

Research Article

Kinetic, Equilibrium and Mechanistic Studies of Nickel Adsorption on Acid Activated *Ipomoea Carnea* Leaves

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Abstract: An adsorbent prepared from *Ipomoea carnea* Leaves (AAIC), by acid treatment was tested for its efficiency in removing nickel ion. The process parameters studied include agitation time, initial Nickel ion concentration, adsorbent dose, pH and temperature. The adsorption followed second order reaction equation and the rate is mainly controlled by intra-particle diffusion. Freundlich and Langmuir isotherm models were applied to the equilibrium data. The adsorption capacity (Qm) obtained from the Langmuir isotherm plot at an initial pH of 6.5 and at 30, 40, 50, 60 ± 0.5 °C. The influence of pH on nickel ion removal was significant and the adsorption was increased with increase in temperature. A portion of the nickel ion was recovered from the spent AAIC using 0.1M HCl.

Keywords: Acid Activated *Ipomoea carnea* Leaves Nano Carbon (AAIC), Nickel ion, Adsorption isotherm, Equilibrium, Thermodynamic parameters, Intra-particle diffusion.

INTRODUCTION

Heavy metal pollution of water and water bodies is a serious environmental problem that affects the quality of water. The consequences are decreasing water supply, increase in cost of purification, eutrophication of water bodies and decrease in aquatic production [1]. In order to tackle the menace posed by heavy metal pollution of water, several options have been adopted. These include oxidation and reduction, chemical precipitation, filtration, electrochemical treatment, ion exchange, membrane separation, reverse osmosis, adsorption, evaporation and electrolysis [2]. However, adsorption has been proven to be one of the best options available for the removal of heavy metals from aqueous solution [3, 4]. In view of the above, several researches have been conducted using various materials as adsorbents [5-9]. However, some of these adsorbents also contain other toxicants; some are expensive and are characterized with limited surface area for adsorption.

A search of literature revealed that fruit stone has been used for adsorption of some heavy metals from aqueous solution but literature is scanty on the use of activated carbon produced from fruit stone for the adsorption of Pb (II) and Ni(II) ions from aqueous solution. Therefore, the objective of the present study is to investigate the possibility of using AAIC as an adsorbent for the removal of Ni (II) ions from aqueous solution.

MATERIALS AND METHODS

Adsorbent

The *Ipomoea carnea* Leaves collected from nearby Thiruvarur district was carbonized with concentrated Sulphuric Acid and washed with water and activated around 400°C in a muffle furnace for 5 hrs then it was taken out, ground well to fine powder and stored in a vacuum desiccators.



Fig 1: *Ipomoea carnea*

Chemicals

All chemicals used of high purity commercially available Analar grade. 1000 mg/L of stock solution of nickel was prepared by dissolving accurately weighed 4.4786 gram of nickel sulphate in 1000 ml distilled water. All experimental solutions were prepared by diluting the stock solution to the required concentration. The pH of each experimental solution was adjusted to the required initial pH value using dilute HCl (or) NaOH before mixing the adsorbent. The concentration of residual nickel ion was

determined with atomic absorption spectrophotometer (Perkin Elemer 2380).

Batch experiments

The effect of various parameters on the removal of nickel ion onto AAIC was studied batch adsorption experiments were conducted at (30-60°C). For each experimental run, 50 ml of nickel solution of known initial concentration and pH were taken in a 250 ml plugged conical flask. A 25 mg adsorbent dose is added to the solution and mixture was shaken at constant agitation speed (150 rpm) sample were withdrawn at appropriate time intervals (10-60 min) and the adsorbent was separated by filtration. The residual solutions were analyzed to determine the nickel ion concentration.

