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Equilibrium, kinetic, spectral and thermodynamic analysis of nickel ion adsorption by *Spirulina platensis* in aqueous solutions

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ABSTRACT

The aqueous phase separation of toxic heavy metal ions by biosorption is an emerging field of interest from resource conservation and environmental remediation. The present study comprises of biosorption of nickel metal ions onto cyanobacteria *Spirulina platensis* in immobilized and non immobilized forms. Optimum pH, algal dose, metal ion concentration and time were found to be 7, 1g/100ml, 100 mg/l and 90 minutes respectively. All the three biosorbents of *S. platensis* obeyed both Langmuir and Freundlich isotherms. The kinetic studies showed that the biosorption rates could be better described by pseudo second order reaction. Pseudo-second-order model fits the experimental data with a very high correlation coefficient and it was greater than 0.9779 in all the cases. Negative values of Gibbs energy indicate spontaneous nature of the process in all the three cases. Fourier transform infra red (FTIR) analysis of *S. platensis* revealed the presence of carboxyl, hydroxyl, amino, amide and imine groups. By blocking of the groups of *S. platensis* the percent removal reduced further confirmed that the carboxylic group was the main group responsible for the biosorption of metal ions. *S. platensis* immobilized in calcium alginate matrix for the nickel ions was the best biosorbent for the five cycles when regenerated with 0.1 M EDTA and from first to fifth cycle percentage desorption was 91.4 to 88.4.

KEYWORDS: Nickel metal ions, *Spirulina platensis*, Biosorption, Fourier Transform Infra Red, Isotherms, Pseudo second order, Gibbs energy and Desorption.

INTRODUCTION

Metal discharged into water bodies are not biodegradable and do not undergo chemical or microbial transformation. Increasing awareness is rapidly growing over worldwide and one of the offshoots of it is treatment and removal of heavy metals from such effluents to permissible limit before discharging into natural streams and rivers. Several conventional technologies are used to reduce the heavy metals at large scale but these are generally expensive and not satisfactorily effective at low concentration of metal in waste water. The need for economical, effective and safe methods for removing heavy metals from the water has resulted in the search of biosorption. Recently, biomass such as seaweeds, molds, yeasts and bacteria were tested for metal biosorption which showed very encouraging results [1, 2].

Pollution by nickel usually comes from several industrial processes, such as electroplating, plastic manufacturing, nickel cadmium batteries, mining and metallurgical processes of the nickel compounds. Nickel is used as alloys for corrosion resistant equipments, cooking utensils, coinage, heating elements, gas turbines, jet engine, electroplating, paints, pigments and batteries. A commonly recognized local reaction of nickel is dermatitis [3]. Nickel is a potential carcinogen for lung and may cause skin allergies, lung fibrosis and cancer of respiratory tract in occupationally exposed populations[4] .The present work reports the isothermal, kinetic and spectral studies of Ni^{2+} ions by *Spirulina platensis* both non immobilized and immobilized in batch process.

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MATERIALS AND METHODS

Preparation of biosorbent

The cyanobacterium *S. platensis* was obtained from the National Facility from Blue Green Algae Division, IARI, and New Delhi, India. The axenic culture of the cyanobacteria *S. platensis* was grown in the Zaurrock's media. The composition of Zaurrock's media[5] was as follows NaCl: 1.00 g/l, NaNO3: 2.50 g/l, Na_2EDTA: 0.08 g/l, $CaCl_2$: 0.04 g/l, $FeSO_4$. $7H_2O$: 0.01g/l, K_2SO_4: 1.00g/l, $MgSO_4$: 0.2g/l, K_2HPO_4: 0.50g/l, $NaHCO_3$: 16.80g/l, A_5:1 ml and to this 1 l distill water was added. The composition of A5 micronutrient solution was H_3BO_3: 2.86 g/l, $MnCl_2$

