

# **BIOSORPTION OF METAL IONS BY YEAST FROM AQUEOUS SOLUTIONS**

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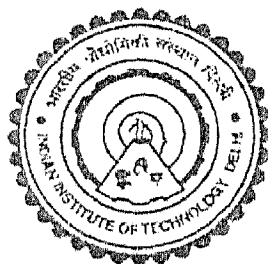
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Submitted

In fulfillment of the requirements of the degree of  
**Doctor of Philosophy**

to the



**INDIAN INSTITUTE OF TECHNOLOGY, DELHI  
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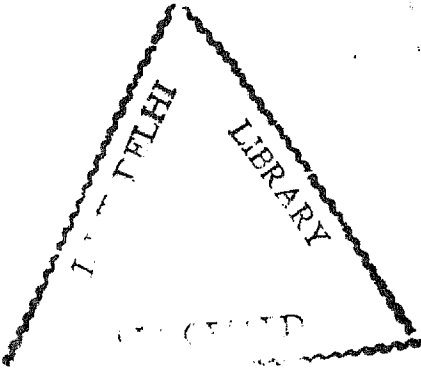
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**Dedicated**  
**To my Parents**

## CERTIFICATE

This is to certify that the thesis entitled, "**BIOSORPTION OF METAL IONS BY YEAST FROM AQUEOUS SOLUTIONS**" being submitted by **Ms. V. Padmavathy** to the Indian Institute of Technology, Delhi for the award of Doctor of Philosophy is a record of bonafide research work carried out by her under our guidance and supervision in conformity with the rules and regulations of Indian Institute of Technology, Delhi.

The research report and results presented in this thesis have not been submitted, in part or full, to any other university or institute for the award of any degree or diploma.

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## ABSTRACT

Industrial effluents carry highly toxic metals into surface waters rendering it unfit for agricultural or domestic use. For example,  $\text{Cd}^{2+}$  is toxic when present above 2.0 mg/l and is found in effluents from electroplating, pigment stabilization, plastic production, metal processing, mining processes and other industries. Often less toxic ions like  $\text{Ni}^{2+}$  also accompany it. Separation of these metal ions by ion exchange, precipitation, reverse osmosis etc., have their limitations. Recently, attention has been focused on the possibility of biosorption, i.e., binding the pollutants on to microbial biomass. This process is efficient even when the metal ions are present in low concentrations. In this process, the uptake of heavy metal ions by deactivated biomass takes place by a passive mode. As compared to bioaccumulation by live biomass, biosorption is rapid, reversible and independent of cell metabolism. However, in depth studies on selected systems are needed for practical applications. Specifically, the sorption capacity, kinetics and mechanism of sorption, must be looked into.

Deactivated yeast was chosen for the present study, as it is inexpensive, readily available and has the ability to accumulate a broad range of metal ions to varying degrees under a wide range of external conditions. A review of literature indicated that only limited work is available on the biosorption of cadmium (II) ion and nickel (II) ion by yeast. Hence, a systematic study was undertaken on the sorption of these two ions on well characterized dead yeast biomass. Since light metal ions are retained in the native yeast during cell growth, the sorbent was washed with 0.1 M HCl, eluting these cations. The yeast thus obtained in its protonated form was used for the sorption studies of light and heavy metal ions.

The total cation content present in the native yeast biomass was about 1.05 meq/g. The FTIR spectra of native and protonated yeast showed bands characteristic to sugar, protein, nucleic acid, chitin and chitosan indicating that these are the potential sites for binding metal ions. Moisture loss of 10-12% on heating to ~ 200°C was recorded by the thermo-analytical techniques, TGA and DTG. Complete decomposition occurs by 800°C resulting in ashing. Metal ions sorbed are fully eluted from the ash by acid treatment.

