# KINETIC, EQUILIBRIUM AND MECHANISTIC STUDIES OF NICKEL ADSORPTION ON ACTIVATED *CORCHORUS OLITORIUS*  L- LEAVES

S Subasri[1*], S Arivoli[2*], V Marimuthu[2] and N Mani[1]

[1*]Department of Chemistry, A.V.V.M Sri Pushpam College, Poondi, Thanjavur, Tamil Nadu, India.

[2*]Department of Chemistry, Thiru.Vi.Ka. Government Arts College Thiruvarur, Tamil Nadu, India.

*Authors for Correspondence: srisuba123@gmail.com, arivu3636@yahoo.com

**ABSTRACT-***An adsorbent prepared from Corchorus Olitorius L Leaves, 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 6.5 and at 30, 40, 50, 60 ± 0.5 $^0C$. 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 ACONC using 0.1M HCl.*

**Key words:  Activated *Corchorus Olitorius L*  Leaves Nano Carbon (ACONC), Nickel ion, Adsorption isotherm, Equilibrium, Thermodynamic parameters, Intra-particle diffusion.**

## 1. 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 poise 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 [5-7]. 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 ACONC as an adsorbent for the removal of Ni (II) ions from aqueous solution.

## 2. MATERIALS AND METHODS

### 2.1. Adsorbent

The *Corchorus Olitorius L* Leaves collected from nearby Thiruvarur district was Carbonized with concentrated Sulphuric Acid and washed with water and activated around 1200°C in a muffle furnace for 5 hrs then it was taken out, ground well to fine powder and

stored in a vacuum desiccators.



*Corchorus Olitorius L* - L. (Jew's Mallow)

### 2.2. 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).

### 2.3. Batch experiments

The effect of various parameters on the removal of nickel ion onto ACONC 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 ACONC till equilibrium was attained. Adsorption equilibrium isotherm is studied using 25 mg of ACONC 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:

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

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:

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

The effect of pH on the rate of adsorption was investigated using nickel concentration of 25 mg/L constant ACONC 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.

## 3. RESULTS AND DISCUSSION

### 3.1 Effect of agitation time and initial Nickel ion concentration:

The kinetics of adsorption of nickel ion by ACONC is shown in (fig. 1) with smooth and single plots indicating monolayer adsorption of metal ion on the ACONC. 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 ACONC concentration dependent.

### 3.2 Effect of ACONC mass:

The amount of nickel ion adsorption increased with the increase in ACONC dose and reached a maximum value after a particular dose (fig.2). Taken an initial metal ion concentration of 50 mg/L, complete metal ion removal was obtained at a maximum ACONC dose of 125 mg. The increase in the adsorption of metal ion with ACONC dose was due to the introduction of more binding sites for adsorption and the availability more surface area.

### 3.3 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 Fig. 3. This indicates the strong force of interaction between the metal ion and ACONC that either $H^+$ or $OH^-$ ions could influence the adsorption capacity. In other words, the adsorption of metal ion on ACONC does involve ion exchange mechanism that have been an influence on the metal ion adsorption while varying the pH. This observation is in line with the type I and II isotherm and positive $\triangle H^0$ value obtained, which indicates irreversible adsorption probably due to polar interactions.

### 3.4 Effect of other ions:

The effect of other ions like $Ca^{2+}$ 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 $30^0$C. The results had shown in the Fig. 4 reveals that low concentration of $Cl^-$ does not affect the percentage of adsorption of metal ion on ACONC, because the interaction of $Cl^-$ at available sites of adsorbent through competitive adsorption is not so effective. While the concentration of other ion $Ca^{2+}$ 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 $Ca^{2+}$ 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[4].

