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A study on lead adsorption by *Mucor rouxii* biomass

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ABSTRACT

Removal of lead from its aqueous solutions by adsorption on different biomasses was studied. *Mucor rouxii* biomass (MRB) had been found to be the most efficient in this respect and removed more than 90% of lead from its aqueous solution. Adsorption of lead by the biomass was dependent on pH and temperature. Maximum sorption was noted at the pH range of 5.0–6.0 and an increase in temperature above 30 °C resulted in the decrease in adsorption indicating the exothermic nature of the process. The adsorption process was very fast initially, and around 70% of the total adsorption was completed within the first 10 min. The process is found to follow the pseudo second order rate kinetics throughout the period. Langmuir isotherm model fitted well to describe the isotherm data. Scanning electron micrographs showed homogeneous accumulation of lead ions on the surface of the biomass. From the FTIR study, involvement of various functional groups like amine, carboxyl, phosphate, etc. for the binding of lead ions was evident. Blocking of these functional groups indicated major involvement of phosphate group for metal ions binding. Lead ions could be desorbed from the loaded biomass with elution with 0.1 M hydrochloric acid.

1. Introduction

Increased industrialization and human activities have imposed negative impact on the environment through the disposal of waste containing heavy metals. Many industries especially metal industries, electroplating, battery manufacturing, pigment and dye industries, lead smelting and internal combustion engine fueled with leaded petroleum etc. discharge lead as a waste to the environment [1]. Lead is extremely toxic even at low concentrations, and can damage the nervous system, reproductive system and kidneys particularly in children [2]. Concentration of lead in the industrial effluent must be brought down to 0.1 mg/L as per instruction of EPA before discharge into the surface water [3].

Conventional methods for removing lead from wastewater include precipitation, ultra filtration and wall processes including reverse osmosis [4,5]. However, such processes have limitations because they are either expensive or inadequate to meet the present environmental regulations particularly when the permissible limit is too low. Moreover, in most cases they generate huge amount of toxic metal bearing sludge, which is difficult to dispose [6,7].

Therefore, an alternative technology is required to reduce the level of metal ion concentration from the effluent to the permissible limit. In this respect, removal of metal ion through adsorption technique has been gaining importance recently [8]. This method generates low amount of metal bearing sludge; moreover metal can be desorbed from the loaded adsorbents by simple elluents and can be reused. Activated carbon is the best choice in this regard but high cost restricts its use in many countries including India [9]. Hence there is a need to search for new adsorbents, especially of biological origins [10]. Among different biosorbents, fungal biomass has certain advantages over other as regard to cost effectiveness, adsorption capacity and specificity [11]. The aim of this work is: (1) to screen different dead fungal biomass for removal of lead from its aqueous solution, and (2) to study the effect of physicochemical parameters on the adsorption process by the most potent biomass.

2. Methods and materials

2.1. Microorganism

Mucor rouxii (MTCC 386), *Rhizopus oryzae* (MTCC 262), *Pleurotus sajor-caju* (MTCC 141), *Aspergillus viridie* (MTCC 1782) used in this study were obtained from the Institute of Microbial Technology, Chandigarh, India. The strains were maintained on potato dextrose agar slant, and subcultured at regular interval of 30 days.

2.2. Chemicals

All chemicals and dehydrated microbiological media used in this study were obtained from E. Merck, Germany, and Hi media, India, respectively.

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2.3. Production of microbial biomass

Fungi were grown in potato dextrose broth (PDB) taken in 100 mL volumes in 250-mL Erlenmeyer flasks, and inoculated with 0.1 mL spore suspension (5×10^6 spores/mL) as described by Chatterjee et al. [12], in potato dextrose broth for 72 h. The flasks were incubated at 30 °C with agitation (120 rpm) for 72 h. At the end of incubation mycelia were harvested by filtration, washed with deionized water, dried by soaking in blotting paper, cut into small pieces, and used as live biomass for adsorption studies. Dead biomass was prepared by autoclaving the flasks at 121 °C for 15 min before harvesting the mycelia. Moisture content of the biomass was determined by drying at 70 °C till constant weight.

2.4. Preparation and estimation of lead solution

Stock solution of lead (1000 mg/L) was prepared by dissolving required amount of lead nitrate in deionized water and diluted to get the desired concentrations of the metal. Concentration of lead was measured by atomic absorption spectrophotometer (Varian Spectra AA 55). Amount of lead adsorbed by one gram of the biomass was calculated using the mass balance equation:

$$q = \frac{(C_o - C_e) \times V}{1000 \times W}$$

where q is the amount of metal uptake (mg/g), C_e and C_o are the respective final and initial metal ion concentration (mg/L), W is the amount of biomass (g) and V is the volume of the solution (L).

