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Chemical Modification and Characterization of Yeast Cells for Extraction of Metal Ion in Water Sample

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ABSTRACT

A novel biosorbent is prepared by coupling a cibacron blue to yeast cells. The chemically modified yeast cells with mentioned ligand has been characterized by Fourier transform infrared spectroscopy and elemental analysis and applied for the preconcentration and extraction of trace Ni(II) from water samples. The optimum pH value for sorption of the nickel ions was 8. The sorption capacity of yeast cells- cibacron blue is 12.2 mg. g^{-1}. A recovery of 91.4% was obtained for Ni(II) when eluted with 0.5 M HCl/HNO_3 (3:1). The equilibrium data of Ni(II) adsorption on yeast cells- cibacron blue was analyzed using Langmuir model. The method was applied for Ni(II) determination in sea water sample.

Keywords: Solid phase extraction; Yeast cells; Nickl; Ion; Isotherm study; Preconcentration

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INTRODUCTION

Heavy metals such as lead, cobalt, cadmium, mercury and nickel are attended due to toxicity and influences on human body and environment. For this reason investigation about pollution of these elements are quite important [1]. These elements are transferred to body organisms through the water, soil, air and foods thus their determination by sensitive, accurate and fast methods had been challenging in recent decades. Nicle in catalysts and alloy production, steel industry, covers, some enzymes play important role. The allowed dosage of nickel for matured human is 30.05 mg/cm^3. Over this concentration, nickel can be carcinogenic and cause skein allergy.

Measurement of trace elements by some techniques like inductively coupled plasma mass spectrometry, graphite furnace atomic absorption spectrometry is usual but flame atomic absorption spectrometry (FAAS) due to cost and simplicity, is preferred. In order to low concentration of these elements in the samples, mentioned techniques can't be applied directly, therefore several preconcentration methods are developed. There are numerous systems of preconcentration such as liquid–liquid extraction [2], coprecipitation [3], , cloud point extraction [4] membrane filter techniques [5] and ion exchange techniques [6]. Several solid phase extrction have been reported in solid phase extraction by organic [7] and inorganic [8] polymers, modified activated carbon [9,10], nanocomposits [11], biomaterial [12] and biocompatible material for instance.

Yeast cell or other materials can be used as a biocompatible supporting solid phase in solid phase extraction systems of organic and inorganic materials [13-16]. The purpose of present study is to demonstrate the practicability of using yeast cell-cibacron blue as a bio-support for extraction of trace nicle in the water samples. Trace nickel can be preserved on the surface of yeast cell- cibacron blue and then desorbed with 0.5 M mixture of nitric and hydrochloric acid (3:1) preceding the determination by FAAS. This proposed novel method has advantages of good accuracy and precision, high recovery, and preconcentration factor.

MATERIALS AND METHODS

Instruments

A flame atomic absorption spectrometer of the Varian AA240 (Mulgrave, Victoria, Australia), equipped with an air–acetylene flame (air and acetylene flow rate 8 and 1.7 L min−1, respectively) was used for concentration measurements of metal ions. The pH measurements were made with a Metrohm model 744 pH meter (Zofingen, Switzerland). Infrared spectra were recorded on a Jasco Fourier transform infrared spectrometer (FT-IR-410; Jasco, Easton, MD) by using the potassium bromide pellet method.

Materials

H_2SO_4, HNO_3 , HCl, NaOH, $Cr(NO_3)_3$, $Pb(NO_3)_2$, $Zn(NO_3)_2$, $AgNO_3$, $Al(NO_3)_3$, NaCl, CH_3COOH, CH_3COONa, NaH_2PO4, Na_2HPO_4, $Pb(NO_3)_2$, $FeSO_4 \cdot 7H_2O$, $CuSO_4 \cdot 5H_2O$, $Co(NO_3)_2 \cdot 6H_2O$, $Ni(NO_3)_3 \cdot 6H_2O$, $Zn(NO_3)_2 \cdot 3H_2O$, cibacron blue were products of Merck (Darmstadt, Germany). The yeast cell was purchased from local supermarket. The stock solution (500 mg L) of Ni(II) was prepared by dissolving appropriate amounts of $Ni(NO_3)_3 \cdot 6H_2O$ in deionized water. To adjust the pH of the solution, buffer or phosphate buffer were used.