The sorption of light metal ions on deactivated protonated yeast was studied over a pH range of 2.0-7.0. The amount of metal ions sorbed by exchange for H<sup>+</sup> ions was quantified by recording the change in pH during the experiment. The total amount of cations sorbed was determined both from reduction in concentration in solution and elution from the sorbent. At the optimum pH of 6.75, the amounts sorbed were in the order Ca (1.0 meq/g) > Mg (0.36 meq/g) > Na (0.125 meq/g) ≥ K (0.11 meq/g). In all the cases, the amount sorbed with pH change in solution was of the order of 0.12 meq/g. These results suggest that while sorption of monovalent ions occurs mainly by ion exchange (proton exchange), divalent ions were sorbed by additional mechanisms without proton release due to ion exchange. FTIR spectra of metal loaded sorbent showed shifts mainly in the sugar region.

The protonated form of yeast was converted to the sodium form and biosorption of cadmium (II) ion was carried out on this form at different pH (2.0 to 7.0) for 100 and 1000 mg/l metal ion concentrations. Sorption studies were also carried out for different initial concentrations of cadmium (II) ion with different amounts (0.1g to 8.0 g/100 ml) of sorbent at the optimum pH of 6.5. The sorption data did not follow Langmuir isotherm, but the

amount of cadmium (II) ion sorbed at equilibrium was directly proportional to the initial metal ion concentration divided by the sorbent mass.

The kinetics of sorption was followed by measuring the amount of metal sorbed after various time intervals over 0-24 hours, for different yeast doses. The sorption process occurred in four distinct stages. While the first stage was controlled by external mass transfer; the subsequent stages followed pseudo-second order kinetics. The sorption capacity was dependent on the dosage rate. FTIR spectra showed peak shifts in the protein and sugar regions.

A comparison of the biosorption capacity of nickel (II) ion on dead native biomass was made with that on protonated biomass at an optimum pH of 6.75. The data fitted the Langmuir isotherm model and the maximum sorption capacity of nickel (II) ion on native yeast and protonated yeast as obtained from this model were 7.9 and 11.4 mg/g respectively.

The kinetics of sorption of nickel (II) ion was studied for different initial metal ion concentrations (10-200 mg/l), keeping the sorbent dosage fixed (1.0 g/l) and by varying the sorbent dose (0.5-8.0 g/l) keeping the nickel (II) ion concentration fixed (100 mg/l). The nickel (II) ion uptake was pseudo-second order with respect to metal ion concentration and the uptake was dependent on the dosage of the yeast.

The kinetics of sorption of nickel (II) ion was also studied for different initial concentrations of nickel (II) ion (100-400 mg/l) at different temperatures of the solution (27,40, 50 and 60°C). The uptake capacity decreased with increase in temperature of the solution for a given initial nickel (II) ion concentration indicating that the sorption is exothermic. The activation energy obtained was 13.3 kJ/mol.

The effect of sorption of nickel (II) ion on protonated yeast heated to different temperatures (60, 200, 450 and 800°C) was studied. Nickel (II) ion sorption capacity was maximum for 200°C heated sample. Nickel (II) ion sorption showed shifts in the peaks corresponding to sugar and nucleic acid regions.

The suitability of yeast biomass for the use in effluent treatment was evaluated. Desorption studies on metal loaded sorbent, using 0.1M HCl revealed that the spent biomass can be regenerated and reused a few times. TGA and DTG measurements showed that the spent sorbent can be incinerated by heating to 800°C. The metal ion recovered quantitatively by acid elution. The sorption capacity of cadmium (II) ion on sodium form of yeast was comparable or superior to many other sorbents reported in the literature. The protonated yeast had only a medium sorption capacity for nickel (II) ion.

Model equations correlating the pseudo-second order constants were derived for nickel (II) ion and cadmium (II) ion for predicting the amount of metal ion sorbed for two cases: a) in terms of initial metal ion concentration and time (t), for a constant sorbent dosage and varying metal ion concentration and b) in terms of mass of sorbent and time (t), for a constant initial nickel (II) ion concentration and varying sorbent dosage.

The above studies on kinetics and mechanism of biosorption would be useful in designing effluent treatment systems in the batch and column modes.

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