



BIOSORPTIVE REMOVAL OF NI (II) IONS FROM AQUEOUS SOLUTIONS USING MAGNIFERAINDICA (MANGO LEAF) LEAF POWDER: ADSORPTION AND CHARACTERIZATION STUDIES

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ABSTRACT

The adsorption behavior of Ni(II) from aqueous solution onto agricultural waste such as mango leaf powder (MLP) was investigated as a function of parameters such as solution pH, initial Ni(II) concentration, contact time, agitation rate and particle size. The Langmuir and Freundlich models were applied to describe equilibrium isotherms using regression analysis. The monolayer adsorption capacity of MLP was found to be 16.62 mg/g. A good agreement (with $R^2 = 0.9966$) between the Langmuir and experimental data was investigated. The Freundlich constant (n) and separation factor (R_L) values suggest that the metal ions were favourably adsorbed onto biosorbent. The characterization studies were carried out using Fourier transform infrared spectrometer (FTIR). Pseudo first order and pseudo second order kinetic models were used to describe the kinetic data and the rate constants were evaluated. The result of kinetic study shows that the adsorption of Ni (II) could be described by pseudo second order equation. Complexation between metal ions and binding sites of the biosorbents was the main adsorption mechanism.

Key words: Biosorption; Divalent Nickel; Electroplating; Mango Leaf Powder

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1. INTRODUCTION

Nickel (II) is one of the toxic pollutant and it can be present in wastewater from electroplating, refining and welding industries. Excessive levels of nickel in water can affect biosystems and pose a threat to human beings. Toxicity of nickel causes adverse health effects such as cancer, skin allergy and lung fibrosis. The most important health problem due to nickel and its compounds are allergic dermatitis (nickel itch) and increases incidences of cancer (Bansal et al., 2009; Xu et al., 2008). The U.S Environmental Protection Agency (EPA) requires nickel not to exceed 0.015mg/L in drinking water. Hence removal of nickel (II) from water and waste water is highly essential (Hannachi et al., 2010).

Chemical precipitation, ion exchange, electro dialysis, solvent extraction, coagulation, evaporation and adsorption are among the most prevalent technologies for the removal of metal ions from aqueous solution, with adsorption being the most widely used method for removing contaminants from waste water (Fu et al., 2012; Maharishi et al., 2010). Sorption methods are considered flexible and easy to operate with much less sludge disposal problems (Bansal et al., 2009; Najim et al., 2009; Cheng et, 2012).

Various adsorbents were narrated in the literature for the removal of heavy metal ions such as sawdust (Bozic et al., 2009; Sewwandi et al., 2012), rice husk (Bansal et al., 2009), algal waste biomass (Bulgariu and Bulgariu 2012) and oil extracts (Rao and Khan 2009); however new adsorbents with local availability, high adsorption capacity as well as economic feasibility are still needed. The present research is to develop inexpensive and effective adsorbent from the source of agricultural waste, such as mango leaf powder (MLP), to replace the existing commercial materials (Kumar et al., 2009).

The studies of biosorption equilibrium as a whole are considered to be most appropriate approach for assessing biosorbent capacity. Interaction of one of the most toxic cation, Ni (II) with the Magnifera indica leaf powder and the dependence on various environmental factors are investigated in this work. The effects of various experimental parameters such as solution pH, initial Ni (II) ion concentration, contact time, agitation rate and particle size have been investigated. Adsorption isotherms and kinetics were also investigated.

2. MATERIALS AND METHODS

2.1. Adsorbent

Mango leaf was selected as adsorbent for removal of Nickel (II) ions in this study. Mature mango leaves were collected and each leaf was washed thoroughly under running tap water to remove dust and any adhering particles. The leaves were then dried in an oven at 80°C until it became crisp. The dried leaves were crushed and blended to powder form using a blender. The resulting material was sieved in the range of 106µm-1mm particle size. The mango leaves powder was boiled and washed for several times until it was free of colour and turbidity. Then the powder was dried in an oven at 80°C overnight and stored in an air tight plastic bag for further use to avoid contact with moisture in atmosphere.

2.2. Adsorbate

All the chemicals used were of analytical reagent (AR) grade. Stock solution of 1000mg/L of Ni (II) was prepared from nickel ammonium sulfate hexahydrate $(\text{NH}_4)_2 \text{Ni} (\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ and double distilled water. 6.7280 g of $(\text{NH}_4)_2 \text{Ni} (\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ was taken into a 1000ml volumetric flask, to this 5ml of 1% HNO_3 was added immediately. Then the contents were made upto 1000 ml with double distilled water. Desired test solutions of Nickel (II) ions were prepared using appropriate subsequent dilutions of stock solution. The range of concentration of Ni (II) ions

prepared from standard solution varies between 5 to 80mg/L. Before mixing the adsorbent, the pH of each test solution was adjusted to the required value with 0.1M HCl and 0.1M NaOH.