### 3.5 Effect of temperature:

The adsorption capacity of ACONC increased with increase in the temperature of the system from 30 to $60^0$ C. Thermodynamic parameters such as change in free energy ($\triangle G^0$), enthalpy ($\triangle H^0$) and entropy ($\triangle S^0$) were determined using the following equations.

$$K_0 = C_{solid}/C_{liquid} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$
$$\triangle G^0 = -RT \ln K_0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$
$$\log K_0 = \triangle S^0/(2.303R) - \triangle H^0/(2.303RT) \ldots (5)$$

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. $\triangle H^0$ and $\triangle S^0$ were obtained from the slope and intercept of van't Hoff plot and are presented in Table 4. Positive value of $\triangle H^0$ 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 temperature[5]. As chemisorptions is mainly an irreversible process, the low positive $\triangle H^0$ value depicts that Nickel ion is both physically as well as chemically adsorbed onto ACONC. This is in agreement with the type I and II isotherm obtained, which is close to irreversible adsorption[6].

The negative values of $\triangle G^0$ (Table 4) indicate that the metal ion adsorption is spontaneous. The positive value of $\triangle S^0$ shows increased randomness at the solid-solution interface during the adsorption of metal ion on ACONC. 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 ACONC at higher temperatures may be attributed the enlargement of pore size and/or activation of the adsorbent surface[7].

### 3.6 Adsorption Isotherms

### 3.6.1 Freundlich isotherm

The linear form of Freundlich isotherm[8] is represented by the equation log

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

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[9] (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 ACONC was found to be around 5.6 L/g. The $K_f$ values indicates that the saturation time for adsorption of metal ion is attained quickly slue to high affinity of activated ACONC towards adsorbate, while low $K_f$ values indicates low adsorption rate of metal ion [10,11]. 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 ACONC during metal ion adsorption are strong rate from the values $K_f$ and 1/n it is reveals that ACONC is more efficient for removal of Nickel ions.

### 3.6.2 Langmuir isotherm

The Langmuir isotherm model[12] 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

$$C_e/q_e = (1/Q_m b) + (C_e/Q_m) \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

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 $R_L$[13,14.] By the equation

$$R_L = (1/(1+bC_o)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8)$$

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 185 mg/L for ACONC.

### 3.7. Thermodynamic treatment of the adsorption process

Thermodynamic parameters associated with the adsorption, via standard free energy change ($\Delta G^0$), standard enthalpy change ($\Delta H^0$), and standard entropy change ($\Delta S^0$) were calculated as follows. The free energy of adsorption process considering the adsorption equilibrium constant, $K_0$ is given by the equation

$$\Delta G° = -RT \ln K_0 \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where $\Delta G°$ 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[15] The adsorption distribution coefficient may be expressed in terms of enthalpy change ($\Delta H°$) and entropy change ($\Delta S°$) as a function of temperature,

$$\ln K_0 = (\Delta H°/RT) + (\Delta S°/R) \ldots\ldots\ldots.(10)$$

Where $\Delta H°$ is the standard heat change of sorption (kJ/mol) and $\Delta S°$ is standard entropy change (kJ/mol). The value of $\Delta H°$ and $\Delta S°$ 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 $\Delta G°$ 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 $\Delta H°$ show the

endothermic nature of adsorption and it governs the possibility of physical adsorption[23]. 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 $\Delta H°$ value depicts metal ion is physisorbed onto adsorbent ACONC.

The negative $\Delta G°$ values table 4 were conform the spontaneous nature of adsorption Ni (II) ions onto ACONC**.** The lesser values of $\Delta G°$ suggest that adsorption is physical adsorption process. The positive value of $\Delta H°$ further confirms the endothermic nature of adsorption process. The positive values of $\Delta S°$ in table 4, showed increased randomness of the solid solution interface during the adsorption of nickel ion onto ACONC.

### 3.8. 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 ACONC 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 ($\square\square$) and the values are close or equal to 1. A relatively high correlation coefficient ($\square$) value indicates that the pseudo second-order model successfully describes the kinetics of Ni (II) ions adsorption.

### 3.8.1 The pseudo second- order equation

The pseudo second-order adsorption kinetic rate equation is expressed as $dq_t/d_t$

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

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:

$$1/(q_e - q_t) = 1/q_e + K_2t \dots\dots\dots (12)$$

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:

$$t/q_t=(1/k_2q_e^2)+ ((1/q_e)t \dots\dots\dots(13)$$

If the initial adsorption rate (h)(mg g$^{-1}$min$^{-1}$) is :

$$h=k_2q_e^2 \dots\dots\dots\dots\dots\dots\dots (14)$$

Equation (11) and (12) becomes,

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

The plot of ($t/q_t$) and t of Eq. (15) 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 ($\square$) 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 ACONC. This is shows that the sorption of Ni (II) ions on ACONC follows pseudo second order kinetic model.