Synthesis of yeast cell-cibacron blue (YC-CB)

Yeast cell beads (20 g) were treated with 1000 mL of distilled water and 8.77 g of NaCl and the mixture was stirred at 70°C for 40 min. Then the reaction mixture was centrifuged for 15min at 4000rpm. After decantation, 50 mL distilled water, 0.3g cibacron blue, 3g NaCl was added to the yeast cells and mixture shacked for 24 h. Next 0.3 g Na_2CO_3 was added to the above solution and shacking continued for more 36 h. The resulted was centrifuged for 15 min at 3700 rpm, and then washed repeatedly with water until free from color, and stored in pH 8.5 buffer.

Metal sorption

The degree metal sorption at optimum condition was determined by batch equilibration technique. A set of solutions (volume of each 100mL) at pH 8, containing 0.5 µg mL^{-1} of Ni(II) was taken. Then 0.3 g of YC-CB was added to each solution and the mixture was shaken for 1 h. The metal ions were measured by FAAS in the eluate with 0.5 M nitric/hydrochloric acid (10 mL).

Total Sorption Capacity

The 0.3 g of YC-CB was stirred for 4 h with 50 mL of the solution containing 5–60 µg mL^{-1} of Ni(II) at pH 8 and 20°C. The metal ion concentration in the supernatant liquid was estimated by FAAS. The sorbed Ni(II) for the metal ion was measured from the difference between the Ni(II) concentrations in solution before and after the sorption. The maximum adsorption capacity was estimate by Langmuir isotherm equation.

RESULTS AND DISCUSSION

Characterization

The IR spectrum of YC-CB is compared with that of bared yeast cell. The bands at 3433 cm^{-1} (O-H), 2919 cm^{-1} (aliphatic C-H) and 1697 cm^{-1} (C=O stretching) for YC-CB indicated that modification was done successfully. The elemental analysis of YC-CB (C, 47.1; H, 6.9; N, 9.8%) and unmodified yeast cells (C, 43.5; H, 6.3; N, 7.7%) demonstrates presence of cibacron blue molecule on the cells wall. The results demonstrated that the percentage of nitrogen was increased in YC-CB rather than bared cells that confirmed immobilization of cibacron blue onto yeast cells wall.

Ni(II) Sorption

The degree of Ni(II) sorption at different levels of pH was studied by batch method. The results in Fig. 1 show that the maximum sorption was achieved at pH 8. In lower pH the protonation of immobilized cibacron blue was increased so the sorption of Ni(II) was decreased. The pH upper than 8 was not examined due to precipitation of nickel hydroxide in alkaline pH. In order to archive higher recoveries different eluting agents (HCl 0.5 M, HNO_3 0.5 M, H_2SO_4 0.5 M and HCl/HNO_3 0.5M 3:1) was examined in batch experiments. Among the examined eluent the HCl/HNO_3 (3:1) provided the best recovery (99%).

The sorption as a function of contact time for Ni(II) is shown in Fig. 2. Approximately 2 min was enough for more than 60% maximum sorption. The profile of Ni(II) uptake by the YC-CB reflects good accessibility of the sorption sites in the modified yeast cells.