.$2H_2O$: 1.81 g/l, $ZnSO_4$.$7H_2O$: 0.22 g/l, Na_2MoO_4.$2H_2O$: 0.39 g/l and $CuSO_4$.$5H_2O$: 0.07 g/l. The media pH was adjusted with 0.1 M NaOH at 9. For biosorbent preparation, exponentially grown cells (9 days) were harvested by centrifuging at 4000 rpm for 10 minutes. The cultures were maintained in the culture room illuminated with cool day light 3000 lux under 16 h light /8 h dark cycle at 24 ± 1°C. The biomass was then washed thrice with deionized water and dried at 60°C in oven for 24 hrs. The dried biomass was ground and sieved through screen of 200 µm pore size.

Chemicals and Reagents

All the chemicals used in the study were of analytical grade and supplied by Qualligenes Fine Chemicals (Bombay) India. The stock metal solution of Ni^{2+} ions were prepared by dissolving appropriate quantities of pure analytical grade metal salt in deionized water. The stock solution was further diluted with deionized water to obtain working solution of desirable concentrations.

Immobilization of Biomass

Immobilization of S. platensis was carried out according to the method known in literature[6]. For each immobilization process, 0.02 g of biomass was entrapped in 1 gm of matrix. The preparations were made as follows: **Calcium alginate beads:** 2% (w/v) sodium alginate was dissolved in hot distilled water with constant stirring. At room temperature, biosorbent was added under stirring condition for even dispersal. The slurry solution was dripped through the nozzle, drop wise into 0.05 M $CaCl_2$. As a result, spherical beads were formed immediately due to phase inversion process as the alginate was cross linked with Ca^{+2} ions. The beads (3.2 ± 0.1 mm) were moderately agitated in deionized water for 24 hrs at 4°C. The curing procedure hardened the beads and resulted in the formation of a micro porous structure. Finally, the beads were stored at 4°C in ultra pure double distilled water until for further use. **Agar beads:** The agar beads were prepared by dissolving agar in distilled water at 90°C. The biomass was added at room temperature and evenly dispersed by stirring. Spherical beads were obtained on drop wise addition of slurry into a hydrophobic liquid phase (Sun flower oil) over distilled water. The beads were collected and then washed with 0.001% Triton X 100 to eliminate the residual oil phase.

Batch Experiments

Standard stock solution of Ni^{2+} ions (1000 ± 2 mg/l) was diluted to the concentration to be investigated for metal biosorption. The pH of the metal solutions was adjusted with the help of 0.01M HCl or 0.01M NaOH as desired in the experiments. The batch experiments were carried out as function of pH, biosorbent dose, initial ion concentration of metal ions and time. All experiments were conducted in triplicate and mean values were used. The batch experiments were carried out in the 250ml conical flasks. All optimization experiments were performed with 100ml synthetic metal ion solution at temperature 30°C. The rotary shaker was used for the batch studies at 100 rpm. After attainment of equilibrium, solution was allowed to stand for 2 minutes, so as to settle down the absorbents. The solutions were filtered through whattman filter paper no. 1, and then filtrate was centrifuged at 5000 rpm for 10 minutes and then analyzed for nickel ions concentration by atomic absorption spectrophotometer[7].

Biosorption Kinetics

The kinetic study was carried out by conducting batch biosorption experiments using *S. platensis,* both non immobilized and immobilized in calcium alginate and agar matrix and was determined by taking 100 ml metal solution of known concentration (100 mg/l) to cyanobacterial biosorbents (1gm) in 250 ml shaking flask.

Thermodynamics Studies

Thermodynamic considerations of a biosorption process are necessary to conclude whether the process is spontaneous or not. The Gibbs free energy change is an indication of spontaneity of a chemical reaction and therefore is an important criterion for feasibility of the process.

Desorption Cycles

For reusability, immobilized biomass after biosorption treated with 0.1M EDTA,100 ml as elutant in desorption cycles in 250 ml flask shaken on orbital shaker for 30 mins at 100 rpm for achieving sorption desorption equilibrium. The initial and final concentration of the solution was recorded for each cycle.