The effect of dosage of adsorbent on the removal of nickel ion was measured by contacting 50 ml of 50 mg/L of nickel ion solution with 25 mg to 250 mg of AAIC till equilibrium was attained. Adsorption equilibrium isotherm is studied using 25 mg of AAIC dosage per 50 ml of nickel ion solution. The initial concentration were ranged from (25 to 125 mg/L) in all sets of experiments. The plugged conical flask was shaken at a speed of 150 rpm for 60 minutes. Then the solution was separated from the mixture and analyzed for nickel ion concentration. The adsorption capacity was calculated by using a mass equilibrium equation as follows:

$$q_e = (C_0 - C_e) V/M \dots\dots\dots (1)$$

Where C_0 and C_e being the initial nickel ion concentration (mg/L) and equilibrium concentration, respectively V is the experimental volume of nickel ion solution expressed in liters [L] and M is the adsorbent mass expressed in grams [g]. The nickel ion percentage can be calculated as follows:

$$\%R = (C_0 - C_t) \times 100/C_0 \dots\dots\dots (2)$$

The effect of pH on the rate of adsorption was investigated using nickel concentration of 25 mg/L constant AAIC dosage. The pH values were adjusted with dilute HCl and NaOH solution. The adsorbent – adsorbate mixture was shaken at room temperature using agitation speed (150 rpm) for 60 minutes. Then the concentration of nickel ion solution was determined.

RESULTS AND DISCUSSION

Effect of agitation time and initial Nickel ion concentration

The kinetics of adsorption of nickel ion by AAIC is shown in (fig. 1) with smooth and single plots indicating monolayer adsorption of nickel ion on the AAIC. The removal of nickel ion increased with the lapse time and attains equilibrium in 60 min for 50 mg/L. With increase in nickel ion concentration from 25 to 125 mg/L, the amount of nickel ion adsorbed increased while the percent removal decreased, indicating that the nickel ion removal by adsorption on AAIC concentration dependent.

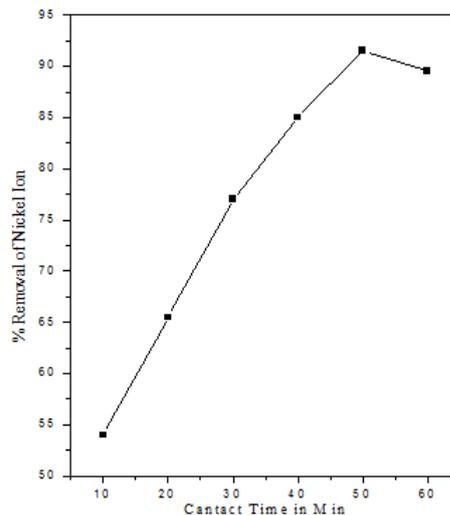


Fig. 1: Effect of contact time on the removal of nickel ion [Ni]=50 mg/mL; Temperature 30°C; Adsorbent dose=25 mg/50mL

Effect of AAIC mass

The amount of nickel ion adsorption increased with the increase in AAIC dose and reached a maximum value after a particular dose (fig.2). Taken an initial nickel ion concentration of 50 mg/L, complete

nickel ion removal was obtained at a maximum AAIC dose of 25 to 50 mg. The increase in the adsorption of nickel ion with AAIC dose was due to the introduction of more binding sites for adsorption and the availability more surface area.

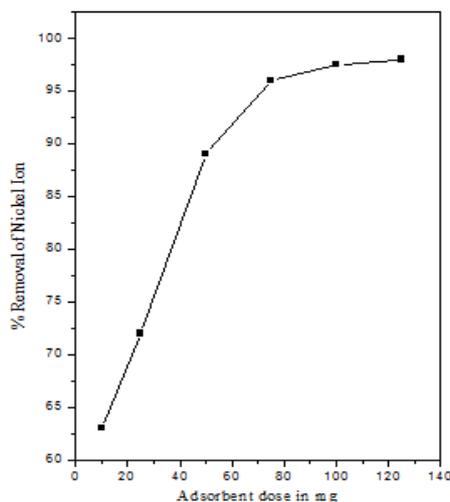


Fig. 2: Effect of Adsorbent dose on the removal of nickel ion
 [Ni]=50 mg/mL; Contact time=60 min, Temperature 30°C

Effect of pH

The experience carried out at different pH show that there was a change in the percent removal of nickel ion over the entire pH range shown in Fig. 3. This indicates the strong force of interaction between the nickel ion and AAIC that either H⁺ or OH⁻ ions could influence the adsorption capacity. In other words,

the adsorption of nickel ion on AAIC does involve ion exchange mechanism that have been an influence on the nickel ion adsorption while varying the pH. This observation is in line with the type I and II isotherm and positive ΔH^0 value obtained, which indicates irreversible adsorption probably due to polar interactions.