2.3. Analysis

The concentration of nickel in the solution before and after equilibrium were determined by Flame atomic absorption spectrometer. The pH of the solution was measured with the pH meter using a combined glass electrode. Fourier transform infrared spectrometer analysis was used to identify the different chemical functional groups which are responsible for the metal binding with the MLP. The analysis was carried out with spectral range 4000-400 cm^{-1} .

2.4. Adsorption Experiments

Batch adsorption experiments were carried out by varying solution pH, initial Ni (II) concentration, contact time, agitation rate and particle size. In each experimental study 0.1g of MLP was added to 20ml of aqueous solution taken in a 50ml conical flask and the reaction mixture was agitated at 150 rpm for 2 hours in a rotary shaker. The analysis of sample was done after filtering it using Whatmann 42 filter paper. The concentration of Ni (II) in the filtrates was analyzed using FAAS. The data obtained in these batch studies were used to calculate the percentage removal of nickel (II) ions by using following relationship:

$$\% \text{ Nickel (II) Removal} = \frac{C_o - C_e}{C_o} \times 100 \quad (1)$$

Where C_o and C_e are the initial and equilibrium concentration (mg/l) of nickel (II) ion concentrations respectively.

2.5. Adsorption Isotherm

A series of solutions containing different initial concentration of nickel (II) ions were prepared and the batch adsorption studies were done at room temperature to check the applicability of the Langmuir and Freundlich adsorption isotherms under the specified condition i.e. initial solution pH of 5, contact time of 120 minutes, MLP dose of 0.1 g and an initial nickel (II) ion concentration range of 10-80 mg/l. Analysis of nickel (II) ion content in various solutions were performed by FAAS. The data obtained in batch equilibrium studies were used to calculate the equilibrium nickel (II) ion adsorptive quantity by using the following relationship:

$$q_e = \frac{(C_o - C_e)V}{m} \quad (2)$$

Where q_e is the amount of N (II) adsorbed (mg/g), V is the volume of solution treated (L), C_o is the initial concentration of Ni (II) ions (mg/l), C_e is the equilibrium Ni (II) ion concentration (mg/l) and m is the mass of adsorbent (g)

2.6. Adsorption Kinetics

The kinetic measurements were conducted under static condition employing a glass vessel equipped with a rotary shaker. Thus, the adsorbent dose of 0.1 g of MLP was contacted with 20ml of nickel (II) ion solution of different known concentration (5, 10 and 20 mg/l). The concentration of Nickel (II) ion in the solution was determined at known time intervals. Analysis of nickel (II) ion content in various solutions were performed by FAAS. The amount of Ni (II) ions adsorbed at time t , q_t (mg/g) was calculated by the following expression:

$$q_t = \frac{(C_o - C_t)V}{m} \quad (3)$$

Where C_t is the concentration of nickel (II) ion solution at any time t (mg/l).

3. RESULTS AND DISCUSSION

3.1. Characterization of MLP

3.1.1. FTIR studies

The chemical functional groups such as carbonyl, hydroxyl, carboxylic, amino and nitro were identified as potential adsorption sites which are responsible for the binding of metallic ions to the adsorbent. Knowledge on surface functional groups would give an insight to the adsorption capability of the MLP. The FTIR spectrum of MLP is shown in figure 1. From the figure, it was found that the broad and intense peak at 3448 cm^{-1} was attributed to the stretching of O-H group due to inter and intra molecular hydrogen bonding (Rao et al., 2006). The peak observed at 2925 cm^{-1} was associated with the stretching vibrations of C-H bond (Feng et al., 2008; Zakaria et al., 2009). The peaks around 1654 cm^{-1} corresponded to the C=C stretching (Florido et al., 2009). The intense peak at 1057 cm^{-1} correspond to the C-O stretching (Nghah and Hanafiah, 2009). The FTIR spectrum of mango leaves loaded with Ni (II) ions was presented in figure 2. It was observed that the peaks at $3438, 2925, 1654$ and 1057 cm^{-1} before adsorption had shifted to $3435, 2924, 1638$ and 1065 cm^{-1} respectively. This was due to the participation of these functional groups in the binding of Ni (II) ions (Nghah and Hanafiah, 2009).