### 3.8.2 The Elovich equation

The Elovich model equation is generally expressed as

$$dq_t / d_t = \alpha \exp(-\beta q_t) \quad \ldots\ldots..(16)$$

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

$$q_t = 1/\square \ln (\square\square) + 1/\square \ln t \quad \ldots\ldots\ldots\ldots (17)$$

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 $(1/\beta)$ and an intercept of $(1/\beta)\ln(\alpha\beta)$. The Elovich model parameters $\alpha$, $\beta$, and correlation coefficient ($\square$) are summarized in table 5. The experimental data such as the initial adsorption rate ($\square$) adsorption constant ($\beta$) and the correlation coefficient ($\gamma$) calculated from this model indicates that the initial adsorption ($\alpha$) 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 ACONC adsorbent.

### 3.8.3 The intra particle diffusion model

The intra-particle diffusion model used here refers to the theory proposed by Weber and Morris[16] based on the following equation for the rate constant: $q_t = k_{id} t^{(1/2)} + C \ldots\ldots\ldots\ldots(18)$

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 gives the value of the intra-particle diffusion coefficient ($k_{id}$) and correlation coefficient ($\square$) 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 ($\gamma$) 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.

### 3.9 Adsorption rate constant:

The rate constant of adsorption of nickel ion on ACONC was determined using the following rate expression given by Lagergren[17].

$$\log (Q_e - Q) = \log Q_e - (K_{id}/2.303) \, t \ldots..(19)$$

Where $Q_e$ is the amount of solute adsorbed per unit weight of the adsorbent (mg/g) at equilibrium time, Q is the amount adsorbed (mg/g) at time t (min) and $K_{id}$ is the rate constant (min$^{-1}$). Linear plots of $\log (Q_e - Q)$ versus t suggest the applicability of the Lagergren equation. The rate constants ($K_{id}$) were calculated from the slope and are presented in Table 5. $K_{id}$ was found to decrease with the increase in the initial concentration from 25 to 125 mg/L. An examination of the effect of metal ion concentration on the rate constant ($K_{id}$, $k_1$, $k_2$) helps to describe the mechanism of removal taking place. In cases of strict surface adsorption, a variation of rate should be proportional to the power of concentration. However, when pore diffusion limits the adsorption process, the relationship between initial solute concentration and the rate of reaction will not be linear[18]. It shows that a direct linear relationship does not exist in the adsorption of metal ion on ACONC. It seems likely that pore diffusion limits the overall rate of adsorption.

The contact-time experimental results can be used to study the rate-limiting step in the adsorption process, as shown by Weber and Morris[16]. Since the particles are vigorously agitated during the adsorption period, it is probably reasonable to assume that the rate is not limited by mass transfer from the bulk liquid to the particle external surface. One might then postulate that the rate-limiting step may be either film or intra-particle diffusion. As they act in series, the slower of the two will be the rate-determining step.

The rate constant for intra-particle diffusion is obtained using the equation

$$Q = K_p t^{1/2} \ldots\ldots\ldots (20)$$

Here, $K_p$ (mg/g/min) is the intra-particle diffusion rate constant. The nature of the plots suggests that the initial curved portion is attributed to the film or boundary layer diffusion effect and the subsequent linear portion to the intra-particle diffusion effect[19]. Also depicts that the intra-particle diffusion is the slow and the rate-determining step. $K_p$ values were obtained from the slope of the linear portions of the curves at each metal ion concentration (Table 5). The $K_p$ values increased with increase in the metal ion concentration, which reveals that the rate of adsorption is governed by the diffusion of adsorbed metal ion within the pores of the adsorbent. **3.10 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 ACONC through physisorption as well as by chemisorptions mechanisms[20]

## 4. CONCLUSION

ACONC prepared from *Corchorus Olitorius L* Leaves (Jew's Mallow) 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 ACONC 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. pH dependent results and desorption of metal ion in mineral acid suggest that the adsorption of metal ion on ACONC involves chemisorptions as well as physisorption mechanism.

