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Research Article

PREPARATION OF ACTIVATED CARBON FROM A BETELNUT BY H_2SO_4 ACTIVATION AND ITS ADSORPTION BEHAVIOUR IN AQEOUS SOLUTION

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ABSTRACT

Activated carbon prepared form BETELNUT (BNAC) for the adsorption of Cd^{2+} ions from aqueous solutions has been studied as a function of contact time, adsorbent dosage, initial metal ion concentration, temperature and pH of adsorbate solution. The experiments were conducted to determine the Langmuir constants, Freundlich parameters and thermodynamic parameters. Since the adsorbent used in this investigation are freely, abundantly and locally available, the resulting carbon are expected to be economically viable for wastewater treatment.

Keywords: Betelnut, Activated carbon, cadmium ions, Adsorption isotherm, Equilibrium and Kinetic.

1. INTRODUCTION

Water pollution raises a great concern nowadays since water constitutes a basic necessity in life and thud, is essential to all living things. Water contaminations by heavy metals are more pronounced than other pollutants especially when heavy metals are exposed to other natural ecosystem. 'Heavy metals' refers to any elements with the atomic weights between 63.5 and 200.6 and a specific gravity greater than 5.0[1,2]. Heavy metals are non biodegradable pollutants and they are very difficult to eliminate naturally from the environment. Almost all heavy metal elements are highly toxic when their concentration exceeds their permissible limit in the ecosystem. High concentration of heavy metals may accumulate in the human food chain and possibly in effect, cause severe health problems if the metal exceeds the permitted concentration[3]. In the present investigation, the efficiency of the activated carbon prepared from the Betelnut for the removal of Cd(II) ions from its aqueous solution has been studied and the applicability of the kinetic and equilibrium models for the Cd(II)-betelnut system has also been discussed.

2. EXPERIMENTAL SECTION

2.1 Adsorbent

Carbon was prepared by using dried betel nut as adsorbent with concentrated sulphuric acid in a weight of ratio of 1:1. The resulting black product was kept in a furnace, maintained at 500˚C for 12 h followed by washing with water until from excess acid and dried at 160 ˚C. The carbon thus obtained was ground well and the portion retained between 0-75µm sieves was used in all the experiments. All the chemicals used were of Analytical Grade.

2.3 Effect of variable parameters

Experiments were carried out to determine the effect of dosage of the adsorbent (1.0-5.0 g/L), effect of different initial concentrations of Cd(II) ions (ranging from 50 to 350 mg/L), effect of contact time on the removal of the cadmium ions, effect of pH were carried out in this adsorption experiments(1 to 7). The acidic and alkaline pH of the media was maintained by adding the required amounts of dil, HCl and NaOH solutions and the effect of solution temperature (35-55 ˚C) at 5 ˚C intervals with an accuracy of ±0.5 ˚C.

3. RESULTS AND DISCUSSION

3.1 Effect of carbon concentration

The physico-chemical properties of the chosen adsorbent, BNAC, were carried out by standard method [4]

Table 1: Characteristics of the adsorbent

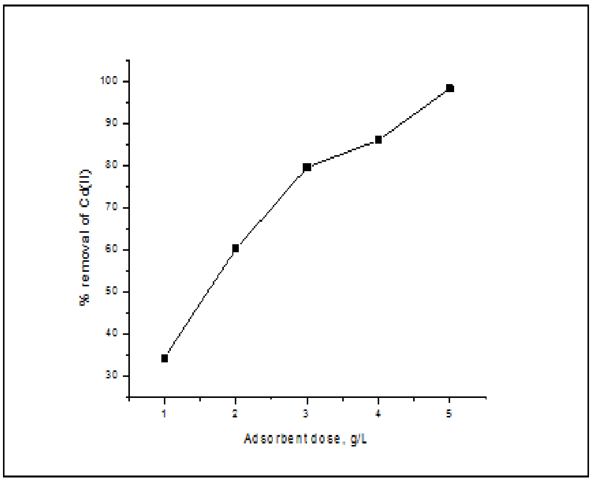
Control Test	BNAC
Bulk density (g/cc)	0.39
Moisture (%)	0.098
Ash (%)	98.32
Matter soluble in water (%)	1.732
Matter soluble in acid (%)	2.934
pH	5.5
Surface area (m^2 / g)	2.9

3.2 Effect of dosage of adsorbent

The adsorption of the Cd^{2+} ions on BNAC was studied by varying the carbon concentration (1.0 to 5.0 g/L) for the cadmium ion concentration of 1.0 g/L. The percentage of adsorption increased with increase in the carbon concentration . This may be due to the increased carbon surface area and availability of more adsorption sites [5,6].