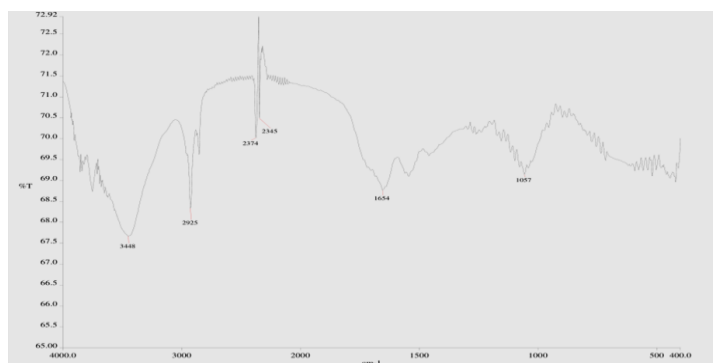


Figure 1 FTIR spectrum of mango leaves before adsorption

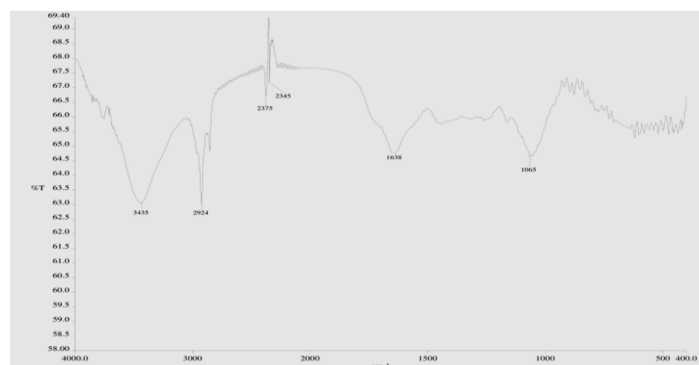


Figure 2 FTIR spectrum of mango leaves loaded with Ni (II) ions

3.2. Effect of solution pH on sorption efficiency

pH of aqueous solution is an important parameter governing the adsorption process as it not only affects the surface charge of adsorbents, but also influences the degree of ionization of metal ions in solution. The effect of solution pH on the adsorption of Ni (II) ions onto mango leaves was evaluated in the pH range of 2 to 10 and the result is shown in Figure 3. At pH 2, which had the highest acidity, Ni (II) ions uptake by mango leaves was the lowest, which was only 14.19%. The uptake increased rapidly to 88.77% at pH 3. At the range of pH 4 to 10, the

uptake became consistent, ranging between 94.14% and 96.75%. The maximum adsorption was found to be 96.75% for Ni(II) ions at pH 5.

The low adsorption of Ni(II) ions at pH 2 was due to high concentration and high mobility of H⁺ ions, which competed with Ni(II) ions for the adsorption sites, hindering the adsorption of Ni(II) ions by adsorbent. Protonated adsorption sites were incapable of binding Ni(II) ions due to electrostatic repulsion between positively charged Ni(II) ions and positive charged sites. Hence, only low percentage of Ni(II) ions were adsorbed. As the pH increased, there were fewer H⁺ ions present in the solution and consequently more negatively charged sites were made available and this facilitated greater Ni(II) ions uptake by electrostatic attraction.

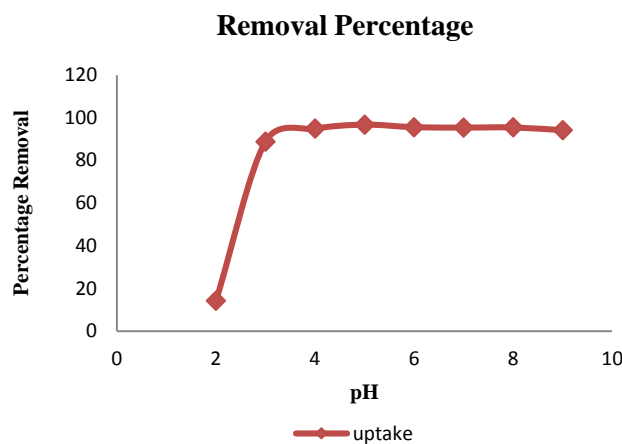


Figure 3 Effect of pH on removal of Ni(II) ions by mango leaves (0.1g of mango leaves in 20ml of 10 mg/l of Ni(II) solution at 150 rpm for 2 hours)

3.3. Effect of initial Ni(II) concentration and contact time on sorption efficiency

Figure 4 shows the dependence of the percentage uptake on the initial metal ions and contact time. The data obtained from the adsorption of Ni(II) ions onto mango leaves showed that the adsorption increased with increasing contact time. The plots in Figure 3 show a rapid uptake of Ni(II) ions during the first 5 minutes of agitation, after which the rate of sorption became slower, attaining equilibrium in 60 minutes. Further increase in contact time had negligible effect on the amount of ions adsorbed. The rapid metal uptake was 92.59%, 91.76% and 91.48% for the total sorption of Ni(II) solutions with initial concentration of 5 mg/L, 10 mg/L and 20 mg/L respectively.

