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Original Research Paper

Biosorption of Lead (II) from Aquatic Environment by a Macrofungus (*Agaricus bisporus*)

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ABSTRACT

Lead, like other heavy metals, is introduced into natural waters by industrial and domestic wastewater discharges causing environmental pollution. Conventional methods are extremely expensive or inefficient for removal of metals from wastewaters containing low concentration of dissolved metals. Biosorption is a process in which sorbents of biological sources are employed for binding heavy metals. It is a promising alternative to treat industrial effluents, mainly because of its low cost and high metal binding capacity. In the present work, lead (II) biosorption process by the fruiting bodies of a macrofungus (*Agaricus bisporus*) has been studied. The work considered the determination of lead-biomass equilibrium data in batch system. The studies were carried out in order to determine some operational parameters of lead sorption such as the effects of pH, initial metal ion concentration, biomass dosage and time required for the metal biosorbent equilibrium, contact period, etc. All the parameters showed important effect on biosorption rate and capacity.

INTRODUCTION

The contamination of aquatic environment by toxic metals like lead (Pb) is of great concern due to their trends to accumulate in vital organs of humans and animals (Alan et al. 2007, Gholivand et al. 2007). The Pb(II) ions pass to aquatic bodies from many industrial processes, such as storage battery manufacturing, printing pigments, fuels, photographic materials and explosive manufacturing (Selatnia et al. 2004). Lead (II) is one of the most toxic heavy metals which may cause health problems such as behavioural anomaly, learning disabilities and seizures (Bulut & Baysal 2006).

Conventional methods for heavy metal removal from aqueous solutions include chemical precipitation, electrolytic recovery, ion exchange/chelation and solvent extraction/liquid membrane separation. But these methods are often cost prohibitive having inadequate efficiencies at low metal concentrations, particularly in the range of 1-100 mg/L (Kapoor & Viraraghavan 1995). Some of these methods, furthermore, generate toxic sludge, the disposal of which is an additional burden on the techno-economic feasibility of treatment procedures. These constraints have caused the search for alternative methods which would be efficient for metal sequestering. Biosorption is a cost effective emerging technology, which offers a method that uses sorbents of biological origin (Low et al. 2000, Babel & Kurniawan 2003) for removal of heavy metals from dilute aqueous solutions (Matheickal & Yu 1997). The most frequently studied biosorbents are bacteria (Ilhan et al. 2004), fungi (Cabuk et al. 2005) and algae (Sheng et al. 2004, Freire-Nordi et al. 2005).

Fungal organisms are found to possess excellent metal uptake potential (Kapoor & Viraraghavan 1995). Studies about the technological aspects of metal removal by macrofungi are scarce. The objective of the present work is to investigate the biosorption potential of macrofungus *Agaricus bisporus* in the removal of Pb (II) ions from aqueous solutions. Optimum biosorption conditions were determined as a function of pH, biomass dosage, contact time and initial metal ion concentration. The Langmuir and Freundlich models were used to describe equilibrium isotherms.

MATERIALS AND METHODS

Biomass: Fruiting bodies of the mushroom *Agaricus bisporus* used in this study were purchased from a grocery shop, which were supplied by Saptarishi Agro Industries Ltd., Pazhayanoor, Tamil Nadu. Mushrooms were washed thoroughly with deionized water to remove the dirt and impurities. The dried fruiting bodies were then pulverized in a mortar and pestle. Particles with 750-1000 µm average size were used for the experiment.

Metal solution: Lead solutions with different initial concentrations were prepared by dissolving $Pb(NO_3)_2$ in deionized water.

Biosorption experiments: Batch experiments of biosorption were performed at constant temperature (28°C) in 250 mL Erlenmeyer flasks containing 100 mL of solution of lead (II) in rotary shaker at 120 rpm. After agitation, the reaction mixtures were filtered through Whatman No.1 filter paper and the filtrate was analysed by atomic absorption spectrophotometer (Varian Spectra 240) for the concentration of lead (II). The effects of pH, contact time and biomass dosage on the biosorption of lead (II) were studied. The effect of pH was investigated in the pH range 2.0-8.0. The experiments were performed with following conditions: biomass dosage - 0.5 g, contact time - 3 hours, metal concentration - 50 mg/L. The effect of contact time was also investigated in an another series of experiments. 0.5 g of biomass was added to 50 mg/L of lead with pH 5 and the flasks were agitated at different time intervals (30, 60, 90, 120, 150, 210, 240 minutes). In order to study the effect of biomass dosage, experiments were performed with different biomass dosage (0.1, 0.2, 0.3, 0.4, 0.5 g) in 50 mg/L of lead at pH 5 for 150 minutes. The effect of initial metal ion concentration was studied by varying the metal concentration from 50 to 225 mg/L). In this experiment 0.5 g of biomass was added to the desired metal concentration at pH 5 and the flasks were agitated for 150 minutes.

