Removal of Acetic Acid from Aqueous Solution by using Activated Carbon

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ABSTRACT: Adsorption of acetic acid from aqueous solution onto activated carbon was investigated to evaluate the effects of initial acetic acid concentration, contact time, nature of adsorbent and adsorbent dose on the removal of acetic acid systematically. The optimal contact time value for acetic acid adsorption onto the activated carbon was found to be 30 minute. Greater percentage of acetic acid adsorbed with increase in the initial concentration of acetic acid and increase in amount of adsorbent used. Adsorption data was modeled using the Langmuir and Freundlich isotherms. For all the samples, these data fitted well the Langmuir isotherm models in the range of the concentrations tested. Maximum amount of acetic acid adsorbed was 16.67 m mol/g. Adsorption of acetic acid onto treated sugar cane bagasse was highly favorable sorption than the activated carbon and the peels of banana.

KEYWORDS: Langmuir isotherm, Freundlich isotherm, Adsorption, Peels of banana (PB), Acetic acid, Activated carbon (AC), Treated sugarcane bagasse (TSG).

1 INTRODUCTION

Chemical industries are a major source of environmental pollution and large quantities of liquid streams that are sent out into the environment. Acetic acid is one of such contaminants found in waste streams. It a major component in the very useful manufacturing processes such as, the high grade phosphate fertilizer, rust proofing of iron, baking powder, phosphate syrups used in soft drinks, and water softening agents [1,2]. Adsorption is a surface phenomenon which involves interactions between the three components: the adsorbent, the adsorbate and the solvent. The interactive force that controls it is the affinity of the adsorbate for the adsorbent, as well as the solubility of the adsorbate in the solvent [3]. Nowadays pollution due to heavy metal contaminants from aqueous solutions is one of the most important environmental concerns due to their high toxicity and impact on human health. Heavy metals and is widely used in many industries including painting, petrochemical, newsprint, smelting, metal electroplating, mining, plumbing and battery industries [4]. Water is of fundamental importance for life on earth. The whole mechanism of metabolism, the synthesis and structure of colloidal cellular constituents, the solution and transport of nutrients inside cells and interactions with the environment are closely related to the specific characteristics of water [5]. The activated carbon has been till now the most used adsorbent but is expensive to use on a large scale and the idea of using natural adsorbents from waste material rises in this perspective. Banana plants belong to the family Musaceae. They are cultivated and used to a lesser extent for the production of fiber and as ornamental plants. The fruit averages 125 g, of which 25% is dry matter and the remaining is water. Banana is one of the largest consumed fruit in the world and useless peels therefore, creates one of the major agro-waste problems. For this reason, banana peels have been tested as adsorbents for acetic acid from aqueous solutions [6]. Sugarcane bagasse is one of the primary agroindustrial wastes. It contains carboxylic and hydroxyl groups, which show the capacity to adsorb the dye molecules by the ion exchange phenomena or by complexation hence it can be used as a cheap, attractive and effective adsorbent for the removal of acetic acid from wastewater [7,8].

This work is based on the identification and on the comparison of the adsorption properties of ACs obtained from sugar cane baggase, peels of banana and industrial prepared charcoal under different operating conditions, different impregnation ratios and to evaluate the validity of Langmuir and Freundlich isotherms and to investigate the effect of different parameters, such as initial concentration, adsorbent dose, and contact time. Acetic acid is an organic pollutant with a specific surface area close to that of nitrogen most often used in adsorption experiments, hence its is used in this study to characterize ACs samples.

2 EXPERIMENTAL SECTION

2.1 MATERIALS AND CHEMICALS

The reagents and chemicals used were Analytical grade acetic acid (99%) sodium hydroxide (Avishkar LAB TECH Chemicals. LOT), Adsorbent (commercial carbon, treated sugar cane bagasse and Peels of banana), Phenolphthalein indicator, distilled water was used throughout the work. Rotary shaker (VRN-480, GEMMY orbital shaker, Taiwan), Electronic balance (OHAUS, E1114, Switzerland), Electronic mill (GERMANY), Filter paper (whatman542, 90 mm diameter), Sieve of different size, oven, Magnetic stirrer, Burette, dropper, Elmneyer flask, measuring cylinder, 250ml of beaker, 50 ml beaker.