The fast initial uptake occurred in the early stage of adsorption was due to the fact that most of the binding sites on mango leaves were free which allowed quick binding of Ni(II) ions on the biomass. As the binding sites became exhausted, the uptake rate slowed down due to competition for decreasing availability of active sites by metal ions. The sorption rate was rapid in the beginning of their experiment with more than 90% of adsorption took place in the first 10 minutes, and thereafter adsorption proceeded at slower rate, reaching equilibrium within 60 minutes.

Figure 4 showed that the uptake of Ni(II) ions decreased from 97.08% to 95.71% with the increment of initial Ni(II) ions concentration from 5 mg/L to 20 mg/L. At lower metal ions concentration, the percentage uptake was higher due to larger surface area of adsorbent being available for adsorption. When the concentration of Ni(II) ions became higher, the percentage removal decreased since the available sites for adsorption became less due to saturation of adsorption sites (Chakrawarti et al., 2010).

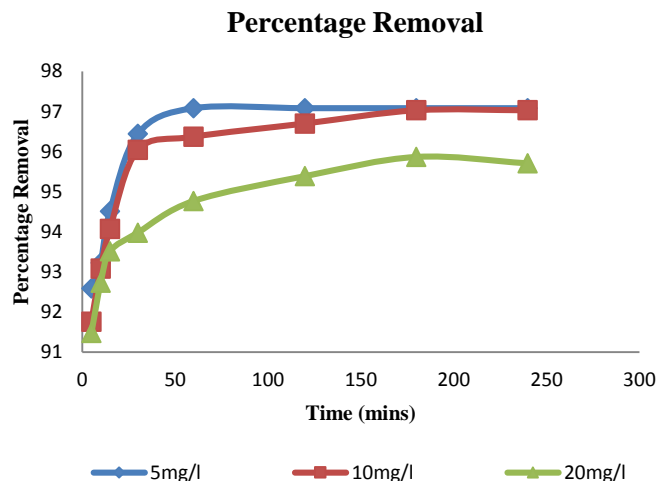


Figure 4 Effect of initial metal ion concentration and contact time on uptake of Ni(II) ions by mango leaves (0.1g of mango leaves in 20ml of 5mg/l, 10mg/l and 20mg/l of Ni(II) solution at 150 rpm for 2 hours)

3.4. Effect of agitation rate on sorption efficiency

Agitation is an important parameter in adsorption phenomena as it influences the distribution of the solute in the bulk solution and the formation of the external boundary film. It was observed that the percentage uptake increased when the agitation rate was increased. During the first 5 minutes, the uptake was 87.20%, 91.76% and 95.35% for the agitation rate of 50 rpm, 150 rpm and 200 rpm, respectively. This was because increasing the agitation rate reduced the boundary layer resistance to mass transfer surrounding the sorbent particles, resulting in higher sorption rate. In addition to that, higher agitation rate also spread the Ni(II) ions in the solution, providing better access to the active sites on adsorbent surface.

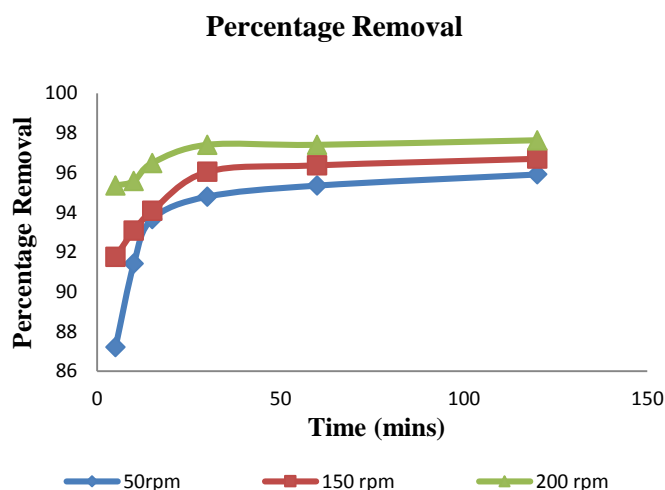


Figure 5 Effect of agitation rate on uptake of Ni (II) ions by mango leaves (0.1g of mango leaves in 20 ml of 10mg/l Ni(II) solution at 50, 150 and 200 rpm for 2 hours)

3.5. Effect of particle size on sorption efficiency

Particle size of adsorbents is an important factor affecting the adsorption capacity as it influences the surface area of adsorbent. The effect of particle size on the adsorption of Ni(II) ions was investigated in the range of 106 μm -1 mm. The results indicated that the metal ions uptake increased with decreasing particle size. As can be seen, for the first 5 minutes of contact, the uptake increased from 91.34% to 96.71% when the particle size decreased from 425 μm -1 mm to <106 μm .