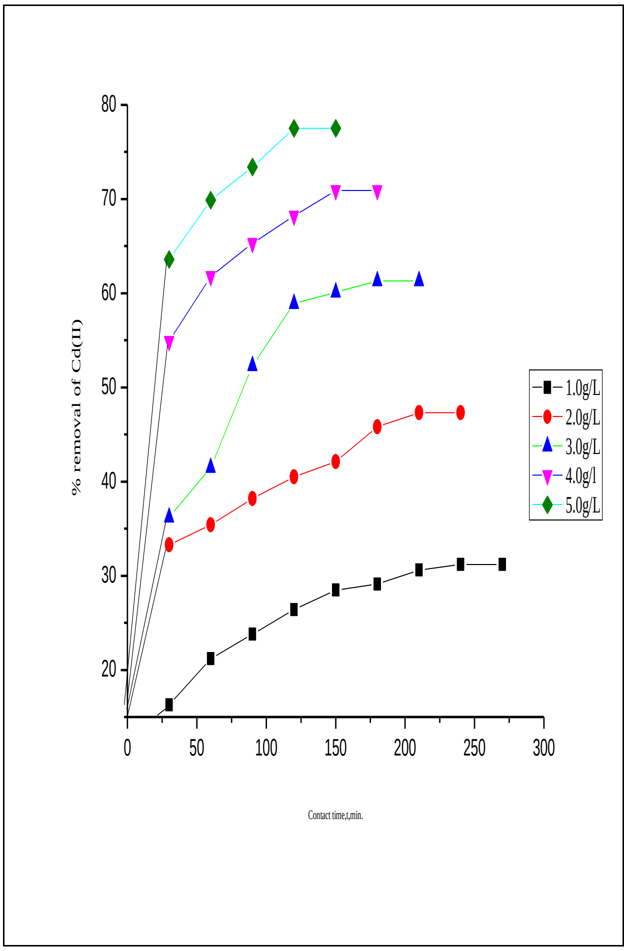
Table 2

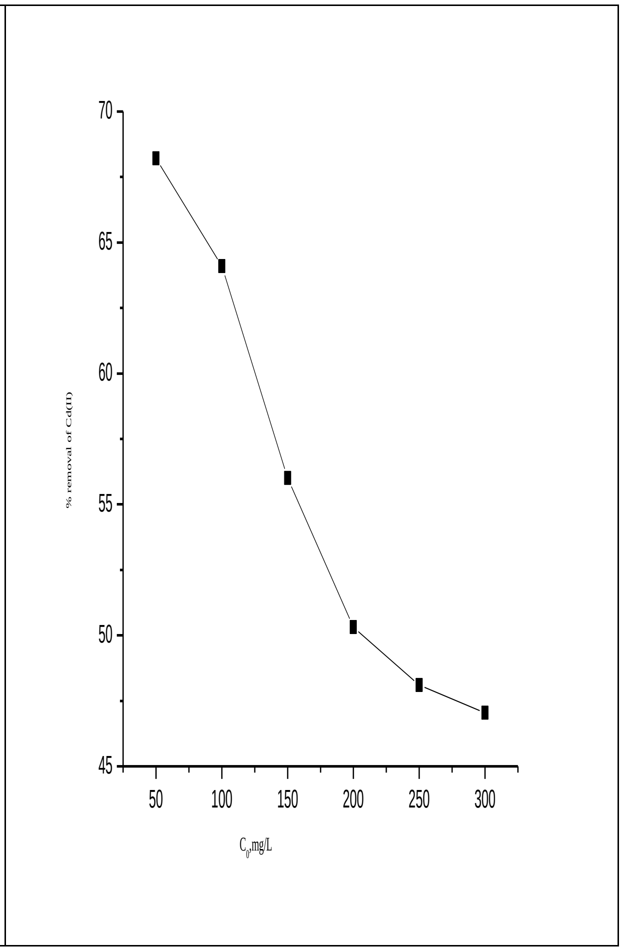
Dose of the adsorbent m, g/L	Maximum adsorption, %
1.0	34.3
2.0	60.1
3.0	79.5
4.0	86.0
5.0	98.22



3.3 Effect of contact time and initial metal ion concentration

The experimental results for the adsorption of Cd^{2+} ions on the activated carbon at various concentration (50,100, 150, 200, 250, 300 mg/L) with contact time presented in Table-2 which reveals that, the present adsorption decreased with increase in initial metal ion concentration, but the actual amount of Cd^{2+} ion adsorbed per unit mass of carbon is found to be increased with increase in metal ion concentration. Equilibrium is established at 35 minutes for all concentrations. The plot of percent Cd(II) adsorbed against contact time for the initial Cd^{2+} ion concentration of 100 mg/L, 5.5 pH and a temperature of 35 ˚C is given which reveals that the curve is single, smooth, and continuous, leading to saturation, suggesting the possible monolayer coverage of the metal ion on BNAC [7,8].