Fourier Transmission Infra Red spectroscopy

Infrared characterization of *S. platensis* was performed. The FTIR spectrum of biosorbent was obtained from sophisticated analytical instrumentation facility, Punjab University, Chandigarh, India. Infrared spectra were recorded on spectrophotometer (Nicolt Model 6000) equipped with a liquid nitrogen cool detector.

Modification of Group of Cyanobacteria

The experiments were conducted to block the carboxylic, hydroxyl, phosphate and amine groups of the cyanobacteria one by one. Carboxylic group was blocked using a method described by Gardea-Torresdey et al. (1990), amine group, phosphate group and hydroxyl group blocked according to Kapoor and Virarghavan (1997), Tobin et al. (1990) and Teskova et al. (2006) respectively. After blocking the groups the biosorption experiments were conducted at optimized conditions for nickel ions biosorption.

RESULTS AND DISCUSSION

The maximum percentage removal was observed at pH 7 for *S. platensis*, *S. platensis* embedded in calcium alginate and *S. platensis*

embedded in agar matrix was 87.2, 88.6 and 84.6% respectively (Table1). The Ni^{+2} ions uptake pattern by non immobilized and immobilized forms of *S. platensis* biosorbents showed similar pattern of regular increase in % removal with increasing pH in the range of 2 to 7 reaching maximum at pH 7.0 and then decreased. At lower pH, the higher concentration of the hydrogen ion, effectively leads to fewer ligands being available for the binding of metal ions. The surface ligands are closely associated with the hydronium ions ($H_3O^{+)}$ and as a result of the repulsive force, restricted the approach of metal cations [12]. Increased pH (i.e. fewer H^+ ions) results in more ligands being available for metal ion binding and hence biosorption is enhanced. An increase in pH means a lower quantity of protons, which caused a decrease in the competition between proton and heavy metal ion [13]. During the optimization experiments of adsorbent dose it was found that from 0.2 gm to 1gm biosorbent dose there was sharp increase in removal and from 1 to 2gm/100ml the percentage removal rate was increasing but slow. It was found that the equilibrium was established at 1gm/100ml so 1 gm/100ml sorbent dose was taken as the optimum dose for the experiments conducted during biosorption process. At the lower adsorbent dose, number of metal ions is relatively higher as compared to availability of adsorption sites. With increase in biosorbent dose, more and more surface becomes available for the solute to adsorb and increase the rate of adsorption. As biosorbent dose was further increased after the optimum value, there was less increase in biosorption capacity of sorbents and as a result, unit adsorption decreased significantly with the increase in mass of biosorbent per unit volume[14]. The reason may be attributed to the fact that the high biomass concentration could make a screen effect on the dense outer layer protecting the binding sites from the metal and there by lowering the specific metal uptake at higher biomass loading [15].

Table 1 Percentage removal of Nickel ions by *S. platensis* (immobilized and non immobilized) at optimized conditions

Optimized parameters	*S. platensis*	*S. platensis* in Calcium alginate	*S. platensis* in agar
pH 7	87.2	88.6	84.6
Algal dose 1gm/l	86.4	89.4	88.6
Metal ion conc.100mg/l	87.7	87.9	87
Time 90 mins.	88	80.1	83

The rate of adsorption is a function of initial metal ion concentration, which makes it an important factor to be considered for effective biosorption. Up to the concentration of 100mg/l, these sorbents were found to be effective in metal ion removal. Biosorption capacity was decreased drastically with increasing initial concentration from 100 to 400 mg/l metal ions. According to Bai and Abraham (2001) percent adsorption was decreased with increase in the metal ion concentration may be due to saturation of all the binding sites with metal ions