2.2 SOLUTION PREPARATION

The stock solution of acetic acid has 17.4 molar concentrations. The working solutions were made by diluting the former with distilled water. The range in concentrations of acetic acid solution was prepared from standard solution varied between 0.2 M – 1.0 M.

2.3 BATCH ADSORPTION STUDIES

The batch tests were carried out in glass-stoppered, Erlenmeyer flasks with 50 mL of working volume, with a concentration of 0.8 M. A weighed amount (2.0g) of adsorbent was added to the solution. The flasks were agitated at a constant speed of 200 rpm for 90 minute in a magnetic stirrer at 298^0K. Initial acetic acid concentration (0.2, 0.4, 0.6, 0.8, 1.0 M), contact time (10, 30, 50, 70, 90 min), adsorbent dose (0.5, 1.0, 1.5, 2, 2.5 g), were evaluated during the present study. The amount of acetic acid adsorbed in milli mole per gram was determined by using the following mass balance equation:

$$q_e = \frac{(c_i - c_e)V}{m}.$$

Where q_e is the amount of acetic acid adsorbed onto per unit weight of the adsorbent in mmol/g, C_i is the initial concentration of acetic acid in M, C_e is the equilibrium acetic acid concentration in M, V is the volume of adsorbate in liter and m is the weight of the adsorbent in grams. The percentage of removal of acetic acid was calculated from the following equation:

$$\text{Removal}(\%) = \frac{(c_i - c_e)}{c_i} \times 100$$

3 RESULT AND DISSCUSSION

3.1 EFFECT OF OPERATING PARAMETERS

The adsorption is influenced by various factors, which include initial acetic acid concentration, amount of adsorbent, nature of adsorbent, temperature, nature of adsorbent and contact time. The initial acetic acid concentration is one of the most important factors that determine the equilibrium concentration.

3.1.1 EFFECT OF INITIAL CONCENTRATION ON ADSORPTION

The effect of acetic acid concentration on activated carbon is given in Fig. 1. An increase in initial concentration of acid led to an increase in the adsorption capacity of acid on the activated carbon. This indicates that the initial concentration of acetic acid played an important role in the adsorption capacity of acetic acid on activated carbon.

3.1.2 EFFECT OF ADSORBENT DOSE ON ADSORPTION

The adsorbent dose is also one of the important parameters to optimize an adsorption system. The effect of adsorbent dose on the adsorption of acetic acid has been investigated by employing different doses of AC varying from 0.5 to 2.5 g. The removal of acetic acid increases with increase in adsorbent dosage is given in Fig. 2. When the activated charcoal dosage was 0.5 g, the removal efficiency of acetic acid was 65.0 %. As the dose increased to 2.5 g, the trend of removal efficiency tended to be increased to 68.13%. An increase in the adsorption with increase in adsorbent dosage can attribute to greater surface area and the availability of more adsorption surface sites.

However, the adsorption capacity decreases from 52.0 to 10.9 mmol/g by increasing the adsorbent amount from 0.5 – 2.5. The decrease in adsorption capacity is basically is because of the available sites for adsorption are unsaturated and is depicted in Fig. 3. In high adsorbent concentration, adsorption capacity is reduced and it can be as a result of overlapping adsorption sites on adsorbent surface. There is an excess surface area of the adsorbent for adsorption and hence for 2.5 g adsorbent the optimum percent of removal of acetic acid and adsorption capacity are found to be 68.13% and 10.9 mmol/g respectively.

3.1.3 EFFECT OF CONTACT TIME ON ADSORPTION

Batch adsorption studies have also been conducted at different contact times (10, 30, 50, 70, 90 min) by taking initial concentration of acetic acid 0.8 M with 2 g adsorbent dose of activated charcoal in 10 mL acetic acid solution and at 25 °C temperature . Effects of contact time on removal of acetic acid by activated charcoal are presented in Fig. 4. Time of contact of adsorbate and adsorbent is of great importance in adsorption since contact time depends on the nature of the system used. It is seen from these curves that initially the uptake of acetic acid is quite rapid, becoming slower with the lapse of time and then equilibrium was achieved. It is clear that after a time of contact of 30 minutes with activated charcoal, the adsorbed amount of the acetic acid does not vary practically any more and attained equilibrium at 30 min for acetic acid in the studied concentration range. Therefore, it is good agreement with literature value.

