Bioremediation Technology for the Nickel-Plating Effluent by Immobilized Biomass of Anabaena

Yasodha T[1], Hemachandran M[2]
[1]*Professor, Department of Biotechnology, Madha Engineering College, Chennai,India*
[2]*Associate Professor, Department of Biomedical Engineering, Sri Muthukumaran Institute of Technology, Chennai, India*

***Abstract*—Bioremediation technology for the removal of Ni (II) by Agarose Immobilized Biomass of *Anabaena* (AIBA), a newly developed immobilized biosorbent was characterized based on adsorption isotherms. The effects of pH, temp, agitation time and adsorbent dosage on metal uptake capacity of AIBA were studied in the present investigation. The kinetic experiments showed that the process equilibrium was reached quickly in less than 15 minutes without the loss of biomass. The immobilized biomass of Anabaena *sp* (AIBA) was found to be influenced by pH of the solution and agitation time. Biosorption at pH 4.5, 120 rpm and 28^{0}C by *Anabaena sp* biomass in immobilized state ranging from 2 to 3 g/ agarose matrix described the solid-solution interaction between AIBA and effluent. Maximum biosorption capacity for AIBA of 58mg Ni at 1gbiomass/ matrix with metal recovery was enhanced up to 90% using 0.1 M EDTA when compared to other eluents. There was a decrease in Ni (II) uptake capacity when used in consecutive five biosorption–desorption cycles. 1/(x/m) values of Langmuir adsorption isotherm model for AIBA ranging from 0.03149 to 0.09322 proved that immobilized form of *Anabaena* is favorable for Ni (II) recovery.Hence continuous removal of Ni (II) from effluent by AIBA proved that it could be used in bioreactors for the removal of nickel from industrial effluent.**

***Index Terms*—Immobilized biosorbent, *Anabaena sp*, kinetic experiments, Ni (II) recovery, adsorption isotherms**

I. INTRODUCTION

Discharge of chemical wastes/toxic load especially from electroplating industries to nearby ecosystem and the degradation of environment are well documented [1]-[6]. Biological treatment of effluents is a well-established remediation techniques which has been successfully applied globally to reduce the cost and curtail pollution [7][8]. Biosorption involves accumulation of metals on the cells or cell fraction by ion exchange [9]-[12]. The Cyanobacteria (live or immobilized biomass) which expose negatively charged group on their cell surface have the capacity to bind metal ion. As a result of metal organic complexes or metal organic chelate formation by specific proteins produced by micro and macroalgae known as metallothionein [13]-[15].

With this background the current research had been focused to develop an efficient bioremediation technology for the removal of Ni (II) in nickel plating effluent using agarose immobilized biomass of *Anabaena sp.*Batch experiments were conducted to assess the effect of parameters such as contact time,pH, temperature and adsorbent dosage on AIBA.

II. .MATERIALS AND METHODS

Effluents from Ni plating industry were collected in plastic containers and analyzed as per standard methods [16]. Selected sp of *Anabaena* was cultured in Chu10 medium according to the method and identification as given in [17] [18]. To study the adsorption capacity of AIBA, batch experiment was conducted.100 ml of sample was collected into each conical flask. To these flasks an adsorbent of 1g/ l was added and agitated thoroughly for 10-150 minutes on orbital shaker at 180 rpm. The suspension was filtered through Whatman filter paper No: 41, and the filtrate was analyzed for residual Ni (II) concentration spectrophotometrically. In the present research work, the effect of pH, contact time, adsorbent dose and kinetic modeling for adsorption data were studied. Initial pH was adjusted with 0.1 N

HCl/H_2SO_4.All the experiments were conducted at 28°C. The percentage of removal and recovery capacity was studied with various eluting agents such as 0.1N HCl,0.1N HNO_3, 0.1N H_2SO_4, 0.1M Thiourea and 0.1M EDTA.

6% of agarose was prepared by dissolving in distilled water at 90^0C cooling to room temperature. *Anabaena* biomass was immobilized in 1g of matrix and the matrices were stored at 4^0C for further use [19].

A. Metal Sorption and Elution Studies:

A batch equilibrium method as in [20] was used to determine biosorption of Ni (II) by AIBA (Agarose Immobilized Biomass of *Anabaena)*. 1g matrix was contacted with 100 ml nickel plating effluent in Erlern Mayer flask for 24 hrs at 28^0C at 150 rpm. 250ml of different eluting agents such as HNO3, H2SO4, HCl, Thiourea and EDTA for 24 hrs in a shaker at 150rpm were used. The Ni (II) content eluted was analyzed by atomic adsorption spectroscopy. After elution the immobilized biomass (AIBA) was washed with calcium chloride and magnesium sulphate for 15 minutes. Reconditioning of AIBA was done with deionised water, acidified to pH 2.5 by H2SO4. All the flasks were agitated for 2 hrs at 28^0C. The concentration of Ni (II) in bulk solution was analyzed after each round of exposure. This elution cycle was repeated up to five cycles.