3.4 Adsorption isotherm

The experimental data were analyzed in the light of Langmuir [9] and Freundlich adsorption isotherm[10].

The Langmuir isotherm is

$$1/q_e = 1/Q_m\, b\, C_e + 1/Q_m$$

Where C_e is the equilibrium concentration (mg/L), q_e is the amount adsorbed at equilibrium (mg/g) and Q_m and b are Langmuir constants related to adsorption efficiency and energy of adsorption, respectively.

The plots of $1/q_e$ versus $1/C_e$ suggest linearity and the applicability of the Langmuir isotherm to the Cd^{2+}- BNAC adsorption system. Values of Q_m and b were determined from slope and intercepts of the plots and are presented in Table-3. From the results, it is clear that the value of adsorption efficiency, Q_m, and adsorption energy, b, of the carbon increases on increasing the temperature. From the values, we can conclude that the maximum adsorption corresponds to a saturated monolayer of adsorbate molecules on adsorbent surface.

The Freundlich isotherm is

$$\log q_e = \log K_F + 1/n \log C_e$$

Where q_e is the amount of cadmium ion adsorbed (mg/g).

C_e is the equilibrium concentration of metal ion in solution (mg/L) and K_F and n are constants incorporating all factors affecting the adsorption capacity and intensity of adsorption respectively.

Linear plot of log (x/m) versus log C_e shows that the adsorption of cadmium ion follows the Freundlich isotherm . Values of K_F and n were determined and are given in the Table-3, which reveals that an increase in the negative charge on the surface that enhances the electrostatic force like van der Waal's force between the carbon surface and metal ion, thereby increases the adsorption of cadium ions. The values clearly indicate that there is dominance in adsorption capacity. The intensity of adsorption is an indicative of the bond energies between metal ion and adsorbent and the possibility of slight chemisorption rather than physisorption. However, the values of n are greater than one indicating the adsorption is much more favourable [11-13].

Table 3: Langmiur and Freundlich Isotherm Constants for Adsorption of Cd(Ii) On BNA

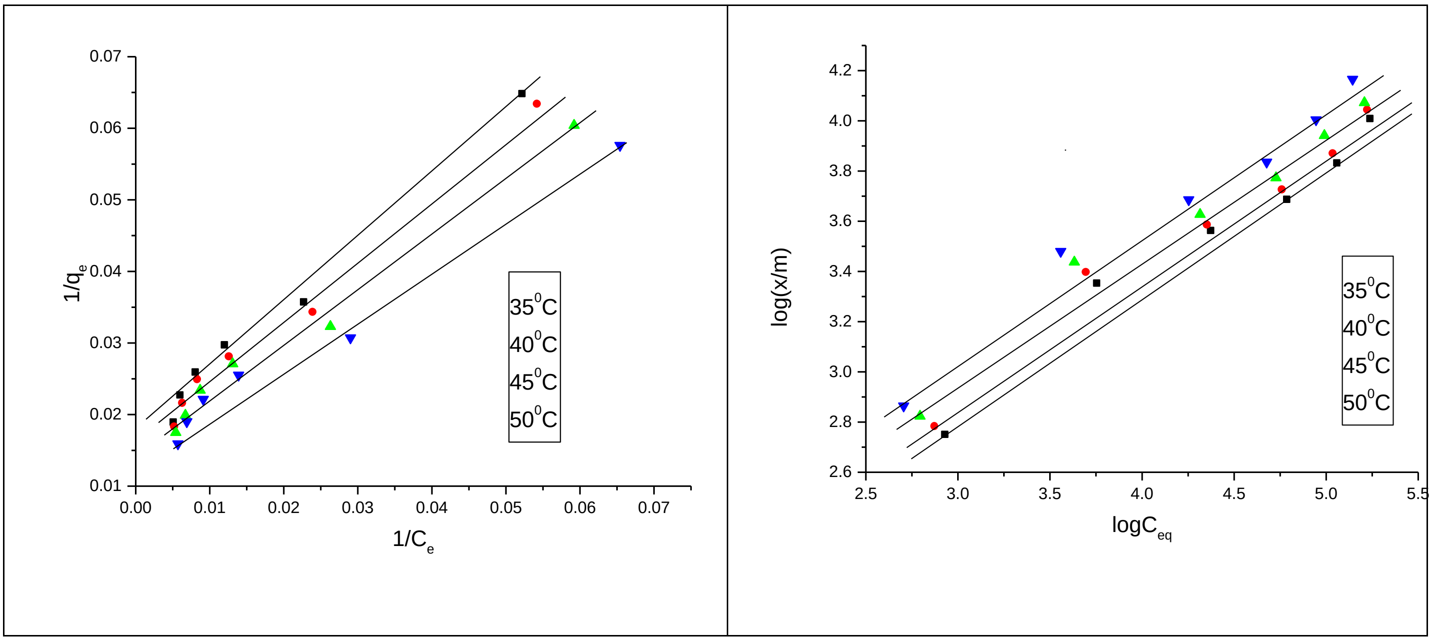
Temp., ˚C	Q_m (mg/g)	b (L/mg)	Correlation Co-efficient	K_F (mg/g)	n (L/mg)	Correlation Co-efficient
35	64.56	0.0155	0.991	3.6873	2.0070	0.970
40	65.67	1.2358	0.979	4.1674	2.0352	0.969
45	70.41	1.4169	0.962	4.7219	2.0700	0.971
50	71.30	1.5724	0.986	4.9429	2.0347	0.967

