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KINETIC, EQUILIBRIUM AND MECHANISTIC STUDIES OF NICKEL ADSORPTION ON ACID ACTIVATED *HIBISCUS SABDARIFFA* STEM NANO CARBON

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ABSTRACT

An adsorbent prepared from Acid Activated *Hibiscus Sabdariffa* Stem, by acid treatment was tested for its efficiency in removing metal 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 (Q_M) obtained from the Langmuir isotherm plot at an initial pH of 6.0 and at 30, 40, 50, 60 \pm 0.5⁰C. The influence of pH on metal ion removal was significant and the adsorption was increased with increase in temperature. A portion of the nickel ion was recovered from the spent AHSNC using 0.1M HCl.

KEYWORDS

AHSNC, Nickel ion, Adsorption isotherm, Equilibrium, Thermodynamic parameters, Intra-particle diffusion and Derivative of quercetin.

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INTRODUCTION

Electroplating is performed in a number of small, medium and large size industries. Metal plating and finishing on the metal are performed to improve the value of the treated metal by providing improvements such as corrosion resistance, durability, electrical properties and aesthetic appearance. The process involves metals and their compounds such as Cadmium, Chromium, Nickel, and Zinc etc. Which are found to be highly toxic and accumulative in nature.

The humans as well as other life forms get affected. Industrial exposure to Nickel may cause Dermatitis and its high occupational exposure has been associated with renal problem and lung cancer. W.H.O. has prescribed the maximum concentration of Nickel in drinking water is 0.1 mg/L whereas the nickel plating effluent water may contain up to 50mg/L of nickel. Thus the effluent water has to be treated for the removal of Nickel. The treatment process, to remove heavy metals such as nickel, copper, zinc comprises of chemical precipitation, coagulation, complexing, solvent extraction, ion-change, sorption, osmosis and electrolysis^{1,2}.

MATERIALS AND METHODS

Adsorbent

The *Hibiscus Sabdariffa* Stem collected from nearby Thiruvavur district was carbonized with concentrated Sulphuric Acid and washed with water and activated around 1100°C in a muffle furnace for 5 hrs and then it was taken out, grind well to fine powder and stored in a vacuum desiccators.

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 1 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 Elmer 2380).

Batch experiments

The effect of various parameters on the removal of nickel ion onto AHSNC was studied by 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 of AHSNC till equilibrium was attained. Adsorption equilibrium isotherm is studied using 25 mg of AHSNC 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 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 ions 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 50 mg/L constant AHSNC 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 in solution was determined.

RESULTS AND DISCUSSION

Effect of agitation time and initial Nickel ion concentration

The kinetics of adsorption of nickel ion by AHSNC is shown in (Figure No.1) with smooth and single plots indicating monolayer adsorption of metal ion on the AHSNC². The removal of metal ion increased with the lapse time and attains equilibrium in 60 min for 50 mg/L. With increase in metal ion concentration from 25 to 125 mg/L, the amount of metal ion adsorbed increased while the percent removal decreased, indicating that the metal ion removal by adsorption on AHSNC concentration dependent.

Effect of AHSNC mass

The amount of nickel ion adsorption increased with the increase in AHSNC dose and reached a maximum value after a particular dose (Figure No.2). Taken an initial metal ion concentration of 50 mg/L, complete metal ion removal was obtained at a maximum AHSNC dose of 125 mg. The increase in the adsorption of metal ion with AHSNC dose was due to the introduction of more binding sites for adsorption and the availability more surface area.

Effect of pH

The experience carried out at different pH show that there was a change in the percent removal of metal ion over the entire pH range shown in Figure No.3. This indicates the strong force of interaction between the metal ion and AHSNC that either H⁺ or OH⁻ ions could influence the adsorption capacity. In other words, the adsorption of metal ion on AHSNC does involve ion exchange mechanisms that have been an influence on the metal ion adsorption while varying the pH³. 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.

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 metal ion solutions and the contents were agitated for 60 min at 30⁰C. The results had shown in the Figure No.4 reveals that low concentration of Cl⁻ does not affect the percentage of adsorption of metal ion on AHSNC, 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 ions⁴.

Effect of temperature

The adsorption capacity of AHSNC increased with increase in the temperature of the system from 30 to 60⁰C. Thermodynamic parameters such as change in free energy (ΔG^0), enthalpy (ΔH^0) and entropy (ΔS^0) were determined using the following equations.