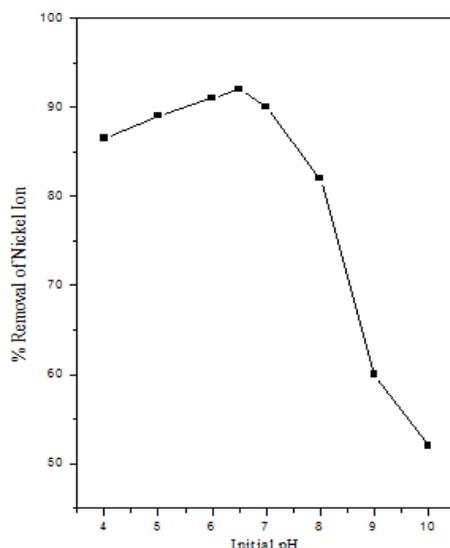


Fig. 3: Effect of Initial pH on the removal of nickel ion
 [Ni]=50 mg/mL; Temperature 30°C, Adsorbent dose=25 mg/50mL

Effect of other ions

The effect of other ions like Ca²⁺ and Cl⁻ on the adsorption process studied at different concentrations. The ions added to 50mg/L of nickel ion solutions and the contents were agitated for 60 min at 30°C. The results had shown in the Fig. 4 reveals that low concentration of Cl⁻ does not affect the percentage of adsorption of nickel ion on AAIC, because the interaction of Cl⁻ at available sites of adsorbent through

competitive adsorption is not so effective. While the concentration of other ion Ca²⁺ increases, the interference of these ions at available surface sites of the sorbent through competitive adsorption increases that, decreases the percentage adsorption. The interference was more in the presence of Ca²⁺ compared with Cl⁻ ion. This is so because ions with smaller hydrated radii decrease the swelling pressure within the sorbent and increase the affinity of the sorbent for such ions.

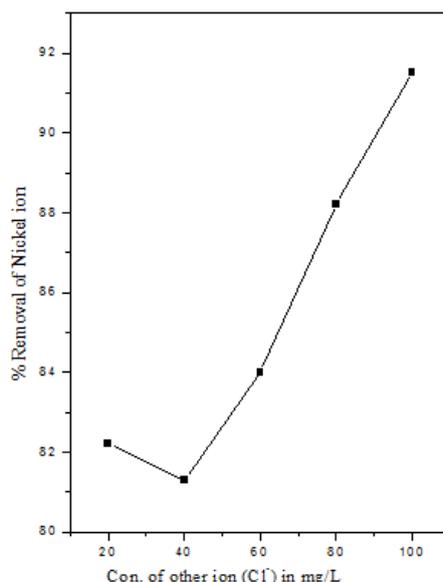


Fig. 4: Effect of Ionic strength on the adsorption of nickel ion
 [Ni]=50 mg/mL; Ph=6.5; Adsorbent dose=25 mg/50mL

Table 1: Equilibrium Parameters for the Adsorption of Nickel Ion onto AAIC

M ₀	Ce (Mg / L)				Qe (Mg / g)				Removal (%)			
	30° C	40° C	50° C	60° C	30° C	40° C	50° C	60° C	30° C	40° C	50° C	60° C
25	2.61	1.67	1.23	1.083	46.77	46.65	47.52	47.83	92.54	93.00	95.04	93.66
50	4.27	4.62	4.096	3.273	91.45	90.75	91.80	93.45	90.45	90.75	91.80	92.45
75	12.38	11.78	10.75	9.547	125.2	126.4	128.49	130.90	82.42	84.29	85.66	87.27
100	24.68	24.76	10.75	27.87	148.6	150.46	178.49	144.24	73.81	75.23	89.24	72.12
125	44.83	39.94	22.79	31.04	160.3	170.10	204.40	187.90	64.13	68.04	81.76	75.16

Table 2: Langmuir and Freundlich Isotherm Parameter for the Adsorption of Nickel Ion onto AAIC

Temp. (°C)	Langmuir Parameter		Freundlich Parameter	
	Q _m	b	K _f	n
30°	175.46	0.23	4.87	2.69
40°	180.36	0.18	5.12	2.54
50°	278.90	0.15	5.16	1.66
60°	198.21	0.28	5.60	2.32