The higher uptake with decreasing particle size was attributed to the fact that smaller particles had larger external surface area compared to larger particles, hence more binding sites were exposed on the surface and thus, leading to higher adsorption capacity since adsorption is a surface process. Apart from that, particles with smaller size also moved faster in the solution compared to larger particles, consequently, the adsorption rate was faster.

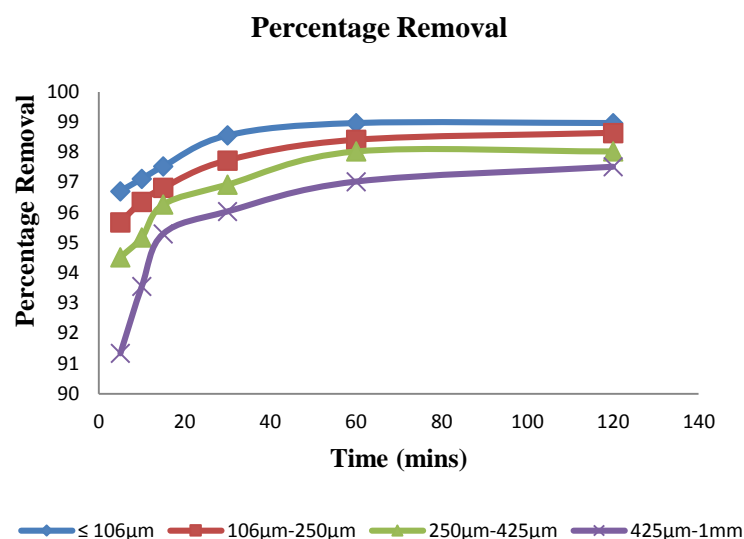


Figure 6 Effect of particle size on uptake of Ni(II) ions by mango leaves (0.1g of mango leaves in 20ml of 10 mg/l of Ni(II) solution at 150 rpm for 2 hours)

3.6. Adsorption Kinetics

In order to investigate the controlling mechanism such as chemical reaction and mass transfer, the pseudo first order and pseudo second order models were applied to model the kinetics of Nickel (II) adsorption onto MLP.

3.6.1. Pseudo first order kinetic model

The pseudo-first order kinetic model assumes that the rate of occupation of sorption sites is proportional to the number of unoccupied sites. The pseudo-first order equation was expressed in equation 4 (Lagergren, 1898):

$$\frac{dq}{dt} = k_1(q_e - q_t) \quad (4)$$

Where

q_e = Amount of Ni(II) ions adsorbed at equilibrium (mg/g)

q_t = Amount of Ni(II) ions adsorbed at time t (mg/g)

k_1 = pseudo first-order rate constant (min^{-1})

By applying the boundary conditions of $t = 0$ and $t = t$ and correspondingly $q_t = 0$ and $q_t = q_t$ and integrating equation 4 gave:

$$\log\left(\frac{q_e}{q_e - q_t}\right) = \frac{k_1 t}{2.303} \quad (5)$$

The resultant equation 5 in linear form was:

$$\log(q_e - q_t) = \log q_e - \frac{k_1 t}{2.303} \quad (6)$$

Figure 7 showed the linear plots of $\log(q_e - q_t)$ against t at initial Ni (II) ions concentration of 5 mg/L, 10 mg/L and 20 mg/L. The k_1 and q_e values were determined from the slope and intercept of the linear plots in Figure 6 respectively. Table 1 gave the values of k_1 and calculated values of q_e , as well as the R^2 values for the pseudo-first kinetic plots. As can be seen, although the R^2 values obtained from the plots were high. The theoretical values of q_e were far lower than the corresponding experimental data obtained. This suggested a poor fit between the kinetics data and the pseudo-first order model.