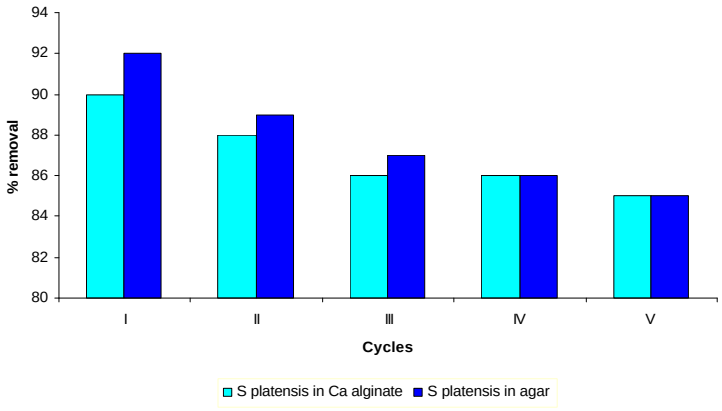

Figure 1. Desorption cycles of immobilized *Spirulina platensis*

and establishment of equilibrium between adsorbate and biosorbent. It was essential to evaluate the role of contact time required to reach equilibrium, as a prior stage to the kinetic study of biosorption of heavy metals, since in most cases, it helps to determine the rate of the process. In this regard, the role of contact time on biosorption of nickel metal ions by free and immobilized cyanobacterial was studied. The experiments were conducted at 100 mg/l metal ion solution at optimum pH 7 for nickel with 1gm/100ml biosorbent dose. The contact time was varied from 15 to 120 minutes at the interval of 15 minutes at temperature 30°C at 100 rpm. In all the studied sorbents metal ion uptake was increased rapidly up to 60 minutes and slight increase in biosorption process was observed from 60 to 90 minutes and may be attributed to the fact that a tendency to approach equilibrium concentration is reached after a certain time period of contact. So, equilibrium time of 90 minutes was chosen for further experiments. Adsorption got slower down in later stages of time period because initially a large number of vacant surface sites were available for adsorption and after some time, the remaining vacant surface sites were difficult to occupy due to repulsive forces between the solute molecules of the solid and bulk phase[16, 17].

Further experimentation was done using optimum pH, algal dose, metal ion concentration and time which were found to be 7, 1g/100ml, 100 mg/l and 90 minutes respectively at temperatures 30°C and at 100 rpm. Percentage metal ion removal is shown in the table1 for all the four optimized conditions.

Experimental data for nickel ions adsorption by adsorbents were applied to two kinetic models first-order and second-order. First order equation is generally expressed as,

$$dq_t / dt = k_{1ad}(q_e - q_t) \qquad (I)$$

Where q_e is the sorption capacity at equilibrium (mg/gm), q_t is the sorption capacity (mg/gm) at time t and k_{1ad} is the rate of pseudo first order of reaction (1/min). After integration and applying the bound-

ary condition, $q_t = 0 - q_t$ at t = 0 - t, the integrated form of equation becomes;

$$\log (q - q_t) = \log q - k_{1ad}\, t / 2.303 \qquad \text{(II)}$$

Pseudo first order rate constant k_{1ad} can be obtained from the slope of plot between log (q - q_t) against time t.The pseudo first order rate constant K_{1ad} values were calculated and their corresponding linear regression correlation coefficient r_1^2 were also calculated as shown in table2.This pseudo first order model reduces to:

$$t / q_t = 1 / k_{2ad}\, q_e^2 + 1(t) / q_e \qquad \text{(III)}$$

k_{2ad} = pseudo-second order rate constant (gm mg^{-1} min^{-1})

If we apply pseudo-second order kinetics, the plot of t/q_t against t of equation (III) should give a linear relationship, from which q and k can be determined from the slope and intercept of the plot. The pseudo-second-order rate constant $k_2$ad, the corresponding linear regression correlation coefficient values r_2^2 are given in table 2. The best equation representing sorption of nickel ions onto all biosorbents during agitation was based on a pseudo-second-order process. At all initial nickel ion concentrations, the linear regression correlation coefficient r_2^2 values were higher than r_1^2. The higher r_2^2 values confirm that the adsorption data are well represented by pseudo-second-order kinetics. The pseudo second order model assumes that metal ion sorbed on to two active sites. The nickel metal ions are divalent ions and when divalent ions sorbed on the biosorbent surface these were attached at two sites of the biosorbent[18]. The pseudo-second model is based on the assumption that the process of sorption of a metal by an adsorbent may involve a chemisorption which can be the rate controlling step because it involves two species, the metal ion and the biomass[19].