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### TABLE: 1. EQUILIBRIUM PARAMETERS FOR THE ADSORPTION OF NICKEL ION ONTO ACONC

| $M_0$ | 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 | 1.61 | 1.67 | 1.23 | 1.083 | 46.77 | 46.65 | 47.52 | 47.83 | 93.54 | 93.30 | 95.04 | 95.66 |
| 50 | 4.27 | 4.62 | 4.096 | 3.273 | 91.45 | 90.75 | 91.80 | 93.45 | 91.45 | 90.75 | 91.80 | 93.45 |
| 75 | 12.38 | 11.78 | 10.75 | 9.547 | 125.2 | 126.4 | 128.49 | 130.90 | 83.48 | 84.29 | 85.66 | 87.27 |
| 100 | 25.68 | 24.76 | 10.75 | 27.87 | 148.6 | 150.46 | 178.49 | 144.24 | 74.31 | 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 ACONC

| Temp. ($^0C$) | Langmuir Parameter | | Freundlich Parameter | |
|---|---|---|---|---|
| | $Q_m$ | b | $K_f$ | n |
| $30°$ | 175.46 | 0.22 | 5.27 | 2.79 |
| $40°$ | 190.46 | 0.18 | 5.13 | 2.53 |
| $50°$ | 258.99 | 0.14 | 5.16 | 1.96 |
| $60°$ | 185.21 | 0.28 | 5.60 | 2.82 |

### TABLE: 3. DIMENSIONLESS SEPERATION FACTOR ($R_L$) FOR THE ADSORPTION OF NICKEL ION ONTO ACONC

| ($C_i$) | 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 ACONC

| $C_0$ | $\Delta G°$ | | | | $\Delta H°$ | $\Delta S°$ |
|---|---|---|---|---|---|---|
| | $30°C$ | $40°C$ | $50°C$ | $60°C$ | | |
| 25 | -6736.37 | -6857.63 | -7934.39 | -8567.66 | 13.15 | 65.03 |

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| 50 | - 5971.37 | - 5942.97 | - 6488.86 | - 7359.88 | 8.18 | 45.97 |
|----|-----------|-----------|-----------|-----------|------|-------|
| 75 | - 4082.32 | - 4371.87 | - 4801.07 | - 5329.62 | 8.52 | 41.40 |
| 100 | - 2676.69 | - 2891.17 | - 5683.66 | - 2631.38 | 6.23 | 30.52 |
| 125 | - 1464.13 | - 1966.71 | - 4028.83 | - 3065.51 | 19.76 | 70.42 |