3.1.4 EFFECT OF NATURE OF ADSORBENT ON ADSORPTION

The amount adsorbed from a solution depends on the properties of the adsorbent (chemical nature of the surface, dimension of the pores) those of the solution and of its constituents. The effect of nature of adsorbent surface on adsorption phenomena is illustrated in Fig. 5. The percent of adsorption of acetic is highest in treated sugar cane bagasse. A high coefficient A_{ma} guarantees a good adsorption of acetic acid on treated sugarcane bagasse.

3.2 ADSORPTION ISOTHERM

3.2.1 LANGMUIR ISOTHERM ADSORPTION

The results obtained from the Langmuir model for the removal of acetic acid onto AC are shown in Fig. 6. The correlation coefficients reported and showed strong positive evidence on the adsorption of acetic acid onto AC follows the Langmuir isotherm. The applicability of the linear form of Langmuir model to AC was proved by the high correlation coefficients R^2 =0.996. This suggests that the Langmuir isotherm provides a good model of the adsorption system.

The R_L parameter is considered as a more reliable indicator of adsorption. In both the cases, the values of R_L (Table 1) are found to be positive and less than one indicating thereby a highly favorable adsorption in all cases.

3.2.2 FREUNDLICH ADSORPTION ISOTHERM

From the Fig. 7 and table 2, it was found that Freundlich adsorption constant value $1/n$ is greater than one and K_F is less than 1, indicating the adsorption of acetic acid from aqueous solution in the concentration range is not favorable [9,10].

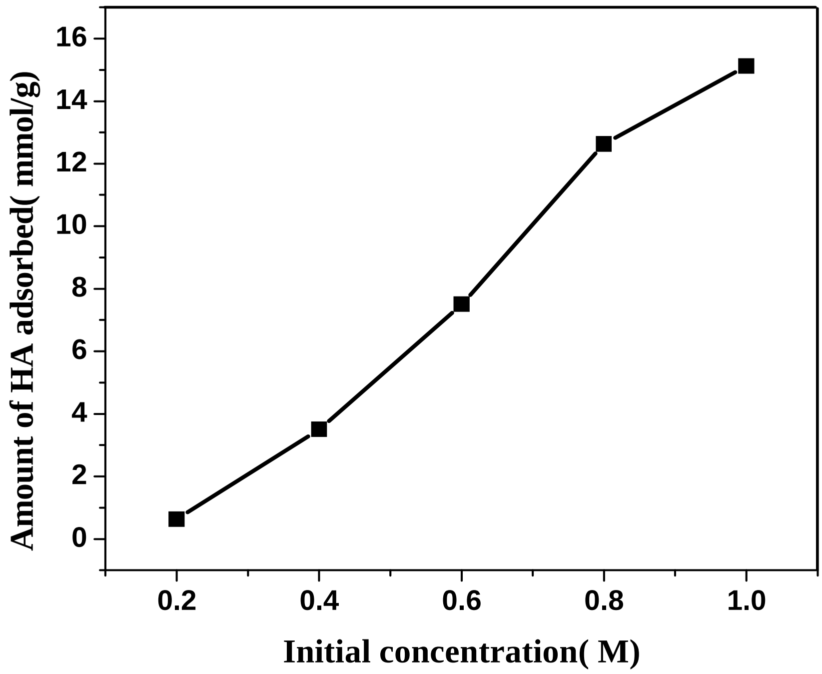

Fig. 1. Effect of adsorbate concentration on adsorption (Adsorbent dose 2.0 g, volume of adsorption medium: 10 mL, temperature: 298 K and contact time 90 min, rpm = 200)