Table 2. Kinetics constant of Nickel ions to *S. platensis* (immobilized and non immobilized)

Kinetic constant	*S. platensis*	*S. platensis* in Calcium alginate	*S. platensis* in agar
Pseudo first order			
K_{1ad}	0.043	0.049	0.048
r_1^2	0.7981	0.8236	0.8473
Pseudo second order			
K_{2ad}	0.0966	0.0964	0.1
r_2^2	0.9874	0.9799	0.9779

The nickel uptake of non immobilized and immobilized *S. platensis* was evaluated using Langmuir and Freundlich adsorption isotherms. The concentration of free metal on adsorbed per unit non immobilized and immobilized cyanobacterial (mg metal/gm dry biosorbent) was determined using following expression:

$$q = V (C_o - C_{eq}) / M \qquad \text{(IV)}$$

q is the metal uptake (mg/gm) of the algal biosorbent, V is the metal ion solution in liter, C_o is the initial metal ion concentration (mg/l), C_{eq} is the metal ion concentration at equilibrium (mg/l), M is the mass of algal biosorbent. According to Freundlich model of adsorption

$$q_e = K_f\, C_e\, 1/n \qquad \text{(V)}$$

K_f is the Freundlich constant for adsorption capacity, n is the Freundlich constant for adsorption intensity, C_e is the equilibrium concentration (mg/l). To simplify the derivation of K_f and n, equation (V) can be lineraized in the logarithmic form

$$\log q_e = \log K_f + 1/n \log C_e \qquad \text{(VI)}$$

Langmuir equation valid for monolayer sorption on surface with a finite number of sites is given in equation.

$$q_e = Q_o\, b\, C_e / 1 + b\, C_e \qquad \text{(VII)}$$

Q_o is the Langmuir constant which is measure of adsorption capacity (mg/gm), b is the Langmuir constant which is measure of adsorption energy (l/mg) and C_e is the equilibrium concentration (mg/l).

$1/q_e$ versus $1/C_e$ gives the straight line with slope $1/Q_o$ b and 1/b intercept. Langmuir and Freundlich isotherms were in good agreement with experimental results for all the three biosorbents. Parameters of Langmuir and Freundlich isotherms are shown in table 3**.** The maximum adsorption capacity was found to be 42.0, 40.2 and 48.2 mg/g for *S. platensis*, *S. platensis* embedded in calcium alginate and *S. platensis* embedded in agar.

Table 3. Isotherm constant of Nickel ions to *S. platensis* (immobilized and non immobilized)

Isotherm constant	*S. platensis*	*S. platensis* in Calcium alginate	*S. platensis* in agar
Langmuir constant			
Q_0 (mg/gm)	42	40.2	48.2
b	0.087	0.01	0.003
r^2	0.9091	0.9261	0.9231
Freundlich constant			
K_f (mg/gm)	0.691	0.418	0.518
n	1.106	0.824	0.885
r^2	0.9203	0.9261	0.914

The isotherms describe the equilibrium for the specific condition, represents the maximum achievable adsorption capacity for a given system[20]. As Langmuir isotherm fitted well for all the three biosorbents, it indicated that metal ions are chemically adsorbed at a fixed number

of well defined sites. All sorption sites are uniform (constant heat of adsorption).Each site can hold any one ion and all sites are energetically equivalent. There is no interaction between metal ions. So during the biosorption process the chemically unsaturated surface atoms (total number of binding sites) do not extend further than the diameter of one sorbed molecule and therefore monolayer absorption occurs on the surface of the biosorbents[21]. Qo is monolayer saturation capacity (mg/gm), of cyanobacterial biosorbents. The results demonstrated that the all biosorbents were good in terms of Qo is monolayer saturation capacity (mg/gm), Lower the value of b equilibrium constant (measure of adsorption intensity) higher the affinity of the biomass[12]. In all the studied sorbents cases for nickel ions the value of b is lower indicated the affinity of metal ions towards the biosorbents.