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

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

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

Where K_0 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. ΔH^0 and ΔS^0 were obtained from the slope and intercept of van't Hoff plot and are presented in Table No.4. Positive value of ΔH^0 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 metal ion adsorption decreases, as desorption increases with temperature⁵. As chemisorption's is mainly an irreversible process, the low positive ΔH^0 value depicts that Nickel ion is both physically as well as chemically adsorbed onto AHSNC. This is in agreement with the type I and II isotherm obtained, which is close to irreversible adsorption⁶.

The negative values of ΔG^0 (Table No.4) indicate that the metal ion adsorption is spontaneous. The positive value of ΔS^0 shows increased randomness at the solid-solution interface during the adsorption of metal ion on AHSNC. 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 AHSNC at higher temperatures may be attributed the enlargement of pore size and/or activation of the adsorbent surface⁷.

Adsorption Isotherms

Freundlich isotherm

The linear form of Freundlich isotherm⁸ is represented by the equation.

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

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 No.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 condition⁹ or the value of $1/n$ are lying in the range of 1 to 10 confirms the favorable condition for adsorption. The adsorption coefficient K_f of Nickel on activated AHSNC was found to be around 45 mg/g. The K_f values indicates that the saturation time for adsorption of metal ion is attained quickly due to high affinity of activated AHSNC towards adsorbate, while low K_f values indicates low adsorption rate of metal ion^{10,11}. The values of $1/n$ were around 3.5 (L/mg) for Nickel ions. The high values of $1/n$ signifies that the forces which are exerted on the surface of AHSNC during metal ion adsorption are strong rate from the values K_f and $1/n$ it is reveals that AHSNC is more efficient for removal of Nickel ions.

Langmuir isotherm

The Langmuir isotherm model¹² 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 is 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 are presented in Table No.1. 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 ^{13,14}. 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 No.3. The values of b were increased with increasing the dose of adsorbent for AHSNC. High b values indicate high adsorption affinity the monolayer saturation capacity Q_m were around 139 mg/L for AHSNC.

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 Singh¹⁴. 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 No.4. The thermodynamic treatment of the sorption data indicates that ΔG° 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° 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 metal ion adsorption increases, this rules out the possibility of chemisorptions. The low ΔH° value depicts metal ion is physisorbed onto adsorbent AHSNC.

The negative ΔG° values Table No.4 were conforming the spontaneous nature of adsorption Ni (II) ions onto AHSNC. The lesser values of ΔG° suggest that adsorption is physical adsorption process. The positive value of ΔH° further confirms the endothermic nature of adsorption process. The positive values of ΔS° in Table No.4, showed increased randomness of the solid solution interface during the adsorption of nickel ion onto AHSNC.

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 AHSNC 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 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) ($\text{mg g}^{-1} \text{min}^{-1}$) 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) s gives a linear relationship from which q_e and k_2 can be determined from the slope and intercept of the plot, respectively. The pseudo-second order rate constants k_2 , the calculated h values, and the correlation coefficients (γ) are summarized in Table No.5. At all studied initial Nickel concentrations, the straight lines with extremely high correlation co-efficient (>0.99) were obtained. From Table No.5, the values of the rate constant k decrease with in increasing initial Nickel concentration for AHSNC. This is shows that the sorption of Ni (II) ions on AHSNC follows pseudo second order kinetic model.

The Elovich equation

The Elovich model equation is generally expressed as

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

Where; α is the initial adsorption rate ($\text{mg g}^{-1} \text{min}^{-1}$) and β is the desorption constant (g/mg) during any one experiment. To simplify the Elovich equation. Chien and Clayton (1980) assumed $\alpha\beta t \gg 1$ and by applying boundary conditions $q_t = 0$ at $t = 0$ and $q_t = q_t$ at $t = t$ Eq. (12) becomes:

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

The 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 $(1/\beta)$ and an intercept of $(1/\beta) \ln (\alpha\beta)$. The Elovich model parameters α , β , and correlation coefficient (γ) are summarized in Table No.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 AHSNC adsorbent.

The intra particle diffusion model

The intra-particle diffusion model used here refers to the theory proposed by Weber and Morris¹⁵ based on the following equation for the rate constant:

$$q_t = k_{id} t^{(1/2)} + C \dots \dots \dots (16)$$

Where k_{id} is the intra-particle diffusion rate constant (mg/g/min) and C is the constant. If the rate limiting step is intra-particle diffusion, then 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 of the will give 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 adsorption¹⁶. 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 adsorption¹⁷⁻¹⁹. The values are given in Table No.5.