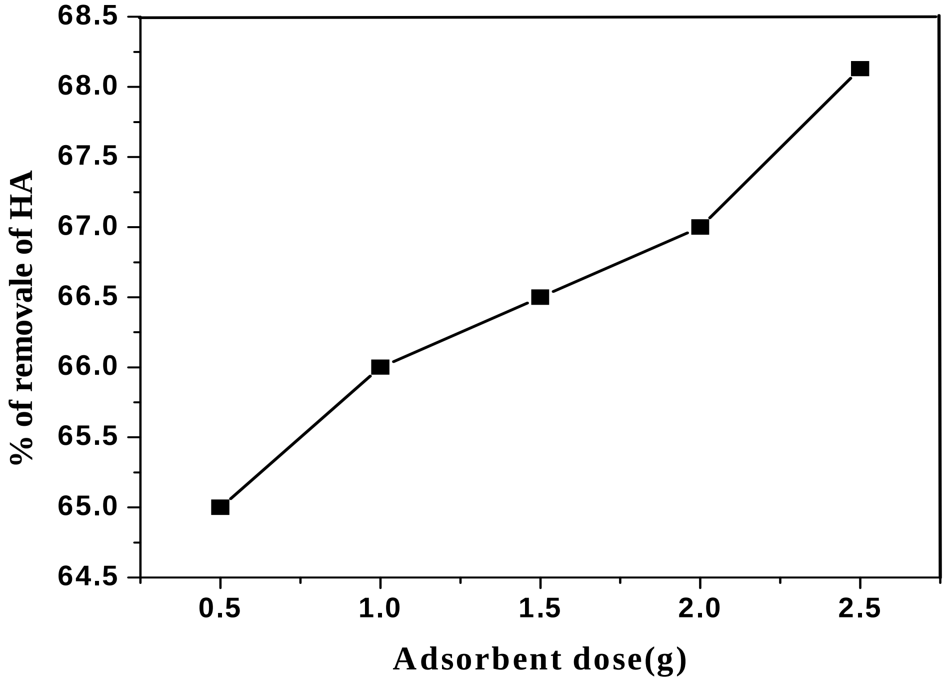

Fig. 2. Effect of adsorbent dosage on adsorption (Contact time 90 min, Initial acetic acid concentration 0.8 M, volume of adsorption medium 10 mL T = 298 K, rpm = 200)

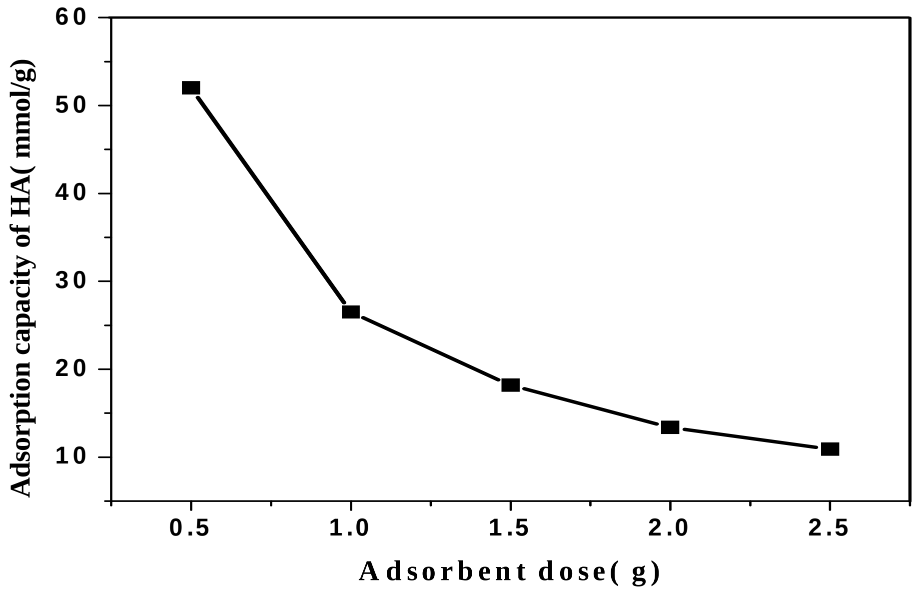

Fig. 3. Effect of adsorbent dosage on adsorption (Contact time 90 min, Initial acetic acid concentration 0.8 M, volume of adsorption medium 10 mL, T = 298 K, rpm = 200)