The experiments conducted in triplicates and were represented as mean $\pm$ standard deviation. All the data were analysed statistically using Duncan's test [21].

III. RESULTS AND DISCUSSION:

A Characteristics of nickel-plating industrial effluent

Results pertaining to the chemical constituents of the nickel-plating effluent are predicted in Table-1.

Table 1: Characteristics of nickel-plating industrial effluent

S. No	Parameters	Values
1	pH	3.8
2	dissolved oxygen (ppm)	4.5
3	Total dissolved solids (mg/ml)	752
4	Total suspended solids (mg/ml)	200
5	Chemical Oxygen Demand (ppm)	280
6	Biological OxygenDemand for 5 days @ 20°C (ppm)	150
7	Sulphate(mg/ml)	450
8	Chloride (mg/ml)	500
9	Nickel (mg/ml)	5.5
10	Copper (mg/ml)	6.01

A. Effect of Ph

pH is an important controlling factor in adsorption process and thus the role of hydrogen ion concentration was studied in the present investigation, covering range of 1.5-5.5. The effect of pH on the adsorption of Ni (II) is shown in Table-2At pH 5.0 nickel removal was increased minimum of 56% whereas at pH 4.5 metal sorption was maximum upto 87%. The equilibrium is attained at pH 5.5 in 150 minutes of agitation time. As the pH increase the biosorption efficiency for Ni(II) was also increased. Immobilised biomass provides enzyme- metallic interaction [22] in the presence of hydrogen ions execute effective biosorption of 58mg of Ni(II) . The ideal pH 4.5 for Ni (II) removal from effluent by AIBA revealed the capacity of hydrogen ions to bind at active sites of AIBA. Similar trend of results was recorded by earlier researchers [23]-[25]. The pH of the metal solution is the most influential factor as it interacts with the metal and biomass/adsorbent. This fact is supported by the distribution of nickel species at various pH values [26] [27].

B. Effect of Adsorbent Dosage:

As the adsorbent dosage (AIBA) increased from 1 g to 3 g the adsorption process also increased due to more active sites in adsorbent. Due to the influence of adsorbent dosage 1 to 3 g of *Anabaena sp* biomass in immobilized state the electrons are easily polarized and to a lower degree retained by the nucleus. In our research the amount of adsorbed bivalent nickel ions was increased upto 28.25 mg/g at 1g dosage of AIBA and is doubled at 2 -3 g of AIBA(Table-3). This is in accordance with the previous investigations which proved that increase in dosage increase the metal recovery up to 98.7% [28]-[30].

Table-2. Effect of pH on Ni(II) removal (mg/g)

pH	Ni(II) removal (mg/g)
2	1.8
2.5	1.9

3	2.2
3.5	2.5
4	5.2
4.5	5.7
5	5.9
5.5	6.0
6	6.0

Table-3. Effect of adsorbent dosage onbiosorption:

Dosage(g/matrix)	Removal mg/g Ni(II)
0.5	25.86
1.0	28.25
1.5	39.03
2.0	50.55
2.5	58.75
3.0	59.50
3.5	59.55

C Effect of Agitation Time on Biosorption

The results recorded clearly indicates the effectiveness of nickel adsorption by AIBA in the contact time during 15 -20 minutes of adsorption of nickel(II) from nickel plating effluent. This point of study clearly indicates that the surface of AIBA has a greater affinity for bivalent nickel ions. The higher degree of nickel removal was observed at 10-15 minutes of time due to the enzyme activity of immobilized biomass with vigorous agitation and contact of nickel plating effluent. The rapid removal is due to sufficient interactions between metal surface and bioactive compounds [31]-[33] revealed the importance of adgitation time in determining the kinetics of the adsorption process.

D. Removal and Recovery Capacity by Eluents

Average recovery of adsorbed Ni(II) from agarose immobilized biomass in 5 adsorption desorption cycles by 5 eluents were compared. Among them 0.1M EDTA pH 4 has the highest (61%) Ni(II) removal (Table-4).

Table-4. Effect of eluents on Ni (ii) removal

Eluents	Removal capacity (mg/g)
Hcl	32.0
H_2SO_4	55.7
HNO_3	44.5
Thiourea	43.1
EDTA	61.2

The bioremediation potentiality of the immobilized cyanobacterial biomass has mainly taken the form of biofilms on support made of a range of inert materials to rectify the disadvantages of freely suspended microbial biomass [34] [35].