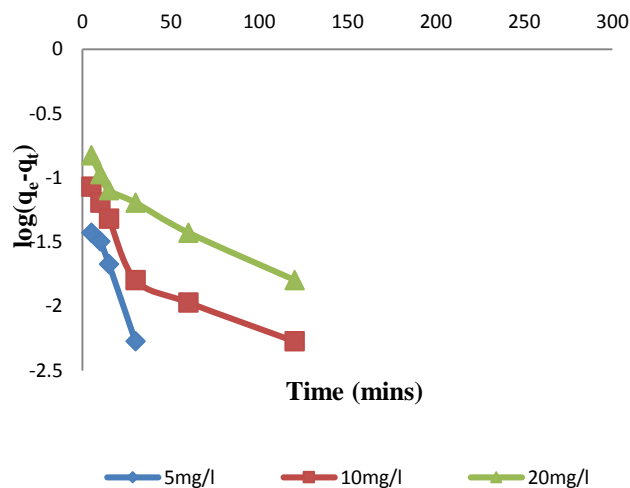


Figure 7 Pseudo first order plot for the sorption of Ni(II) ions onto mango leaves (0.1g of mangoleaves in 20 ml of 5mg/l, 10mg/l and 20mg/l of Ni(II) solution at 150 rpm for 2 hours)

3.6.2. Pseudo second order kinetic model

The pseudo second order is based on the assumption that the rate limiting step may be chemical sorption involving valence forces through sharing or exchange of electrons between heavy metal ions and adsorbent. The pseudo-second order kinetic rate equation was expressed as (Ho & McKay, 1998):

$$\frac{dq}{dt} = k_2(q_e - q_t)^2 \quad (7)$$

Where, k_2 is the pseudo second-order rate constant (g/mg min). Integrating equation 7 and applying the boundary conditions of $t = 0$ and $t = t$ and correspondingly $q_t = 0$ and $q_t = q_t$ gave:

$$\frac{1}{q_e - q_t} = \frac{1}{q_e} + k_2 t \quad (8)$$

Equation 8 was rearranged to obtain a linear form:

$$\frac{t}{q_t} = \frac{1}{h} + \frac{1}{q_e} t \quad (9)$$

Where, $h = k_2 q_e^2$ (mg/g min) is the initial sorption rate. Figure 8 showed the linear plots of t/q_t against t at initial Ni(II) ions concentration of 5 mg/L, 10 mg/L, and 20mg/L. The values of q_e and h were calculated from the slope and intercept of the plots respectively. . Table 1 gives

the values of k_2 and calculated values of q_e , as well as the R^2 values for the pseudo-second order plots. It was observed that all three linear plots with different initial concentration in Figure 8 showed R^2 values of 1. This indicated that the kinetics data fitted perfectly well with the pseudo-second order model. In addition to the high values of R^2 , the calculated q_e values also agreed well with the experimental data obtained from the pseudo-second order kinetics.

From Table 1, it was observed that the values of h increased from 2.870 mg/mg min to 7.391 mg/mg min when the initial concentration of Ni(II) ions increased from 5 mg/L to 20 mg/L. This was because the higher the initial concentration of Ni(II) ions, the higher the chances of collision with the binding sites of adsorbent and hence, leads to a higher initial sorption rate. Apart from that, it was obvious that the values of k_2 was higher than the corresponding values of k_1 . This was because the pseudo-second order kinetic model assumed that the sorption rate is proportional to the square of number of unoccupied sites (Gupta et al., 2008). The values of k_2 decreased from 4.283 g/mg min to 0.677 g/mg min with increasing initial Ni(II) ions concentration from 5 mg/L to 20 mg/L. This occurred because at higher concentration of metal ions, the competition for surface active sites was high and consequently lower sorption rates are obtained (Senthil Kumar et al., 2010).

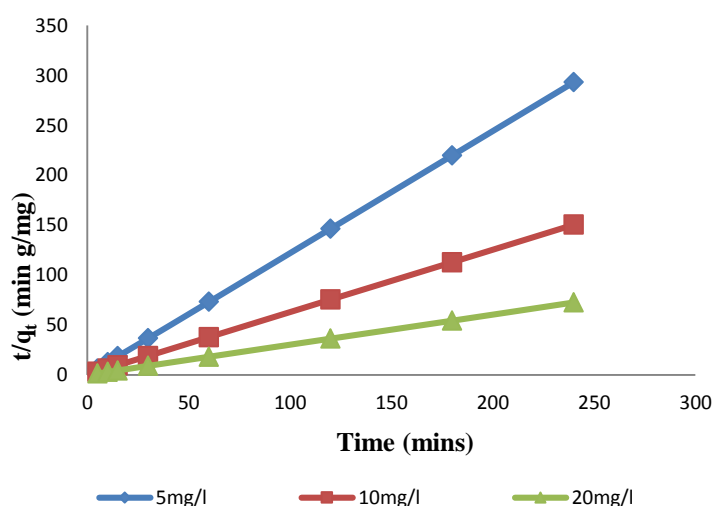


Figure 8 Pseudo second order plot for the sorption of Ni(II) ion onto mango leaves (0.1g of mango leaves in 20ml of 5mg/l,10mg/l and 20mg/l of Ni(II) ions at 150 rpm for 2 hours)