Table 3: Dimensionless Separation Factor (R_i) for the Adsorption of Nickel Ion onto AAIC

(C _i)	Temperature °C			
	30°C	40°C	50°C	60°C
25	0.15	0.18	0.21	0.12
50	0.08	0.09	0.12	0.06
75	0.05	0.06	0.08	0.04
100	0.04	0.05	0.06	0.03
125	0.03	0.04	0.05	0.02

Table 4: Thermodynamic Parameter for the Adsorption of Nickel Ion onto AAIC

C ₀	ΔG°				ΔH°	ΔS°
	30° C	40° C	50° C	60° C		
25	-6536.37	-6757.63	-6934.39	-8267.66	11.15	62.03
50	-5871.37	-5922.97	-6288.86	-7359.88	8.18	43.97
75	-4082.32	-4311.87	-4201.07	-5339.62	7.52	40.40
100	-2656.69	-2991.17	-5883.66	-2631.38	6.23	31.52
125	-1364.13	-1866.71	-4128.83	-3165.51	19.76	69.42

Table 5: The Kinetic Parameters for the Adsorption of Nickel Ion onto AAIC

C ₀	Temp °C	Pseudo Second Order				Elovich Model			Intra-particle Diffusion		
		q _e	k ₂	γ	h	α	β	γ	K _{id}	γ	C
25	30	50.80	20×10 ⁻³	0.994	7.72	56.482	0.12	0.998	1.64	0.992	0.18
	40	49.10	15×10 ⁻³	0.995	13.89	2313.4	0.22	0.991	1.78	0.994	0.10
	50	50.34	14×10 ⁻³	0.997	11.79	1622.7	0.21	0.993	1.78	0.991	0.107
	60	52.26	16×10 ⁻³	0.999	7.86	91.607	0.14	0.992	1.67	0.992	0.16
50	30	101.0	22×10 ⁻³	0.998	13.49	118.16	0.06	0.991	1.63	0.991	0.18
	40	96.65	18×10 ⁻³	0.997	20.07	1907.0	0.105	0.992	1.74	0.992	0.11
	50	97.76	17×10 ⁻³	0.998	21.23	1987.3	0.103	0.991	1.75	0.991	0.11
	60	98.93	16×10 ⁻³	0.992	22.43	2909.2	0.106	0.993	1.77	0.993	0.10
75	30	134.4	22×10 ⁻³	0.994	25.51	1173.8	0.068	0.997	1.68	0.991	0.12
	40	135.5	21×10 ⁻³	0.991	26.83	1384.2	0.069	0.994	1.69	0.992	0.124
	50	137.3	21×10 ⁻³	0.992	28.32	1854.2	0.07	0.994	1.71	0.991	0.120
	60	140.1	21×10 ⁻³	0.991	28.76	1591.5	0.06	0.9953	1.71	0.991	0.123
100	30	161.5	25×10 ⁻³	0.992	25.35	549.98	0.05	0.997	1.60	0.991	0.14
	40	162.4	23×10 ⁻³	0.991	28.80	876.94	0.053	0.999	1.62	0.992	0.13
	50	167.0	11×10 ⁻³	0.993	30.68	951.25	0.052	0.998	1.64	0.993	0.136
	60	150.1	12×10 ⁻³	0.991	94.26	948023	0.10	0.997	1.74	0.992	0.06
125	30	177.5	25×10 ⁻³	0.992	24.00	403.69	0.04	0.998	1.52	0.993	0.15
	40	184.4	23×10 ⁻³	0.994	31.53	673.76	0.04	0.999	1.56	0.992	0.14
	50	193.1	15×10 ⁻³	0.991	31.93	686.28	0.042	0.996	1.58	0.998	0.146
	60	203.6	24×10 ⁻³	0.992	32.26	742.99	0.040	0.997	1.60	0.995	0.145

Effect of temperature

The adsorption capacity of AAIC increased with increase in the temperature of the system from 30 to 60⁰ C. Thermodynamic parameters such as change in free energy (ΔG⁰), enthalpy (ΔH⁰) and entropy (ΔS⁰) were determined using the following equations.