E. Adsorption Isotherms

The study of solid-solution interface between AIBA and effluent revealed the kinetics of adsorption (Figure-1) by describing the solute uptake rate and the residence time of adsorbate. Lagergren and Langmuir adsorption isotherms are helpful in determining the adsorption capacity of an adsorbent[36][37].The values of $R_L < 1$, obtained in the present investigation indicates the Langmuir adsorption intensity as $1/n<<1$ ranging from 0.03149 to 0.09322 and the applicability of Langmuir adsorption isotherm (Figure-2 & 3).

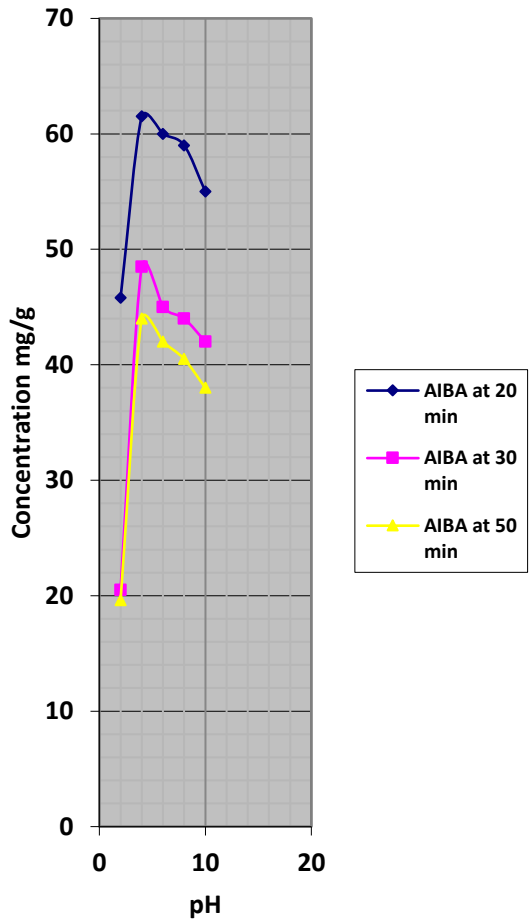

Fig 1. Kinetic modeling for the adsorption of Ni (II) by AIBA

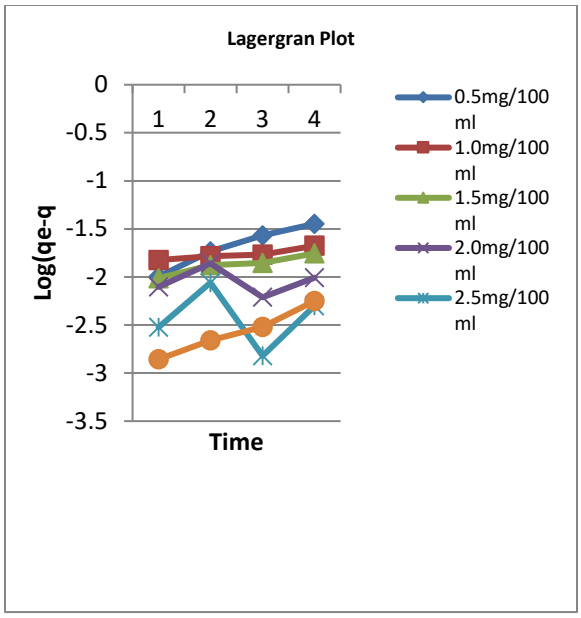

Fig 2. Lagergren Plot for Ni (II) recovery by AIBA

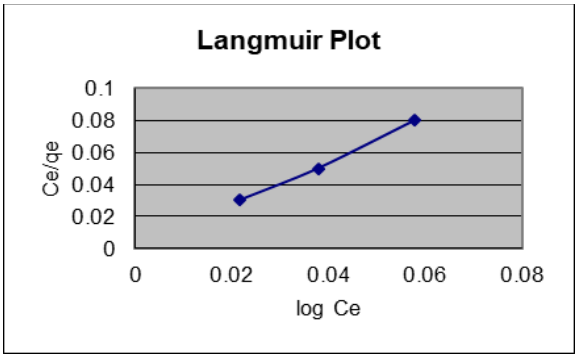

Fig 3. Langmuir Plot for Ni (II) recovery by AIBA

IV. CONCLUSIONS

Several parameters are bound to affect the process of biosorption. The pH, amount of adsorbent and agitation time influences the biosorptive potentiality. Time course of Ni(II) biosorption at pH 4.5, 120 rpm, 28^0C by *Anabaena sp* biomass in immobilized state (AIBA) ranging from 2 to 3 g/ agarose matrix reveals that the maximum biosorption of 58mg Ni at 1gbiomass/ matrix. The data obtained from the kinetic experiments proved *Anabaena sp* biomass could be the useful in designing and demonstrating an efficient treatment plant for Ni (II) rich effluent. It is concluded that agarose immobilized biomass of *Anabaena* (AIBA) is recommended as a cost effective and potential bioremediation technology for nickel plating effluents.

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