Table 4: Values of R_L for Cd(II) Adsorption on BNAC

$[Cd(II)]_{ini.}$, C_0, mg/L	R_L at different temp., ˚C			
	35	40	45	50
50	0.5362	0.5168	0.4926	0.4785
100	0.3663	0.3484	0.3268	0.3145
150	0.2782	0.2628	0.2445	0.2342
200	0.2242	0.2109	0.1953	0.1866
250	0.1878	0.1762	0.1626	0.1550
300	0.1615	0.1513	0.1393	0.1326

Table 5: Equilibrium Parameters for The Adsorption Of Cd(Ii) Onto Bnac Langmiur Adsorption Isotherm

$Cd(II)_{ini.}$, mg/L	C_e, mg/ L				x, mg/ L				x/m, mg/ g				% Metal adsorbed			
	35˚	40˚	45˚	50˚	35˚	40˚	45˚	50˚	35˚	40˚	45˚	50˚	35˚	40˚	45˚	50˚
50	18.8	17.75	16.35	14.95	31.2	32.25	33.65	35.05	15.6	16.13	16.83	17.53	62.4	64.5	67.3	70.1
100	42.9	40.4	37.8	35.1	57.1	59.6	62.2	64.9	28.5	29.8	31.1	32.45	57.1	59.6	62.2	64.9
150	79.65	78.0	74.85	70.35	70.35	72.0	75.15	79.65	35.17	36.0	37.6	39.83	46.9	48.0	50.1	53.1
200	120.4	117.2	113.0	107.4	79.6	82.8	87.0	92.6	39.8	41.4	43.5	46.3	39.8	41.4	43.5	46.3
250	158.0	154.5	147.0	140.5	92.0	95.5	103.0	109.5	46.0	47.8	51.5	54.8	36.8	38.2	41.2	43.8
300	189.3	186.3	182.7	171.3	109.8	113.7	117.3	128.7	54.9	56.9	58.7	64.4	36.6	37.9	39.1	42.9



3.5 Effect of temperature

The adsorption capacity of the carbon increased with increase in the temperature of the system from 35-50 ˚C. Thermodynamic parameters such as change in free energy (ΔG), enthalpy (ΔH) and entropy (ΔS) were determined using the following equations [14],