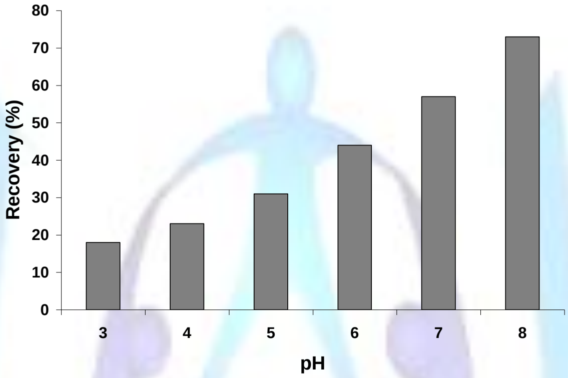

Fig 1. Effect of pH sorption of Ni(II) onto YC-CB

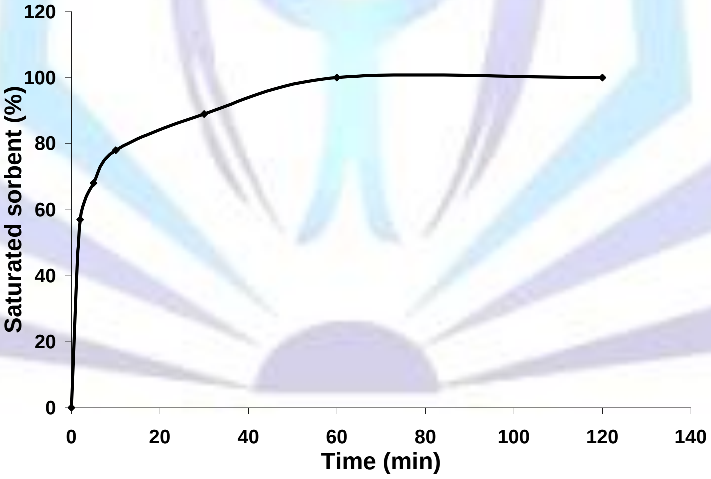

Fig 2. Kinetics of the Ni(II) sorption on YC-CB

In order to estimate the capacity of the the YC-CB, the Langmuir model was applied [17]:

$$C_e/q_e= (1/q_{max}.K_L) + (C_e /q_{max}) \qquad (1)$$

where q_{max} (mg.g^{-1}) is the capacity of YC-CB corresponding to complete monolayer coverage on the surface, C_e (mg. L^{-1}) is the equilibrium liquid phase concentrations of Ni(II) and K_L (L.mg^{-1}) is the Langmuir constant. The parameters can be estimated from the intercepts and the slopes of the plots of C_e/q_e versus C_e (Fig. 3). Langmuir constants and q_{max} were obtained 0.034 L.mg^{-1} and 12.2 mg g^{-1}, respectively.

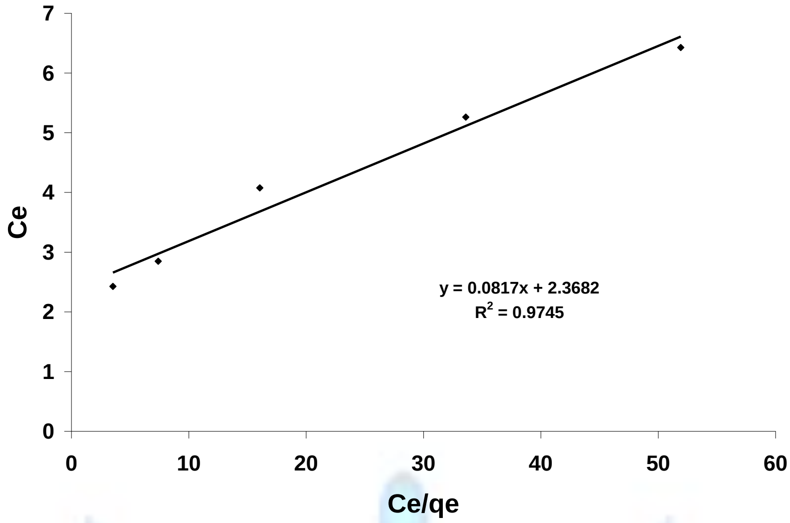

Fig 3. Langmuir isotherm for Ni(II) adsorption onto YC-CB at 20 °C

Effect of Foreign Ions

To evaluate the efficiency of the extraction system, the effect of some metal ions on the sorption of Ni(II) was studied. The results indicated that the most effective ions on adsorption of Ni(II) on YC-CB are Cd(II), Al(III) and Zn(II).

Application of Method

YC-CB was used to extraction of Ni(II) ions in the Caspian sea water (Tonekabone Iran). The pH of the water sample was adjusted to the 8. Solid phase extraction with YC-CB coupled with FAAS was applied to determine Ni(II) in the sample. The results are presented in Table 1. This result demonstrated the applicability of the procedure for the Ni(II) determination in samples with high recovery.

Table 1. Results obtained for the Ni(II) determination in sea water sample

Sample	Concentration of Ni(II) (μg L^{-1})	Added (μg L^{-1})	Preconcentration factor	Found* (μg L^{-1})	Recovery (%)
sea water	40	100	10	128±8	91.4

[a]For three determinations

Conclusion

A novel modification procedure of yeast cells was introduced. The chemical reaction for modification of the yeast cells is simple. The YC-CB has a good potential for extraction of trace amount of Ni(II) from water sample. The Ni(II) is adsorbed to YC-CB at moderate pH of 8. Langmuir isotherm analysis reveal that the adsorption capacity was 12.2 mg.g^{-1}.

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