$$K_0 = C_{solid}/C_{liquid} \dots\dots\dots (3)$$

$$\Delta G^0 = -RT \ln K_0 \dots\dots\dots (4)$$

$$\log K_0 = \Delta S^0/(2.303R) - \Delta H^0/(2.303RT) \dots\dots (5)$$

Where K₀ is the equilibrium constant, C_{solid} is the solid phase concentration at equilibrium (mg/L), C_{liquid} is the liquid phase concentration at equilibrium (mg/L), T is the temperature in Kelvin and R is the gas constant. ΔH⁰ and ΔS⁰ were obtained from the slope and intercept of van't Hoff plot and are presented in Table 4. Positive value of ΔH⁰ shows the endothermic nature of adsorption. This rules the possibility of both physical as well as chemical adsorption. Because in the case of physical adsorption alone, while increasing the temperature of the system the extent of nickel ion adsorption decreases, as desorption increases with temperature[10]. As chemisorptions is mainly an irreversible process, the low positive ΔH⁰ value depicts that Nickel ion is both physically as well as chemically adsorbed onto AAIC. This is in agreement with the type I and II isotherm obtained, which is close to irreversible adsorption [10].

The negative values of ΔG⁰ (Table 4) indicate that the nickel ion adsorption is spontaneous. The positive value of ΔS⁰ shows increased randomness at the solid-

solution interface during the adsorption of nickel ion on AAIC. The adsorbed water molecules, which are displaced by the adsorbate species, gain more translational entropy than is lost by the adsorbate molecules thus allowing the prevalence of randomness in the system. Enhancement of adsorption capacity of AAIC at higher temperatures may be attributed the enlargement of pore size and/or activation of the adsorbent surface [11].

Adsorption Isotherms

Freundlich isotherm

The linear form of Freundlich isotherm [12] is represented by the equation

$$\log q_e = \log K_f + (1/n)\log C_e \dots\dots\dots(6)$$

Where q_e is the amount of Ni (II) ions adsorbed per unit weight of the sorbent (mg/L), K_f is a measure of adsorption capacity and 1/n is the adsorption intensity. The value of K_f and n are calculated from the intercept and slope of the plot of log Q_e vs log C_e respectively. The constant K_f and n values are given in (table-2). In general K_f value increases the adsorption capacity for a given adsorbate increases. The magnitude of the exponent 1/n gives an indication of the favorability of adsorption. The value of n>1 represents favorable adsorption condition (or) the value of 1/n are lying in the range of 1 to 10 confirms the favorable condition for adsorption. The adsorption co-efficient K_f of nickel on AAIC was found to be around 5.6 L/g. The K_f values indicates that the saturation time for adsorption of nickel ion is attained quickly slue to high affinity of AAIC towards adsorbate, while low K_f values indicates

low adsorption rate of nickel ion [13-15]. The values of $1/n$ were around 3.0 (mg/L) for Nickel ions. The high values of $1/n$ signifies that the forces which are exerted on the surface of AAIC during nickel ion adsorption are strong rate from the values K_f and $1/n$ it is reveals that AAIC is more efficient for removal of nickel ions.

Langmuir isotherm

The Langmuir isotherm model [16] is based on the assumption that maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface. The linear form of the Langmuir isotherm equation can be described by

$$C_e/Q_e = (1/Q_m b) + (C_e/Q_m) \dots\dots\dots(7)$$

Where C_e (mg/L) is the equilibrium concentration of the adsorbate, Q_e (mg/g) is the amount of adsorbate per unit mass of adsorbent, Q_m and b are Langmuir constants related to adsorption capacity and rate of adsorption respectively. Q_m is the amount of adsorbate at complete monolayer coverage (mg/g) which gives the maximum adsorption capacity of the adsorbent and b (L/mg) is the Langmuir isotherm constant that relates to the energy of adsorption (or rate of adsorption). The linear plot of specific adsorption capacity C_e/q_e against the equilibrium concentration (C_e). The Langmuir constant Q_m and b were determined from the slope and intercept of the plot and are presented in table 2. In order to find out the feasibility of the isotherm, the essential characteristics of the Langmuir isotherm can be expressed in terms of dimensionless constant separation factor R_L by the equation

$$R_L = (1/(1+bC_o)) \dots\dots\dots(8)$$

Where, C_o (mg/L) is the highest initial concentration of adsorbent and b (L/mg) is Langmuir isotherm constant. The parameter R_L indicates the nature of shape of the isotherm accordingly.