Table 1 Kinetic models and other statistical parameters at 30°C and at pH 5

Kinetic Model	Parameters	Concentration of Ni(II) solution		
		5mg/L	10mg/L	20mg/L
Pseudo first order equation	$k_1(\text{min}^{-1})$	0.081	0.023	0.018
	$q_e(\text{mg/g})$	0.81	1.59	3.30
	R^2	0.980	0.846	0.954
Pseudo second order equation	$k_2(\text{g/mg min})$	4.283	1.469	0.677
	$q_e(\text{mg/g})$	0.82	1.60	3.31
	$h(\text{mg/g min})$	2.870	3.371	7.391
	R^2	1	1	1

3.7. Adsorption isotherm models

The analysis of the adsorption isotherms data was done by fitting them into different isotherm models is an important step to find the suitable model that can be used for design process. It was found that adsorptive equilibrium time of Nickel (II) onto MLP was 60 minutes. The experimental data were applied to two parameter isotherm models; Langmuir and Freundlich.

3.7.1. Langmuir isotherm model

The Langmuir isotherm is based on assumptions that: (Langmuir, 1916)

Maximum adsorption corresponds to a saturated monolayer of adsorbate molecules on the adsorbent surface

The energy of adsorption is constant

There is no transmigration of adsorbate in the plane of the surface

The Langmuir model was expressed in equation 10-

$$q_e = \frac{q_m K_L C_e}{1 + K_L C_e} \quad (10)$$

Where,

C_e = Concentration of Ni(II) ions at equilibrium (mg/L)

q_e = Amount of Ni(II) ions adsorbed at equilibrium (mg/g)

K_L = Langmuir isotherm constant related to free energy of adsorption (L/mg)

q_m = Maximum adsorption capacity (mg/g)

Equation 10 could be linearized into:

$$\frac{C_e}{q_e} = \frac{1}{q_m K_L} + \frac{C_e}{q_m} \quad (11)$$

The plot of C_e/q_e against C_e gave a straight line with slope of $1/q_m$ and intercept of $1/q_m K_L$. Figure 9 shows the Langmuir plot of Ni(II) ions adsorption by mango leaves with a correlation coefficient of 0.9966, which was close to unity, thus indicating that the data confirm well to the Langmuir isotherm model. According to the Langmuir equation, the maximum uptake capacity for Ni (II) ions was 16.15 mg/g.

The Langmuir parameters were also used to predict the affinity of the leaf powder surfaces towards the Nickel (II) ions by using dimensionless separation factor, R_L , which is expressed in equation 12:

$$R_L = \frac{1}{1 + K_L C_o} \quad (12)$$

According to R_L , the isotherm shape may be interpreted as in Table 2 -

Table 2 Shape of isotherm

Value of R_L	Type of adsorption
$R_L > 1$	Unfavorable
$R_L = 1$	Linear
$0 < R_L < 1$	Favorable
$R_L = 0$	Irreversible

The R_L values obtained as in table were in the range of 0.024 and 0.167, which indicated a favourable isotherm shape for adsorption of Ni(II) ions onto mango leaves in the concentration range studied.

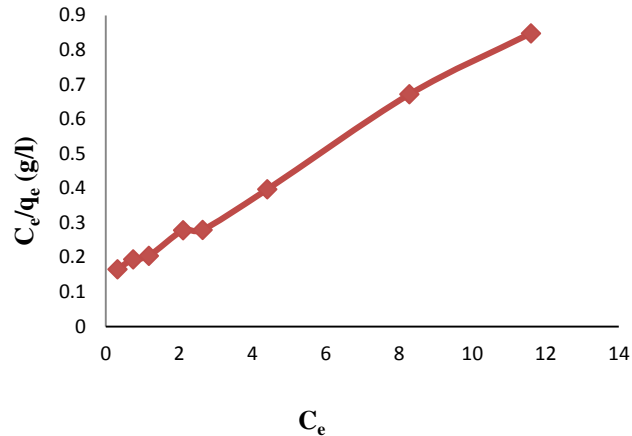


Figure 9 Langmuir isotherm plot for the sorption of Ni (II) ions onto mango leaves (0.1g of mango leaves in 20ml of 10,20,30,40,50,60,70 and 80mg/l of Ni (II) ion solution at 150 rpm for 2 hours)