A better fit Freundlich model signifies that there may be heterogeneous surface and surface energy dose not remain constant during the process of adsorption but varies with the surface coverage as the adsorption progresses. Results reveals that Freundlich fitted well to the *Spirulina platensis*, *Spirulina platensis* immobilized in calcium alginate and agar matrix. The high value of K_f indicated a high adsorption capacity which is adsorbate adsorbed per unit weight of biosorbent. 1/n is the measure of adsorption intensity and according to Saravanan et al. (2000) higher the n value, higher is the intensity of adsorption *Spirulina platensis* showed more values as compared to other biosorbents. The adsorptive behaviour of all the three biosorbents follows not only Langmuir adsorption assumption but also Freundlich adsorption isotherm i.e. multilayer formation on surface of the biosorbent with an exponential distribution of site energy. The equilibrium constant K_c for the feasibility of the process was calculated using equation:

$$\mathbf{Kc = Cad/Ce} \qquad \mathbf{(VIII)}$$

Where Cad is the concentration of metal ion on the adsorbent at equilibrium and C_e is the amount remaining in the solution at equilibrium (mg/l). The values of G°, the Gibbs free energy for the adsorption were calculated using equation (VIII)

$$\mathbf{G^\circ = -RT\ lnK_a} \qquad \mathbf{(IX)}$$

Where G° is standard Gibbs free energy change, R is the universal gas constant, T is absolute temperature (K). The Gibbs free energy was obtained for each system and was found to be negative (Table 4). Thermodynamic parameter shows the feasibility and spontaneity of a reaction. The biosorption experiment can be regarded as heterogeneous and reversible process at equilibrium. The negative value of Gibbs free energy in all the cases indicates the feasibility and spontaneous nature of adsorption. The studies further confirm that the process is exothermic[20] .

Table 4 Free Energy values for biosorption of Nickel ions by *S. platensis* (immobilized and non immobilized)

Species	Gibb's free energy value KJ/mole
S. platensis	-4.98
S. platensis in Ca alginate	-4.21
S. platensis in agar	-4.39

Desorption of adsorbed Ni^{+2} ions from the immobilized *S. platensis* were studied using 0.1M EDTA. In order to asses the reusability of the biosorbent, adsorption-desorption cycles were repeated five times and the percentage removal has shown little decrease in percentage removal from first to fifth cycle for all the studied immobilized cyanobacterial biosorbents. It was cleared from the results that from first cycle to fifth cycle the percentage removal of nickel ions desorption for 0.1 M EDTA was from 91.4 to 88.7 percent for *S. platensis* embedded in calcium alginate and 91.4 to 88.8 percent *S. platensis* embedded in agar. Desorption offers the option of metal ion recovery and concentration. 0.1M EDTA effectively removed nickel for both immobilized cyanobacterial biosorbents throughout the five cycles slight loss in the biosorption capacity because ethylenediamine tetracarboxylic acid (EDTA), a hexa-dentate compound with two nitrogen and four oxygen donor atoms. EDTA possesses lone pairs of electrons which are available to form the complex. The capacity of repeated use for free *S. platensis* was poor in terms of separation therefore it was not used for desorption cycles. Therefore, the possibility of using the studied immobilized cyanobacteria in sorption-desorption cycles is a great advantage for its possible practical uses[22]. FTIR Spectroscopy has been frequently used to detect frequency changes in functional groups present on the biosorbent surface. The different wavelength using IR spectra obtained at 4000-600 cm^{-1} range (Figure 2). The native biomass exhibited characteristic absorption at 3500-3000 cm^{-1} to 1200-900 cm^{-1}. The infrared spectrum showed several peaks reflecting complex nature of *Spirulina platensis*. A broad band in the region 3900-3000 cm^{-1} was found for the cyanobacteria. Bands at 3855, 3357 cm^{-1} is due to hydroxyl groups that are hydrogen bonded to various degrees together with the N-H, stretching of the secondary amide (RNHCOCH3) group. The bands at 3296 cm^{-1} (broad and sharp) were assigned to bonded –OH, -NH stretching. Band at 2923 cm^{-1} (sharp) can be assigned to asymmetric stretch of aliphatic chains. Sharp peak observed at 2361.5 cm^{-1} was attributed to nitrile (-CN). Peaks observed at 1652.9, 1541.1, 1454, 1240, 1034.2, 668.3 cm^{-1} were attributed to asymmetric C=O stretching from ketone and aldehyde, amide, symmetric C=O, C-O stretch of –COOH and C-O stretch of an alcohol (-OH) respectively. Strong absorption of the carbonyl region at 1653 and 1542 cm^{-1} can be assigned to amide I band (C-O) stretching of the amide bond in poly-N acetyl glucosamine and the protein peptide bond present in the biomass. The absorption under 1241.3 cm^{-1} characterizes phosphate carrying components, oligosac-