- $R_L > 1$ Unfavorable adsorption
- $0 < R_L < 1$ Favorable adsorption
- $R_L = 0$ Irreversible adsorption
- $R_L = 1$ Linear adsorption

The R_L values between 0 to 1 indicate favorable adsorption for all initial concentration (C_o) and temperatures studied. The calculated R_L values are given in table 3. The values of b were increased with increasing the concentration of nickel ion. High b values indicate high adsorption affinity the monolayer saturation capacity Q_m were around 195 mg/L for AAIC.

Thermodynamic treatment of the adsorption process

Thermodynamic parameters associated with the adsorption, via standard free energy change (ΔG^0), standard enthalpy change (ΔH^0), and standard entropy

change (ΔS^0) were calculated as follows. The free energy of adsorption process considering the adsorption equilibrium constant, K_0 is given by the equation

$$\Delta G^0 = -RT \ln K_0 \dots\dots\dots(9)$$

Where ΔG^0 is the free energy of adsorption (kJ/mol), T is the temperature in Kelvin and R is the universal gas constant (8.314 J mol/K). The adsorption distribution coefficient K_0 for the sorption reaction was determined from the slope of the plot of $\ln(Q_e/C_e)$ against C_e at different temperature and extrapolating to zero C_e according to the method suggested by Khan and Singh [17] The adsorption distribution coefficient may be expressed in terms of enthalpy change (ΔH^0) and entropy change (ΔS^0) as a function of temperature,

$$\ln K_0 = (\Delta H^0/RT) + (\Delta S^0/R) \dots\dots\dots(10)$$

Where ΔH^0 is the standard heat change of sorption (kJ/mol) and ΔS^0 is standard entropy change (kJ/mol). The value of ΔH^0 and ΔS^0 can be obtained from the slope and intercept of plot of $\ln K_0$ against $1/T$. The value of thermodynamic parameter calculated from equation 9 and 10 are shown in table 4. The thermodynamic treatment of the sorption data indicates that ΔG^0 values were negative at all temperature. The results point out that physisorption is much more favorable for the adsorption of Ni (II) ions. The positive values of ΔH^0 show the endothermic nature of adsorption and it governs the possibility of physical adsorption. Because in the case of physical adsorption, while increasing the temperature of the system, the extent of nickel ion adsorption increases, this rules out the possibility of chemisorptions. The low ΔH^0 value depicts nickel ion is physisorbed onto adsorbent AAIC.

The negative ΔG^0 values table 4 were conform the spontaneous nature of adsorption Ni (II) ions onto AAIC. The lesser values of ΔG^0 suggest that adsorption is physical adsorption process. The positive value of ΔH^0 further confirms the endothermic nature of adsorption process. The positive values of ΔS^0 in table 4, showed increased randomness of the solid solution interface during the adsorption of nickel ion onto AAIC.

Adsorption kinetics

The study of adsorption dynamics describes the solute up take rate and evidently this rate controls the residence time of adsorbate uptake at the solid-solution interface. The kinetics of Ni (II) ions adsorption on the AAIC were analyzed using pseudo second-order, Elovich and intra-particle diffusion kinetic models. The conformity between experimental data and the model predicted values was expressed by the correlation co- efficient (γ) and the values are close or equal to 1. A relatively high correlation coefficient

(γ) value indicates that the pseudo second-order model successfully describes the kinetics of Ni (II) ions adsorption.

The pseudo second- order equation

The pseudo second-order adsorption kinetic rate equation [18] is expressed as

$$dq_t/dt = k_2(q_e - q_t)^2 \dots\dots\dots(11)$$

Where: K_2 is the rate constant of pseudo second-order adsorption (g mg/min). For the boundary conditions $t = 0$ to $t = t$ and $q_t = 0$ to $q_t = q_t$ the integrated form of Eq. (9) becomes:

$$1/(q_e - q_t) = 1/q_e + K_2 t \dots\dots\dots (12)$$

This is the integrated rate law for a pseudo second-order reaction. Equation (12) can be rearranged to obtain Eq.(13),which has a linear form:

$$t/q_t = (1/k_2 q_e^2) + ((1/q_e)t) \dots\dots\dots(13)$$

If the initial adsorption rate (h)(mg g⁻¹min⁻¹) is :