3.7.2. Freundlich isotherm model

The Freundlich isotherm assumes a heterogeneous surface with a non-uniform distribution of heat of biosorption over the surface and a multilayer biosorption can be expressed (Freundlich, 1906). The Freundlich model was expressed as:

$$q_e = K_F c_e^n \quad (13)$$

Where, K_F = Freundlich indicative of relative adsorption capacity of adsorbent

n = Freundlich indicative of the intensity of adsorption

Equation 13 could be linearized by taking logarithms as followed:

$$\log q_e = \log K_F + \frac{1}{n} \log C_e \quad (14)$$

The plot of $\log q_e$ against $\log C_e$ gave a straight line with slope of $1/n$ and intercept of K_F . Figure 10 showed the Freundlich isotherm plot of Ni(II) ions adsorption onto mango leaves, with a correlation coefficient of 0.9322. The value of K_F and n obtained from the plot were 4.9854 and 2.1195 respectively. The n value of Freundlich equation could give an indication on the favorability of sorption. It is generally stated that values of n in the range of 2 to 10 is good, 1 to 2 as moderately difficult and less than 1 as poor sorption characteristic (Cheng et al.,2010).

The parameters and correlation coefficients obtained from the plots of Langmuir and Freundlich, models are listed in Table 3. By comparing the correlation coefficients obtained from the two isotherm models, the Langmuir isotherm gave the best correlation for the sorption process and this indicated that Ni(II) ions are adsorbed onto mango leaves surface in a monolayer pattern.

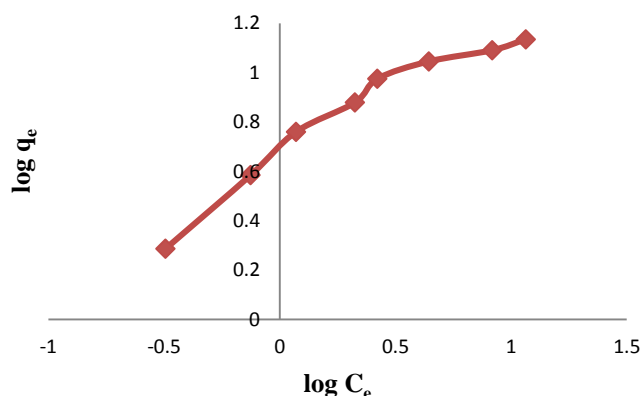


Figure 10 Freundlich isotherm plot for the sorption of Ni (II) ions onto mango leaves (0.1g of mango leaves in 20ml of 10,20,30,40,50,60,70 and 80mg/l of Ni (II) ion solution at 150 rpm for 2 hours)

Table 3 The value of parameters for two parameter isotherm models

Isotherm model	Parameters	R ²
Langmuir	q _m (mg/g)=16.15	0.9966
	k _l =0.50	
Freundlich	K _F (mg/g)=4.99	0.9322
	n=2.12	

Table 4 Comparison of maximum monolayer adsorption of Nickel (II) ions onto various adsorbents

Adsorbents	q _m (mg/g)	Reference
MPP	77.52	Garba et al., 2015
Chitosan	227.27	Patrice et al., 2016
Henna	76.92	Parisa et al., 2015
Rice Bran	153.60	Zafar et al., 2014
Bagasse Flyash	6.49	Mishra et al., 2006
Black Carrot residues	6.51	Yakut et al., 2008
MLP	16.15	This study

3.8. Conclusion

The present study shows that the mango leaf powder can be used as an adsorbent for the removal of Nickel (II) from aqueous solutions. The removal of Nickel (II) from aqueous solutions strongly depends on solution pH, initial Nickel (II) ion concentration, contact time, particle size and agitation rate. It was observed that the adsorption was pH dependent and the maximum adsorption of 96.75% occurred at pH of 5 for an initial Nickel (II) concentration of 10mg/L. With increase in initial Nickel (II) ion concentration adsorption was found to decrease owing to corresponding decrease in surface area of adsorbent. The adsorption was rapid and equilibrium was achieved within 60 minutes. The percentage removal of Nickel (II) ions increased with increase in agitation rate and decrease in particle size of adsorbent. The equilibrium data has been analyzed using Langmuir and Freundlich adsorption isotherms. The characteristic parameters for each isotherm and related correlation coefficients were determined. The Langmuir adsorption isotherm provided the best correlation for adsorption of Nickel (II) onto MLP. The maximum monolayer adsorption capacity of MLP was found to be 16.15mg/g. The adsorption kinetics of Nickel (II) onto MLP was studied by using pseudo first

order and pseudo second order equation. The pseudo second order equation provided the best correlation of the experimental data. Based on the results obtained from these studies, it can be concluded that since MLP is an easily, locally available, low cost adsorbent and has a high adsorption capacity, it may be treated as an alternative adsorbent for treatment of waste water containing Nickel (II) ions.

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