$$\log_{10} b = \frac{-\Delta H}{2.303\,R}\;\frac{1}{T} + \log_{10} b^{1}$$

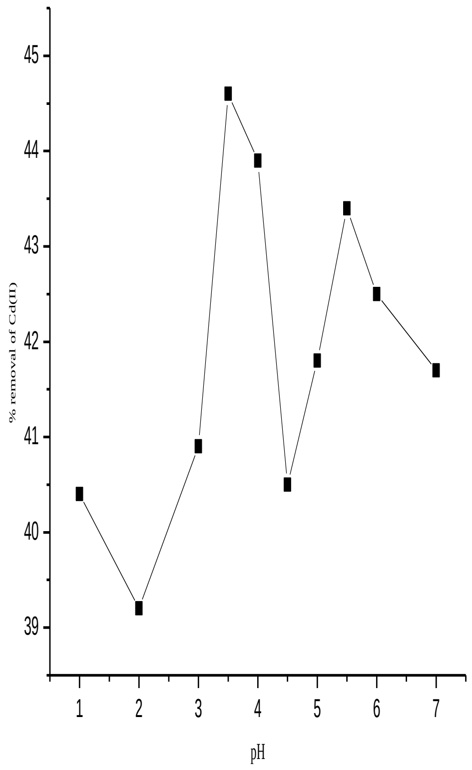
$$\frac{\log 1}{T} = \frac{\Delta G}{2.303R}\;.\;\frac{1}{T}$$

$$\Delta S = \frac{\Delta H - \Delta G}{T}$$

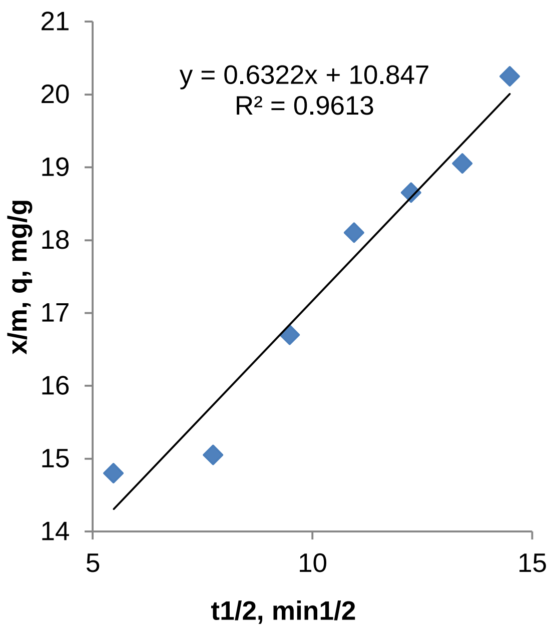
Where,
b = Langmuir constant
ΔH = apparent enthalpy change of adsorption
ΔG = apparent free energy of adsorption and
ΔS = apparent entropy change of adsorption

In the present work, the plot of $\log_{10}$ b against the reciprocal of temperature shown in Figure and that of log $_{10}$ 1/b against the reciprocal of temperature are found linear. From the slopes of these linear plots, ΔH and ΔG were determined and subsequently, ΔS was calculated.
The values of ΔH and ΔG are found to be 14580.1 and 14929.96 $KJmol^{-1}$ respectively. The term ΔH represents the enthalpy associated with the overall adsorption process. It is not possible to arrive at any conclusion regarding the heat of adsorption for any of the different processes expected to be involved in the adsorption process. The positive ΔH value found in the present investigation indicates that Cd(II)-BNAC, adsorption process is endothermic. Thermodynamically, the value of ΔG is positive and the value of ΔH is positive, suggesting that the adsorption is spontaneous at higher temperature [15]. The positive values of ΔS showed that the increasing randomness at the solid/liquid interface during the process.

3.6 Effect of pH
The solution pH plays a major role in determining the amount of cadmium ions absorbed. Adsorption was studied over the range of pH~1-7 and the results are shown in Figure. The initial metal ion was kept constant. Adsorption of cadmium ions increased appreciably (2 times) with increase of pH from 1to 7 and consistent with results obtained by others.



Effect of pH on Cd(II) removal



3.8 Desorption Studies

Desorption of metal ion were studied by using different concentrations of hydrochloric acid. Under these conditions, the metal ion transferred from the sorbents to the acid solution until new equilibrium was reached. The maximum removal percentages of 92.72% of Cd(II) was realized with 0.15 mol/L HCl . This indicates that ion exchange is involved in the adsorption process and the metal ion was adsorbed onto the activated carbon through physisorption.

4. CONCLUSION

From this study,it can be concluded that chemically modified adsorbents can effectively remove Cd(II) ion from aqueous solution under optimized environmental conditions. The experimental data correlated reasonably well by the Langmuir and Freundlich isotherms and the isotherm parameters were calculated. The amount of metal ion adsorbed increased with increase in pH. The amount of metal ion adsorbed slightly decreased with increasing ionic strength and increased with increase in temperature. The dimensionless separation factor (R_L) showed that the activated carbon can be used for the removal of metal ion from aqueous solution. The values of ΔH, ΔG and ΔS results show that the carbon employed has a considerable potential as an adsorbent for the removal of Cd(II) ions.

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