Data evaluation: The amount of metallic ions biosorbed per g of the biomass (Q) was calculated using the following equation:

$$Q = \left(\frac{C_i - C_f}{m}\right) \times V$$

Where C_i is the initial concentration of the metallic ion (mg/L), C_f is the final or equilibrium concentration of the metallic ion (mg/L), m is the dry mass of the biosorbent in the reaction mixture (g) and V is the volume of the reaction mixture (L).

Two models were used to fit the experimental data: The Langmuir model and the Freundlich model. The Langmuir model was chosen for the estimation of maximum metal biosorption by the biosorbent. The Langmuir isotherm can be expressed as:

$$q_{eq} = \frac{q_{max} b C_{eq}}{1 + bC_{eq}} \quad ...(1)$$

The Freundlich model is represented by the equation:

$$q_{eq} = K_f C_{eq}^{1/n} \quad ...(2)$$

Where q_{eq} and q_{max} are the observed uptake capacity at equilibrium and maximum uptake capacity (mg/g), C_{eq} is the equilibrium concentration (mg/L), b (L/mg) is the equilibrium constant of adsorption with relation to the affinity of the binding sites for the metals, K_f and n are indicators of the adsorption capacity of the biomass and adsorption intensity, respectively.

RESULTS AND DISCUSSION

Effect of pH: Fig. 1 shows the effect of initial pH on lead removal by *Agaricus bisporus.* It can be observed that at pH 2, the lead adsorption by *A. bisporus* was minimum (35.6 %). Lead adsorption increased to 49.0 % at pH 3 and then to 63.0% at pH 4. Maximum adsorption was noted (70.0 %) at pH 5. There was not much significant difference in lead adsorption in pH 5, pH 6 and pH 7. This can be explained by the fact that at low pH, protonation of the cell wall component adversely affected the biosorption capacity of the fungal biomass, but its effect became minor with increasing pH in the medium. With an increasing pH, the negative charge density on the cell surface increases due to the deprotonation of the metal binding sites and thus increasing biosorption (Say et al. 2001). Therefore, when pH increases, availability of H^+ ions decreases leading to higher adsorption of lead ions. In the present study, pH 5 was selected as optimum for *A. bisporus* lead systems. Previous studies also reported that the maximum biosorption efficiency for Pb(II) ions was at pH 5 (Chojnacka 2005, Yan & Viraraghavan 2003). Similar results is also reported in case of Lichen (*Parmelina tiliaceae*) biomass (Uluozlu et al. 2008).

Effect of biosorbent dose: The biosorption efficiency for Pb (II) ions as a function of biomass dosage was investigated (Fig. 2). The percentage of metal biosorption increased with the biomass loading up to 5g/ L. The maximum biosorption for Pb (II) was attained at about biomass dosage of 5g/L, and it was almost same at higher dosages. This result can be explained as a consequence of a partial aggregation, which occurs at higher biomass dosage giving rise to a decrease in active sites on the biomass (Karthikeyan et al. 2007). Therefore, the amount of biomass was selected as 5g/L for further experiments.

Effect of contact time: Fig. 3 shows the effect of contact time on biosorption of Pb (II) ions onto *A. bisporus.* It can be seen that the biosorption yield of Pb (II) increases with rise in contact time up to 150 minutes. After this time there was no considerable increase. Therefore, the optimum contact time selected as 150 minutes.

Effect of initial metal concentration: Experiments on the influence of concentration of synthetic lead solution on the removal of lead by *A. bisporus* at fixed values of pH (5.0) and biomass concentration (0.5 g/L) were carried out with the purpose of observing the effect of this parameter on the rate of metallic biosorption. The results obtained are shown in Fig. 4.

The results showed that the biosorption capacity of biomass increased up to 20 mg/g with increasing of the initial concentration of metal ions up to 200 mg/L and reached a saturation value at this point.

Adjustment of experimental data: The Langmuir and Freundlich constants were derived from linear regression graphs. Langmuir constants were found to be q_{max} = 28.8 mg/g; b = 0.0205 L/mg, and the Freundlich constants as K = 1.7092; n = 1.8681. The isotherms obtained by Langmuir and Freundlich models are presented in Fig. 5 and Fig. 6.