$$h = k_2 q_e^2 \dots\dots\dots (14)$$

Equation (11) and (12) becomes,

$$t / q_t = 1 / h + 1 / q_e t \dots\dots\dots (15)$$

The plot of (t/q_t) and t of Eq. (15) gives a linear relationship from which q_e and k₂ can be determined from the slope and intercept of the plot, respectively. The pseudo-second order rate constants k₂, the calculated h values, and the correlation coefficients (γ) are summarized in Table 5. At all studied initial nickel concentrations, the straight lines with extremely high correlation co-efficient (>0.99) were obtained. From table 5, the values of the rate constant k decrease with in increasing initial nickel concentration for AAIC. This is shows that the sorption of Ni (II) ions on AAIC follows pseudo second order kinetic model

The Elovich equation

The Elovich model equation is generally expressed as

$$dq_t/ d_t = \alpha \exp (-\beta q_t) \dots\dots\dots(16)$$

Where; α is the initial adsorption rate (mg g⁻¹ min⁻¹) and β is the desorption constant (g/mg) during any one experiment. To simplify the Elovich equation. Chien and Clayton [19] assumed $\alpha\beta t \gg t$ and by applying boundary conditions $q_t = 0$ at $t = 0$ and $q_t = q_t$ at $t = t$ Eq. (12) becomes:

$$q_t = 1/\beta \ln (\alpha\beta) + 1/\beta \ln t \dots\dots\dots (17)$$

If Ni (II) ions adsorption fits with the Elovich model, a plot of q_t vs. ln(t) yields a linear relationship

with a slope of (1/β) and an intercept of (1/β)ln (αβ). The Elovich model parameters α, β, and correlation coefficient (γ) are summarized in table 5. The experimental data such as the initial adsorption rate (α) adsorption constant (β) and the correlation co-efficient (γ) calculated from this model indicates that the initial adsorption (α) increases with temperature similar to that of initial adsorption rate (h) in pseudo-second-order kinetics models. This may be due to increase the pore or active site on the AAIC adsorbent.

The intra particle diffusion model

The intra-particle diffusion model used here refers to the theory proposed by Weber and Morris [20] based on the following equation for the rate constant:

$$q_t = k_{id} t^{(1/2)} + C \dots\dots\dots(18)$$

Where k_{id} is the intra-particle diffusion rate constant (mg/g/min) and C is the constant. The rate limiting step is intra-particle diffusion, the graph drawn between (q_t) (mg/g) verses square root of the contact time (t^{1/2}) yields a straight line passing through the origin. The slope gives the value of the intra-particle diffusion coefficient (k_{id}) and correlation coefficient (γ) indicate the fitness of this model. The value of C gives an idea about the thickness of the boundary layer. From these data the intercept value indicate that the line were not passing through origin, there are some other process affect the adsorption. But the correlation coefficient (γ) value is very high, so that the intra-particle diffusion takes place along with other process that may affect the adsorption. The values are given in table 5.

Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the nickel ions. If the adsorbed nickel ions can be desorbed using neutral pH water, then the attachment of the nickel ion of the adsorbent is by weak bonds. The effect of various reagents used for desorption studies. The results indicate that hydrochloric acid is a better reagent for desorption, because we could get more than 90% removal of adsorbed nickel ion. The reversibility of adsorbed nickel ion in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of nickel ion by mineral acids and alkaline medium indicates that the nickel ion was adsorbed onto the AAIC through physisorption as well as by chemisorptions mechanisms.

CONCLUSION

AAIC prepared from *Ipomoea carnea* Leaves was found to be effective in removing nickel ion from aqueous solution. The adsorption is faster and the rate is mainly controlled by intra-particle diffusion. Using the sorption equation obtained from the Langmuir and Freundlich isotherms, it was found that AAIC is an effective one for the removal of nickel ion. The

equilibrium data conformed well to the Langmuir and Freundlich isotherm models. The temperature variation study showed that the nickel ion adsorption is endothermic and spontaneous with increased randomness at the solid solution interface. Significant effect on adsorption was observed on varying the pH of the nickel ion solution. pH dependent results and desorption of nickel ion in mineral acid suggest that the adsorption of nickel ion on AAIC involves chemisorptions as well as physisorption mechanism.

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