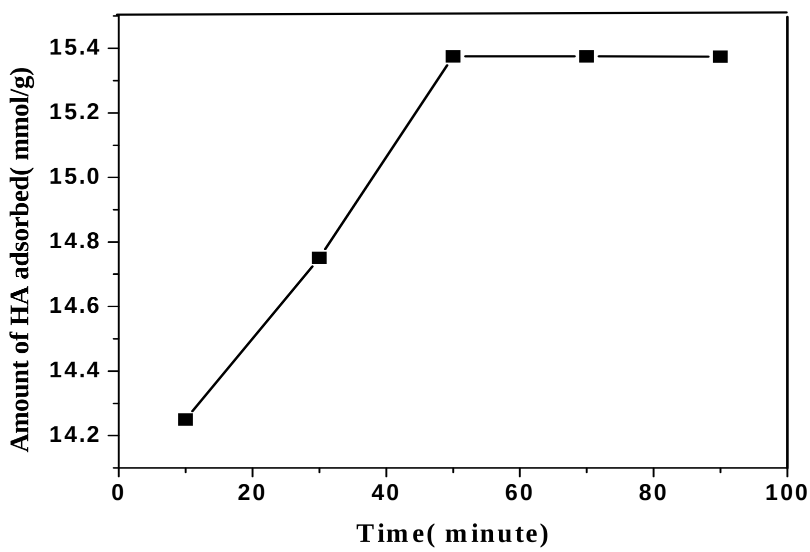

Fig. 4. Effect of contact time on adsorption (Adsorbent dose 2 g, Initial acetic acid concentration 0.8 M, volume of adsorption medium 10 mL, T = 298 K, rpm = 200)

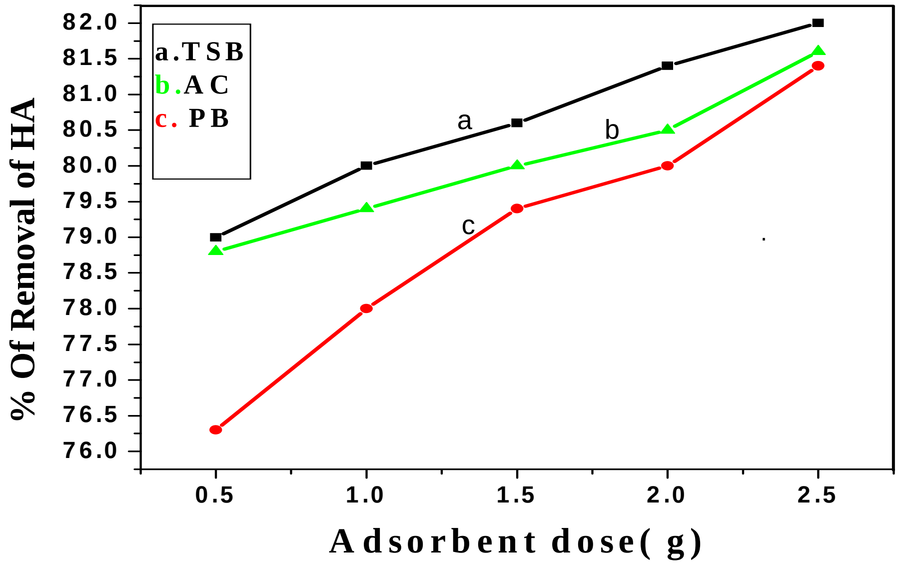

Fig. 5. Effect of nature of adsorbent on adsorption (Adsorbent dose 0.5-2.5 g, Initial acetic acid concentration 0.8 M, volume of adsorption medium 10 mL, T = 298 K, rpm = 200)