2.5. Screening of adsorbents

To different 250-mL Erlenmeyer flasks containing 50 mL of lead solution (100 mg/L, pH 5.0), 0.25 g (dry wt) of different adsorbents were added. Flasks were incubated at 30 °C with shaking (120 rpm) for 24 h, which is expected to be far beyond the equilibrium time. At the end of incubation, biomass was separated by centrifugation and concentration of lead in the supernatant was measured as described above.

2.6. Effect of pH and temperature

The effect of pH and temperature on adsorption of lead by *M. rouxii* biomass (MRB) was conducted as described above, over a pH range 2.0–6.0 at 30 °C, and 30–70 °C at pH 5.0, respectively. Initial concentration of lead was 100 mg/L.

2.7. Equilibrium adsorption study

50 mL solution containing varying amount of lead ions (10–500 mg/L) was taken in different 250-mL Erlenmeyer flasks. 0.25 g of dry MRB was added to each flask and incubated at 30 °C (pH 5.0) in a rotary shaker (120 rpm) for 24 h. Biomass was separated by centrifugation (10,000 rpm for 15 min), and concentration of lead in the supernatant was determined.

2.8. Kinetic study

Kinetic experiments were carried out with 50 mL lead solution (100 mg/L) at pH 5.0 and temperature 30 °C. Other experimental conditions were the same as described above. The residual metal ion concentration in the supernatant was determined by withdrawing samples at different time intervals. Each of the data was obtained from individual flask, and therefore no correction was necessary due to withdrawal of sampling volume.

2.9. Surface morphology observation

The surface morphologies of MRB before and after lead adsorption were examined with a scanning electron microscope (FESEM, JEOL, JSM-6700F). Samples were platinum-coated by a vacuum electric sputter coater to a finest thickness before glue mounted on it.

2.10. Infrared spectroscopic study

FTIR spectra of MRB before and after adsorption of lead were taken in NICOLET Magma 750 FTIR spectrophotometer in the region of 4000–400 cm^{-1} at a resolution of 4 cm^{-1}. Approximately 40 mg powdered sample was blended with 100 mg spectroscopic grade KBr for the preparation of pallets.

2.11. Chemical modification of MRB and adsorption study

The dried MRB was subjected to chemical treatments for modification of functional groups as described below. The modified biomass was dried, cut into small pieces and used for lead adsorption study with 50 mL of lead solution (100 mg/L) at 30 °C and pH 5.0. The amount of dried biomass taken was 0.25 g.

Triethyl phosphate-nitromethane: 1 g of MRB was refluxed with 25 mL of triethyl phosphate and 20 mL of nitromethane for 6 h.

Formaldehyde-formic acid: 1 g of MRB was refluxed for 4 h with 15 mL of 10% formaldehyde and 30 mL of 50% formic acid.

Methyl iodide: 1 g of biomass was stirred for 4 h at room temperature (30 °C) with 20 mL of methyl iodide.

2.12. Desorption study

Loaded MRB (0.25 g) after adsorption isotherm experiment with 400 mg/L lead was taken in different 100-mL Erlenmeyer flask and 50 mL of 0.1 M aqueous solution of EDTA, HCl, HNO_3, H_2SO_4 and Na_2CO_3 were added separately to either of the flasks. The flasks were agitated (120 rpm) for 3 h at 30 °C, centrifuged and concentration of the lead in the supernatant was estimated.

3. Results and discussion

3.1. Screening of adsorbent

In the first phase of this work, different dead fungal biomass was used to study their adsorption capacity towards lead from its aqueous solution. It was found that the biomass of *M. rouxii* adsorbs 95% of the metal, which was the maximum among all. Other biomasses adsorb 72–91% of the metal ion (Fig. 1). Difference in the adsorption capacity

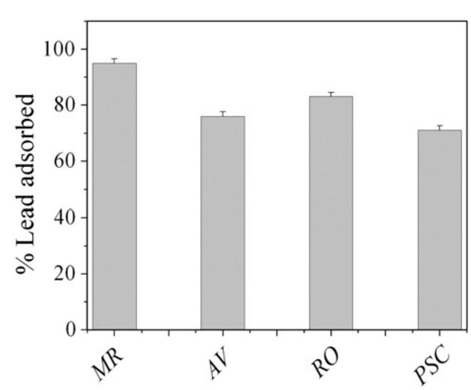

Fig. 1. Adsorption of lead by different biomass, lead concentration 100 mg/L, pH 5.0, biomass concentration 5 g/L and temperature 30 °C. MR — *Mucor rouxii*, AV — *Aspergillus viridie*, RO — *Rhyzopus oryzae*, PSC — *Pleurotus sajor-caju*. Data represent an average of four independent experiments ± SD shown by error bar.