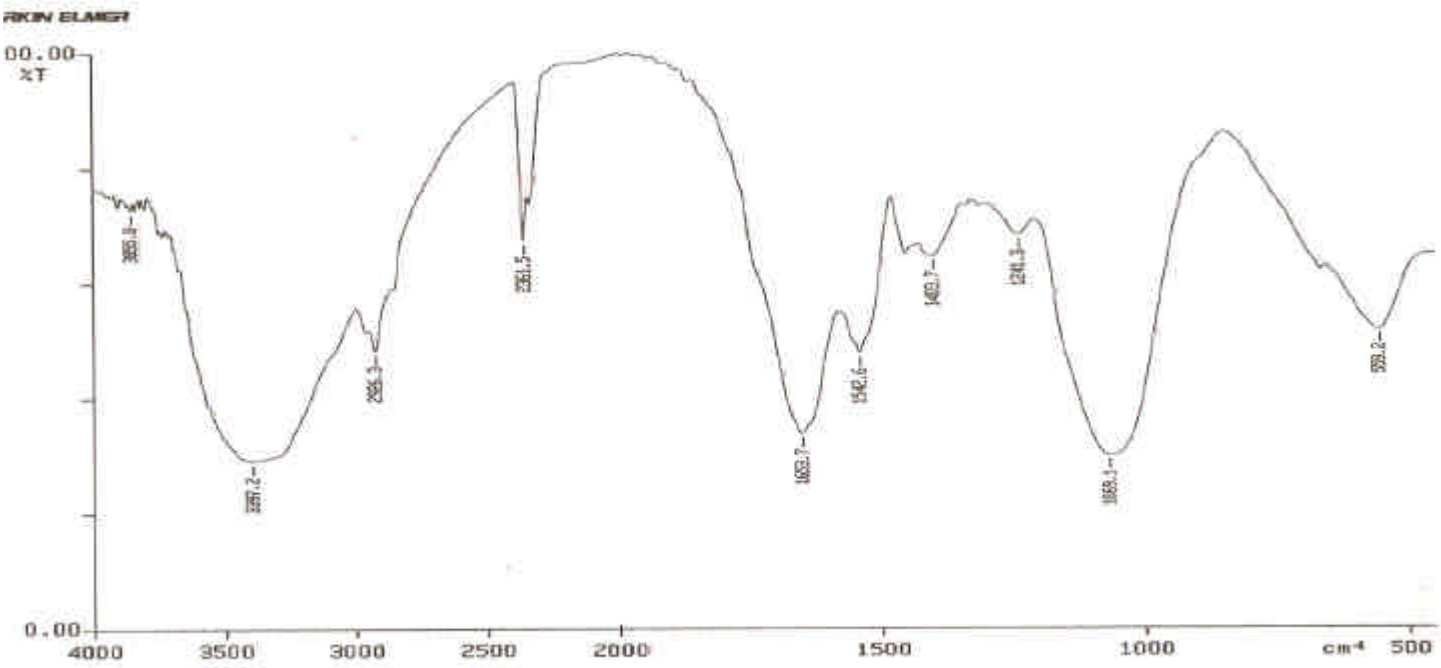

Figure 2 FTIR spectra of *Spirulina platensis*

charide and polysaccharides of cell wall. FTIR study confirmed that in *Spirulina platensis* carboxylic, hydroxyl, amino, amide and imine groups responsible for the process of biosorption of nickel ions. It can be seen that the infrared spectra indicated the presence of ionisable functional groups; their ionization leaves vacant sites which can be replaced by metal ions. This gives an indication that those materials could be used as adsorbents for heavy metal removal[24]. The biosorption was due to the formation of the bonds between the ions to the different functional groups.

The experiments were conducted to block the carboxylic, hydroxyl, phosphate and amine groups of *Spirulina platensis*, after blocking the groups the biosorption experiments were conducted at optimized conditions for nickel. When carboxylic group was blocked the percentage removal was observed 11.8% and when hydroxyl, phosphate and amine group of *Spirulina platensis* were blocked the percentage removal was 84.9, 87.1 and 85.1 respectively. It was found that after blocking of the carboxylic group the percentage removal of the metal ions showed drastic decrease during biosorption in comparison when other groups were blocked, further confirmed that the carboxylic