Desorption studies

Desorption studies help to elucidate the nature of adsorption and recycling of the spent adsorbent and the metal ions. If the adsorbed metal ions can be desorbed using neutral pH water, then the attachment of the metal 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 metal ion. The reversibility of adsorbed metal ion in mineral acid or base is in agreement with the pH dependent results obtained. The desorption of metal ion by mineral acids and alkaline medium indicates that the metal ion was adsorbed onto the AHSNC through physisorption as well as by chemisorptions mechanisms.

Table No.1: Equilibrium parameters for the adsorption of nickel ion onto AHSNC

| 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 | 1.9429 | 1.6882 | 1.4707 | 1.3357 | 46.114 | 46.6235 | 47.0586 | 47.3285 | 92.228 | 93.247 | 94.117 | 94.657 |
| 50 | 9.1980 | 8.1196 | 6.6667 | 5.6254 | 81.604 | 83.7609 | 86.6666 | 88.7492 | 81.604 | 83.761 | 86.667 | 88.749 |
| 75 | 20.580 | 18.176 | 15.868 | 13.830 | 108.84 | 113.647 | 118.263 | 122.340 | 72.561 | 75.765 | 78.842 | 81.560 |
| 100 | 40.034 | 36.987 | 15.868 | 30.608 | 119.93 | 126.026 | 168.263 | 138.784 | 59.966 | 63.013 | 84.132 | 69.392 |
| 125 | 62.470 | 58.614 | 33.785 | 51.220 | 125.06 | 132.773 | 182.429 | 147.560 | 50.024 | 53.109 | 72.972 | 59.024 |

Table No.2: Langmuir and freundlich isotherm parameter for the adsorption of nickel ion onto AHSNC

| S.No | Temp. (°C) | Langmuir Parameter | | Freundlich Parameter | |
|------|------------|--------------------|--------|----------------------|--------|
| | | Q _m | b | K _f | N |
| 1 | 30° | 134.29 | 0.2095 | 40.208 | 3.3753 |
| 2 | 40° | 142.48 | 0.2184 | 42.323 | 3.2985 |
| 3 | 50° | 220.28 | 0.1211 | 39.266 | 2.2366 |
| 4 | 60° | 157.84 | 0.2593 | 47.385 | 3.1704 |

Table No.3: Dimensionless separation factor (r₁) for the adsorption of nickel ion onto AHSNC

| S.No | (C _i) | Temperature °C | | | |
|------|-------------------|----------------|--------|--------|--------|
| | | 30°C | 40°C | 50°C | 60°C |
| 1 | 25 | 0.0872 | 0.0839 | 0.1418 | 0.0716 |
| 2 | 50 | 0.0456 | 0.0438 | 0.0763 | 0.0371 |
| 3 | 75 | 0.0308 | 0.0296 | 0.0522 | 0.0251 |
| 4 | 100 | 0.0233 | 0.0224 | 0.0397 | 0.0189 |
| 5 | 125 | 0.0187 | 0.0180 | 0.0320 | 0.0152 |

Table No.4: Thermodynamic parameter for the adsorption of nickel ion onto AHSNC

| S.No | C ₀ | ΔG° | | | | ΔH° | ΔS° |
|------|----------------|---------|---------|---------|---------|--------|--------|
| | | 30° C | 40° C | 50° C | 60° C | | |
| 1 | 25 | -6231.8 | -6831.7 | -7445.4 | -7958.2 | 11.338 | 58.037 |
| 2 | 50 | -3752.9 | -4269.1 | -5026.6 | -5718.1 | 16.394 | 66.306 |
| 3 | 75 | -2449.7 | -2966.2 | -3532.5 | -4116.3 | 14.407 | 55.575 |
| 4 | 100 | -1017.9 | -1386.4 | -4479.4 | -2266.1 | 20.443 | 71.481 |
| 5 | 125 | -2.4400 | -324.05 | -2667.1 | -1010.4 | 16.823 | 56.052 |