The Langmuir model predicts the formation of an adsorbed solute monolayer, with no side interactions between the adsorbed ions. It also assumes that the interactions take place by adsorp-

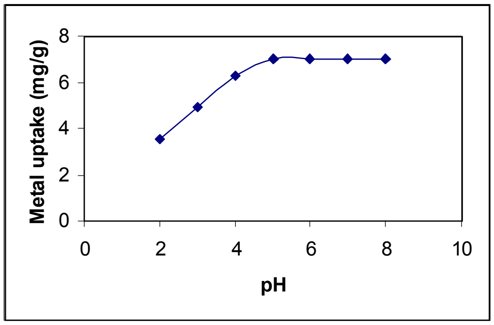

Fig.1: Effect of initial pH on biosorption of Pb(II) onto *A. bisporus.*

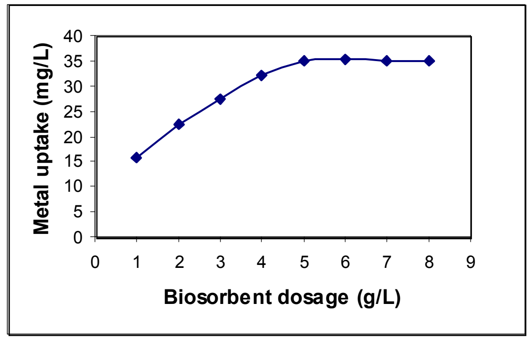

Fig. 2: Effect of Biomass dosage on biosorption of Pb(II) onto *A. bisporus.*

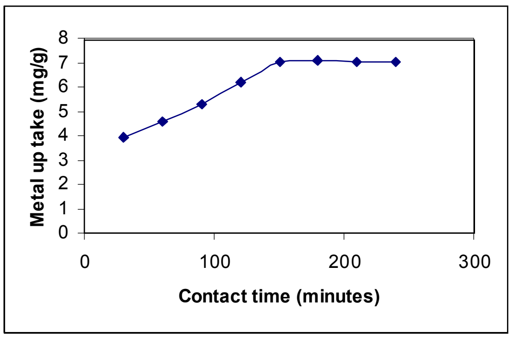

Fig. 3: Effect of contact time on biosorption of Pb(II) onto *A. bisporus.*

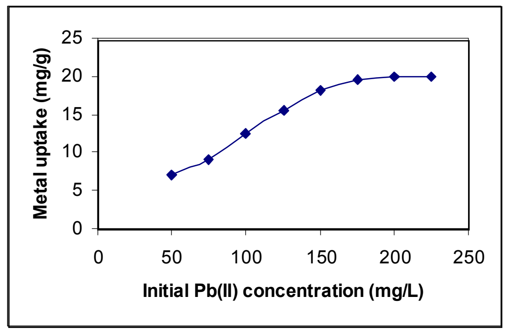

Fig. 4: Biosorption of Pb(II) by *A. bisporus* in relation to initial concentration of lead.

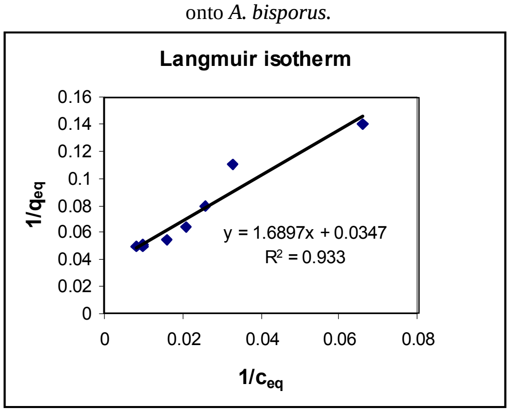

Fig. 5: Langmuir adsorption isotherm for lead (II) on *A. bisporus.*

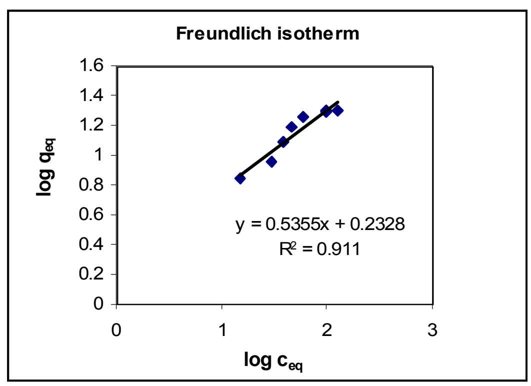

Fig. 6: Freundlich adsorption isotherm for lead (II) on *A. bisporus.*

tion of one ion per binding site and that the sorbent surface is homogenous and contains only one type of binding site. The Freundlich model does not predict surface saturation. It considers the existence of a multilayered structure. The present results indicate that both the models, Langmuir and Freundlich, fit reasonably well with the experimental data.