group was the main group responsible for the biosorption of metal ions though hydroxyl amine and phosphate group take part in the biosorption process but up to little extent. The reduced biosorption was observed during the block of carboxylic group for metal ions may due to conversion of free carboxylic groups to methyl esters which is responsible for the reduction of biosorption. The carboxyl oxygen atoms of esters also take part in the bond formation but the interaction was much weaker. In native cyanobacteria the percentage removal was more than 90 percent for for nickel ions[8, 11].

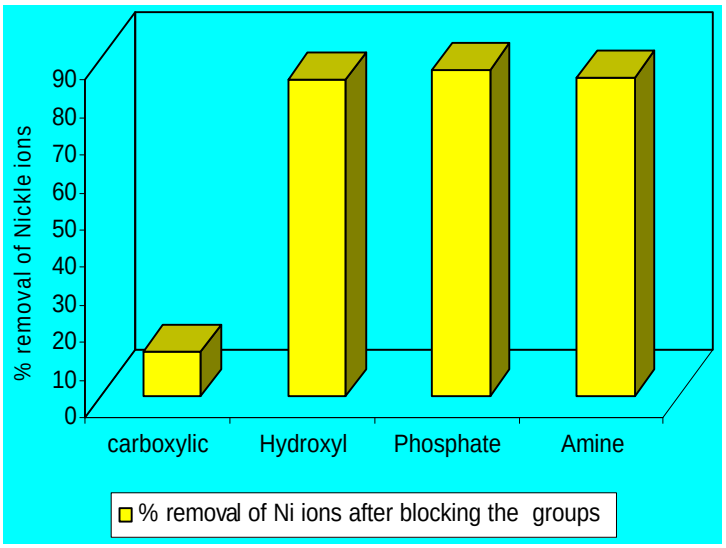

Figure 3. Percentage removal of metal ions after blocking the groups of *Spirulina platensis*

On the basis of above results it could be concluded that the *S.platensis* (immobilized and non immobilized) can be used for the removal of nickel metal ions. From the point of view of reusability, strength, measure of intensity of adsorption, adsorption capacity and percentage removal efficiency it is concluded that the *Spirulina platensis* immobilized in calcium alginate matrix for the nickel metal ions are

proposed as the best biosorbent for the five cycles when regenerated with 0.1 M EDTA without significant reduction in the adsorption capacity.

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