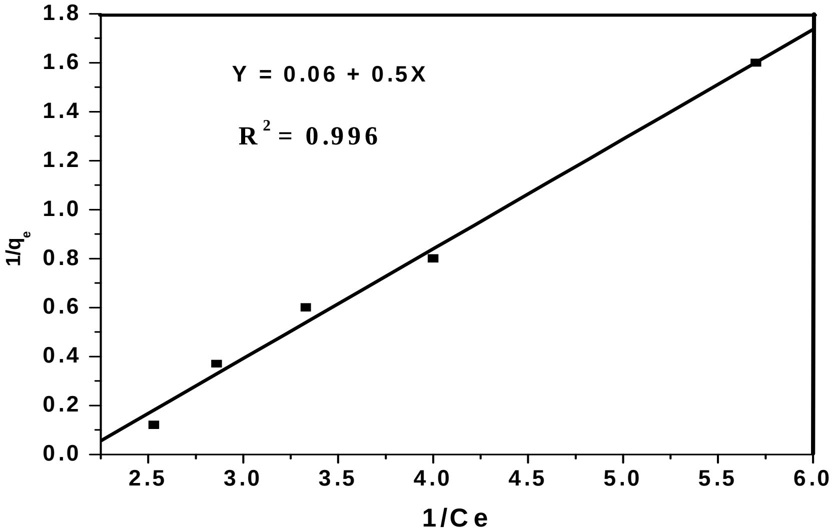

Fig. 6. Langmuir plots for adsorption of acetic acid on various concentrations at 25^0C, adsorbent dose 2 g, volume of adsorption medium 10 mL, T = 298 K, rpm = 200

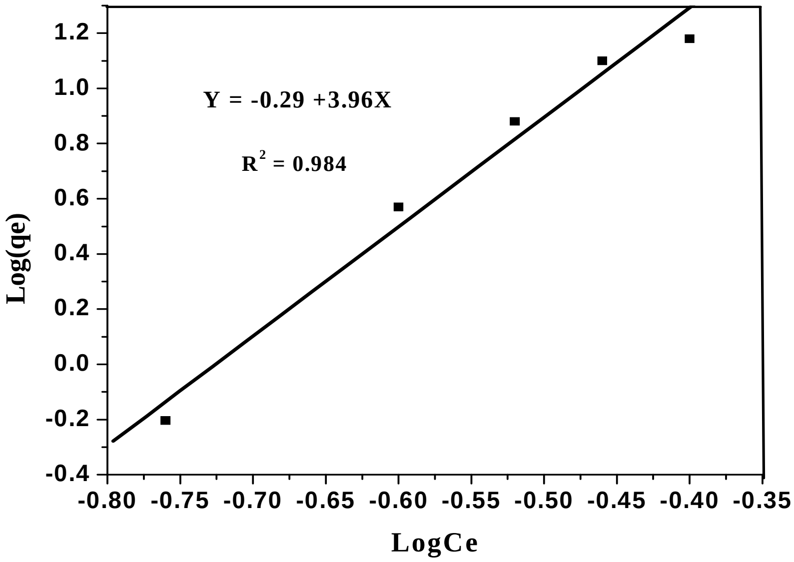

Fig. 7. Freundlich plots for adsorption of acetic acid on various concentrations at 25^0C, adsorbent dose 2 g, volume of adsorption medium 10 mL, T = 298 K, rpm = 200

Table 1. Characteristics of Langmuir isotherm constant (separation factor, R_L)

Initial Acetic acid Concentration (C_0)	$R_L = \frac{1}{1+K_L C_0}$
0.2	0.97
0.4	0.94
0.6	0.92
0.8	0.89
1.0	0.86

Table 2. Freundlich and Langmuir adsorption isotherm constants

Lanqmuir isotherm			Freundlich isotherm		
A_{max}	K_L	R^2	K_F	*1/n*	R^2
16.67	**0.125**	**0.996**	**0.513**	**3.96**	**0.984**

4 CONCLUSION

The adsorption behavior of acetic acid on activated carbon was studied as a function of the adsorbent dose, concentration of the adsorbate, contact time and nature of adsorbent. Analysis of the results shows that the acetic acid adsorption process on activated carbon was increased as the initial concentration of acetic acid increased. Furthermore amount of adsorbed solute increases the adsorption also increases at constant concentration. The effect of contact time was conducted and the balance time was achieved at 30 minute. But adsorption capacity of acetic acid decreases with increases the amount of adsorbent dose. From this study, the adsorption isotherm studies were performed and from this the Langmuir separation factor is between 0 and 1 and hence the process of acetic acid adsorption on activated carbon is well fitted with the Langmuir adsorption isotherm. However the Freundlich adsorption intensity 1/n is greater than one and the Freundlich constant K_F is less than one, which indicates unfavorable adsorption.

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