## TABLE: 5. THE KINETIC PARAMETERS FOR THE ADSORPTION OF NICKEL ION ONTO ACONC

| $C_0$ | Temp $^\circ$C | Pseudo Second Order | | | | Elovich Model | | | Intra-particle Diffusion | | |
|-------|------|-------|-----|---|---|---|---|---|-------|---|---|
| | | $q_e$ | $k_2$ | □ | h | □ | □ | □ | $K_{id}$ | □ | C |
| 25 | 30 | 51.80 | $20\times10^{-3}$ | 0.994 | 7.72 | 56.482 | 0.12 | 0.998 | 1.64 | 0.992 | 0.18 |
| | 40 | 49.10 | $15\times10^{-3}$ | 0.995 | 13.89 | 2313.4 | 0.22 | 0.991 | 1.78 | 0.994 | 0.10 |
| | 50 | 50.34 | $14\times10^{-3}$ | 0.997 | 11.79 | 1622.7 | 0.21 | 0.993 | 1.78 | 0.991 | 0.107 |
| | 60 | 52.26 | $16\times10^{-3}$ | 0.999 | 7.86 | 91.607 | 0.14 | 0.992 | 1.67 | 0.992 | 0.16 |
| 50 | 30 | 101.0 | $22\times10^{-3}$ | 0.998 | 13.49 | 118.16 | 0.06 | 0.991 | 1.63 | 0.991 | 0.18 |
| | 40 | 96.65 | $18\times10^{-3}$ | 0.997 | 20.07 | 1907.0 | 0.105 | 0.992 | 1.74 | 0.992 | 0.11 |
| | 50 | 97.76 | $17\times10^{-3}$ | 0.998 | 21.23 | 1987.3 | 0.103 | 0.991 | 1.75 | 0.991 | 0.11 |
| | 60 | 98.93 | $16\times10^{-3}$ | 0.992 | 22.43 | 2909.2 | 0.106 | 0.993 | 1.77 | 0.993 | 0.10 |
| 75 | 30 | 134.41 | $22\times10^{-3}$ | 0.994 | 25.51 | 1173.8 | 0.068 | 0.997 | 1.68 | 0.991 | 0.12 |
| | 40 | 135.52 | $21\times10^{-3}$ | 0.991 | 26.83 | 1384.2 | 0.069 | 0.994 | 1.69 | 0.992 | 0.124 |
| | 50 | 137.35 | $21\times10^{-3}$ | 0.992 | 28.32 | 1854.2 | 0.07 | 0.994 | 1.71 | 0.991 | 0.120 |
| | 60 | 140.19 | $21\times10^{-3}$ | 0.991 | 28.76 | 1591.5 | 0.06 | 0.9953 | 1.71 | 0.991 | 0.123 |
| 100 | 30 | 161.52 | $25\times10^{-3}$ | 0.992 | 25.35 | 549.98 | 0.05 | 0.997 | 1.60 | 0.991 | 0.14 |
| | 40 | 162.42 | $23\times10^{-3}$ | 0.991 | 28.80 | 876.94 | 0.053 | 0.999 | 1.62 | 0.992 | 0.13 |
| | 50 | 167.05 | $11\times10^{-3}$ | 0.993 | 30.68 | 951.25 | 0.052 | 0.998 | 1.64 | 0.993 | 0.136 |
| | 60 | 150.16 | $12\times10^{-3}$ | 0.991 | 94.26 | 948023 | 0.10 | 0.997 | 1.74 | 0.992 | 0.06 |
| 125 | 30 | 177.52 | $25\times10^{-3}$ | 0.992 | 24.00 | 403.69 | 0.04 | 0.998 | 1.52 | 0.993 | 0.15 |
| | 40 | 184.46 | $23\times10^{-3}$ | 0.994 | 31.53 | 673.76 | 0.04 | 0.999 | 1.56 | 0.992 | 0.14 |
| | 50 | 193.10 | $15\times10^{-3}$ | 0.991 | 31.93 | 686.28 | 0.042 | 0.996 | 1.58 | 0.998 | 0.146 |
| | 60 | 203.66 | $24\times10^{-3}$ | 0.992 | 32.26 | 742.99 | 0.040 | 0.997 | 1.60 | 0.995 | 0.145 |
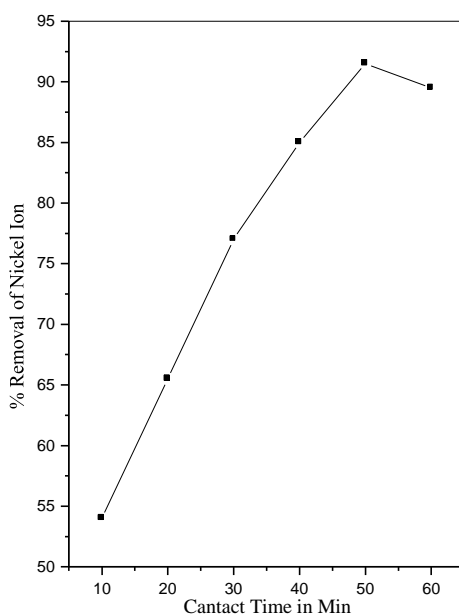
Fig:1- Effect of Contact Time on the Removal of Nickel Ion
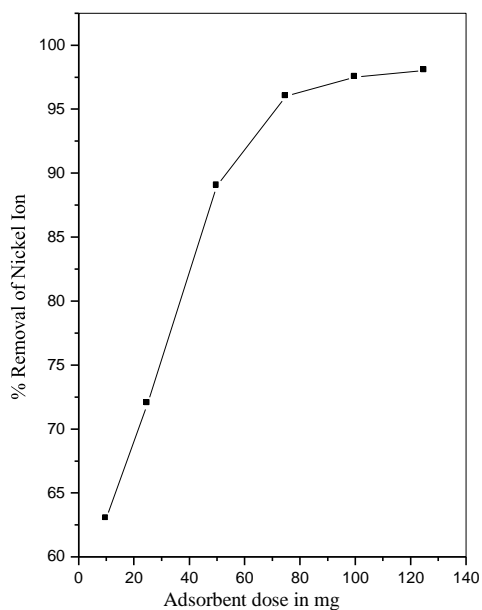[Ni]=50 mg/L;Temprature 30°C;Adsorbent dose=25mg/50ml