Table No.5: The kinetic parameters for the adsorption of nickel ion onto AHSNC

| 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 | 53.587 | 0.0017 | 0.9908 | 4.7954 | 18.725 | 0.1058 | 0.9818 | 0.2440 | 0.9868 | 1.5236 |
| | 40 | 53.538 | 0.0018 | 0.9929 | 5.1225 | 23.345 | 0.1108 | 0.9839 | 0.2285 | 0.9889 | 1.5545 |
| | 50 | 53.458 | 0.0019 | 0.9900 | 5.5156 | 29.627 | 0.1160 | 0.9810 | 0.2143 | 0.9860 | 1.5835 |
| | 60 | 53.866 | 0.0019 | 0.9911 | 5.5131 | 28.600 | 0.1140 | 0.9821 | 0.2169 | 0.9871 | 1.5819 |
| 50 | 30 | 96.056 | 0.0008 | 0.9902 | 7.7614 | 26.050 | 0.0563 | 0.9812 | 0.2637 | 0.9862 | 1.4340 |
| | 40 | 97.902 | 0.0009 | 0.9913 | 8.2189 | 30.271 | 0.0569 | 0.9823 | 0.2520 | 0.9873 | 1.4649 |
| | 50 | 99.942 | 0.0009 | 0.9904 | 9.2938 | 39.255 | 0.0581 | 0.9814 | 0.2357 | 0.9864 | 1.5103 |
| | 60 | 102.391 | 0.0009 | 0.9925 | 9.6777 | 40.652 | 0.0566 | 0.9835 | 0.2357 | 0.9885 | 1.5225 |
| 75 | 30 | 132.784 | 0.0005 | 0.9906 | 8.7648 | 23.950 | 0.0378 | 0.9816 | 0.3019 | 0.9866 | 1.3141 |
| | 40 | 135.829 | 0.0005 | 0.9899 | 10.0365 | 30.340 | 0.0384 | 0.9809 | 0.2808 | 0.9859 | 1.3711 |
| | 50 | 140.012 | 0.0006 | 0.9899 | 11.327 | 37.499 | 0.0384 | 0.9809 | 0.2651 | 0.9859 | 1.4194 |
| | 60 | 142.955 | 0.0005 | 0.9918 | 9.7153 | 41.905 | 0.0410 | 0.9828 | 0.2421 | 0.9878 | 1.4450 |
| 100 | 30 | 158.650 | 0.0003 | 0.9901 | 7.2750 | 15.790 | 0.0284 | 0.9811 | 0.3846 | 0.9861 | 1.0831 |
| | 40 | 162.374 | 0.0003 | 0.9912 | 8.2488 | 18.788 | 0.0285 | 0.9822 | 0.3595 | 0.9872 | 1.1489 |
| | 50 | 166.760 | 0.0003 | 0.9923 | 9.3921 | 22.646 | 0.0285 | 0.9833 | 0.3366 | 0.9883 | 1.2117 |
| | 60 | 170.105 | 0.0004 | 0.9914 | 11.208 | 29.592 | 0.0291 | 0.9824 | 0.3079 | 0.9874 | 1.2870 |
| 125 | 30 | 187.230 | 0.0002 | 0.9938 | 5.7168 | 11.519 | 0.0230 | 0.9848 | 0.4857 | 0.9898 | 0.8248 |
| | 40 | 191.277 | 0.0002 | 0.9939 | 6.4953 | 13.186 | 0.0227 | 0.9848 | 0.4581 | 0.9899 | 0.8985 |
| | 50 | 200.754 | 0.0002 | 0.9925 | 6.9513 | 14.223 | 0.0217 | 0.9835 | 0.4498 | 0.9885 | 0.9364 |
| | 60 | 199.056 | 0.0002 | 0.9932 | 8.4399 | 17.699 | 0.0222 | 0.9842 | 0.4070 | 0.9892 | 1.0365 |