CONCLUSION

The biomass of *A. bisporus* demonstrated a reasonable capacity of lead biosorption, highlighting its potential for effluent treatment processes. The parameters viz., pH, biomass dosage, contact time and initial metal concentration showed strong effect on lead biosorption capacity. Langmuir and Freundlich sorption models were in good agreement with the experimental results.

REFERENCES

Alan, M., Kara, D. and Fisher, A. 2007. Preconcentration of heavy metals and matrix elimination using silica gel chemically modified with 2,3-dihydroxybenzaldehyde. Sep. Sci. Technol., 42: 879-895.

Babel, S. and Kurniawan, T.A. 2003. Low cost adsorbents for heavy metal uptake from contaminated water: A review. J. Hazard. Mater., B97: 219-243.

Bulut, Y. and Baysal, Z. 2006. Removal of Pb (II) from wastewater using wheat bran. J. Environ. Manag., 78: 107-113.

Cabuk, A., Ilhan, S., Filik, C., and Caliskan, F. 2005. Pb^{2+} biosorption by pretreated fungal biomass. Turk. J. Biol., 29: 23-28.

Chojnacka, K. 2005. Biosorption of Cr (III) ions by egg shells. J. Hazard. Mater, B121: 167-173.

Freire-Nordi, C.S., Vieira, A.A.H. and Nascimento 2005. The metal binding capacity of *Anabaena spiroides* extra-cellular polysaccharide: An EPR study. Process Biochem., 40: 2215-2224.

Gholivand, M.B., Ahmadi, F. and Rafiee, E. 2007. Solid phase extraction and determination of ultra trace amounts of copper using activated carbon modified by N,N'-bis (salicylidene)-1,2-phenylenediamine. Sep. Sci. Technol., 42**:** 897-910.

Ilhan, S., Noubakhsh, M. N., Kilicarslan, S. and Ozdag, H. 2004. Removal of chromium, lead and copper ions from industrial wastewater by *Staphylococcus saprophyticus.* Turk. Electronic J. Biotechnol., 2: 50-57.

Kapoor, A. and Viraraghavan, T. 1995. Fungal biosorption - An alternative treatment option for heavy metal bearing wastewaters: A review. Bioresour. Technol., 53: 195-206.

Karthikeyan, S., Balasubramanian, R. and Iyer, C.S.P. 2007. Evaluation of marine algae *Ulva fascita* and *Sargassum* sp. for the biosorption of Cu(II) from aqueous solution. Biores. Technol., 98: 452-455.

Low, K.S., Lee, C.K. and Liew, S.C. 2000. Sorption of cadmium and lead from aqueous solutions by spent grain. Process Biochem., 36: 59-64.

Matheickal, J.T. and Yu, Q. 1997. Biosorption of lead (II) from aqueous solutions by *Phellinus badius.* Miner. Eng., 10(9): 947-957.

Say, R., Denizil, A. and Arica, M.Y. 2001. Biosorption of cadmium (II), lead (II) and copper (II) with filamentous fungus *Phanerochaete chrysosporium.* Bioresour. Technol., 76: 67-70.

Selatnia, A., Boukazoula, A., Kechid, N., Bakhti, M.Z., Chergui, A. and Kerchich, Y. 2004. Biosorption of lead (II) from aqueous solution by a bacterial dead *Streptomyces rimisus* biomass. Biochem. Engg. J., 19: 127-135.

Sheng, P.S., Ting, Y.P., Chen, J.P. and Hong, L. 2004. Sorption of lead, copper, cadmium, zinc and nickel by marine algae biomass: Characterization of biosorptive capacity and investigation of mechanisms. J Colloid Interface Sci., 275: 131-141.

Uluozlu, O.D., Sari, A., Tuzen, M. and Soylak, M. 2008. Biosorption of Pb(II) and Cr (III) from aqueous solution by lichen (*Parmelina tiliaceae*) biomass. Bioresour. Technol., 99(8): 2972-80.

Yan, G. and Viraraghavan, T. 2003. Heavy metal removal from aqueous solution by fungus *Mucor rouxii.* Water Res., 37: 4486-4496.