Fig;2- Effect of Adsorbent dose on the removal of Ni Ion
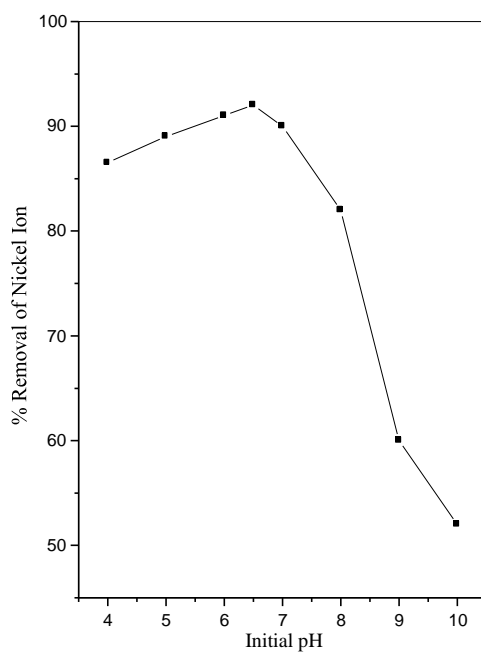[Ni]=50mg/L;Contact Time 60min;Temprature 30°C

Fig;3- Effect of Initial pH on the removal of Ni Ion
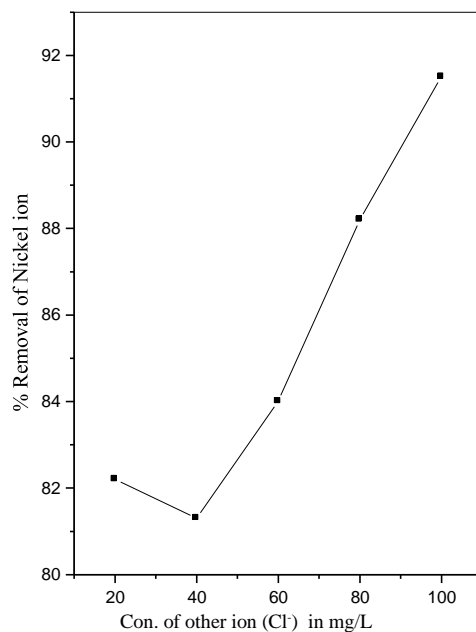[Ni]=50 mg/L;Temprature 30ºC;Adsorbent dose=25mg/50ml

Fig.4-Effect of ionic strength on the adsorption of Nickel ion
[ Ni]=50 mg/L;pH=6.5;Dose=25mg/50 ml

Dr. S. Arivoli has been working as an Associate Professor and Head, PG and Research Department of Chemistry, Thiru. Vi. Ka. Government Arts College, Thiruvarur, Tamil Nadu, India. He has been 115 Research publications in National and International Journals and presented 35 Research articles in National and International Seminars with 675 citations along with h-index 14 and i-10 index 19. He has completed one UGC Minor Research Project and one ongoing UGC Major Research Project.