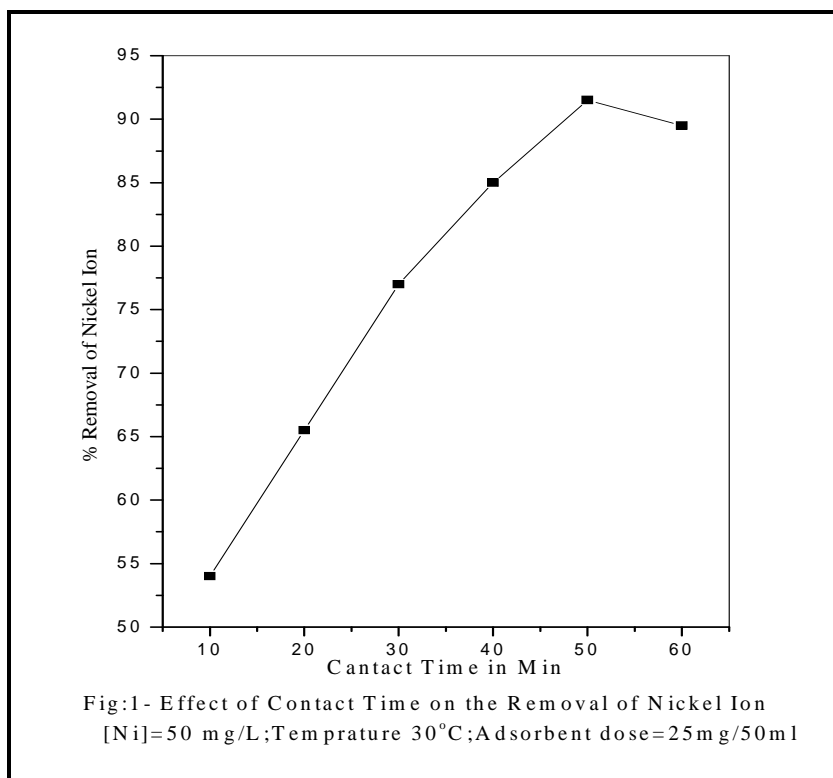


Figure No.1: Effect of Contact Time on the Removal of Nickel Ion

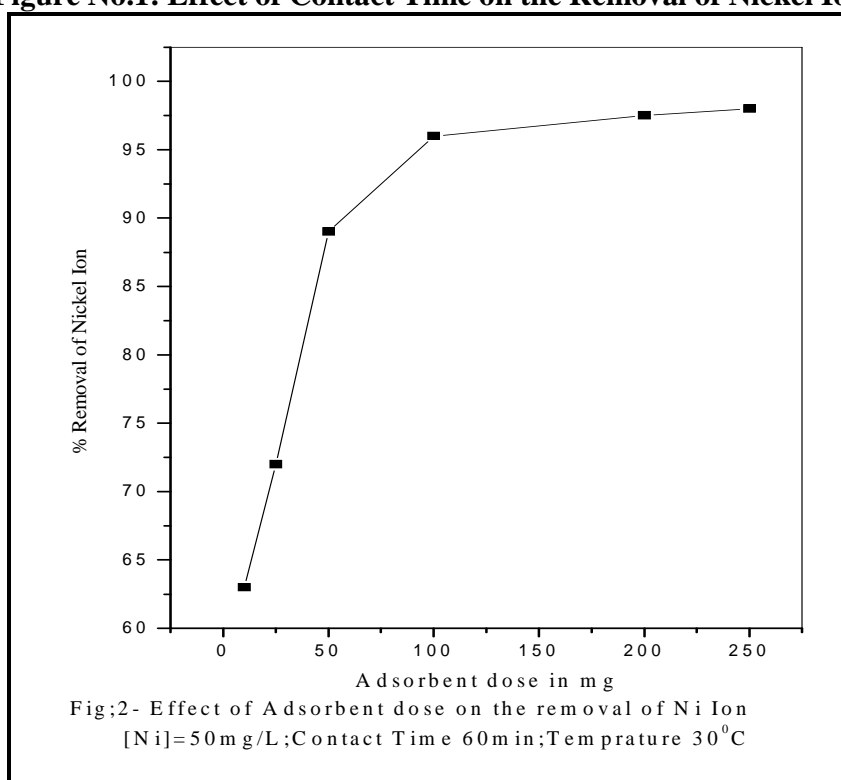


Figure No.2: Effect of Adsorbent dose on the Removal of Ni Ion

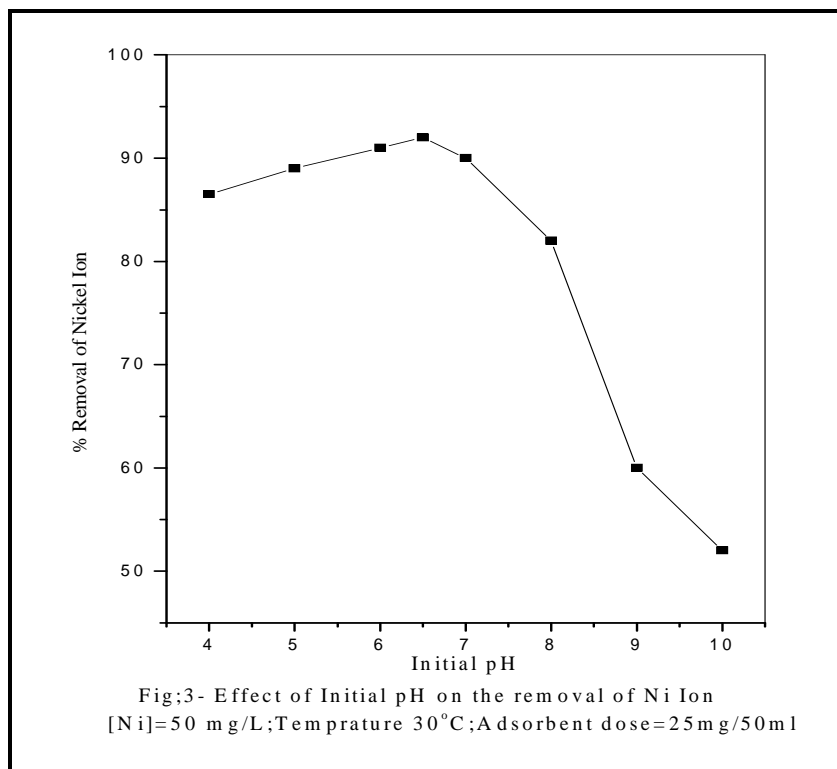


Figure No.3: Effect of Initial P^H on the Removal of Ni Ion

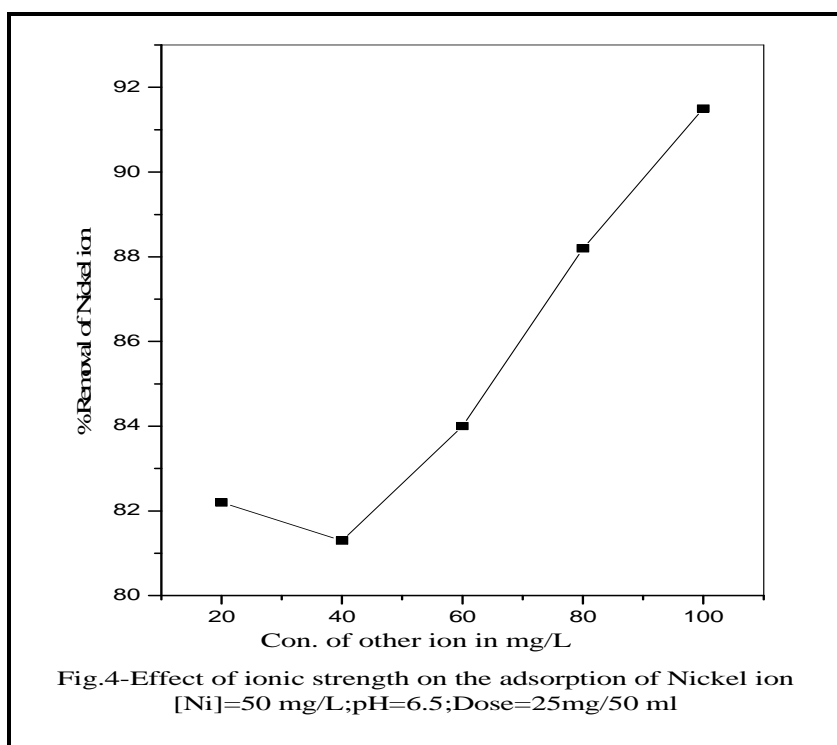


Figure No.4: Effect of ionic Strength on the adsorption of Nickel Ion

CONCLUSION

AHSNC prepared from acid Activated *Hibiscus Sabdariffa* Stem Nano Carbon was found 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 AHSNC is an effective one for the removal of metal ion. The equilibrium data conformed well to the Langmuir and Freundlich isotherm models. The temperature variation study showed that the metal 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 metal ion solution. The type I and II isotherm obtained, positive ΔH^0 value, pH dependent results and desorption of metal ion in mineral acid suggest that the adsorption of metal ion on AHSNC involves chemisorption as well as physisorption mechanism.

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CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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