Biosorption of aqueous chromium (VI) by living mycelium of phanerochaete chrysosporium

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In this study the biosorption of Cr(VI) from artificial wastewater onto the living mycelium pellets of white-rot fungi, *Phanerochaete chrysosporium*, was investigated in the batch mode with respect to the contact time and initial metal concentration. Biosorption equilibrium was established after about 120 min.The fungus biomass exhibited the highest sorption capacity of 48.6 mg/g and the removal efficiency was found to be higher at lower initial concentration of the Cr(VI) ion. The adsorption of Cr(VI) followed the Longmuir isotherm over the whole range of initial metal concentration tested (20-500mg/l) and kinetic was found to be best-fit pseudo-second order equation.

Key words: Biosorption, Heavy metal, Chromium, Isotherm, Kinetic, Phanerochaete chrysosporium

1. Introduction

Human activities, such as mining operations and the discharge of industrial wastes, have resulted in the accumulation of metals in the environment.
Many industries such as tannery, coating, car aeronautic and steel industries generate great quantities of wastewater containing various concentrations of Cr .The potential use of microorganisms in the treatment of heavy metal contaminated wastewater and in the recovery of metals in mining wastes or in metallurgical effluents is of special importance.
Conventional methods of treating solutions which contain heavy metals include: precipitation, ionic exchange, reduction process, coagulation, membrane technologies and adsorption in activated coal .These methods are associated with either a high cost or a low efficiency, not guaranteeing the limits of metal concentration demanded by legal standards.
The search for alternative and innovative treatment techniques has focused attention on the use of biological materials such as algae, fungi, yeast and bacteria for the removal and recovery technologies and has gained importance during recent years because of the better performance and low-cost of these biological materials.

So far some studies have been conducted on the biosorption of zinc, cadmium, copper, lead and mercury by P.chrysosporium (Arica, M., Y., Bayramoglu, G (2005) and Park, D., and et al (2005) and Han, X.and et al (2007)), but none of them investigated the biosorption of Cr(VI), the soluble and highly toxic anion [4], from aqueous solutions. The present study aims to confirm the potentialities of this fungal biomass as a cost-effective metal biosorbent for Cr(VI) removal and also explain the adsorption equilibrium by isotherm models.

2. Materials and methods

2.1 Biomass preparation

The white rot basidiomyycete, P.chrysosporium ATCC 24725 was obtained from microbial collection of Iranian Research Organization of Science and Technology. The fungal strain was maintained by subculturing on a 2% YMG agar medium (yeast extract 4g, malt extract 10 g, glucose 6g per liter of distilled water, pH=6.0).The fungus was grown on YMG agar for 5 days at 27°C and a small portion (0.5cm×1cm) of the agar medium covered with the fungus was cut into 0.2cm × 0.2cm pieces. For the preparation of an aqueous fungal suspension, the small pieces were transferred to 150 ml of YMG broth in a 500 ml Erlenmeyer flask and incubated at 27°C on a shaker incubator (Kuhner ISF-W) at 150 rpm and 27°C. After 5 days 3-5 fungal pellets were formed. Mycelium pellets were harvested from the medium, washed twice with distilled water and stored at 4°C until metal adsorption.

2.2 Metal solution

Standard stock solutions of Cr(VI) was prepared with $K_2Cr_2O_7$ salt from Merck and was used to make the required concentrations metal ion.

2.3 Biosorption tests

The biosorption capacity of biosorbent was determined by contacting a known amount of metal solution (100mg/l) in 250 ml flasks and incubating with biosorbent on an orbital shaker at 100 rpm and room temperature. Biomass was then removed from metal solution by centrifugation at 5000 rpm for 5 min.

Residual metal concentration in the metal supernatant solutions were determined spectrophotometrically (540 nm) after complexation with 1, 5 diphenyl carbazide. The amount of absorbed metal ions per g biomass was obtained by using the following expression.

$$Q= [(Co-C).V] /M$$

Where Q is the amount of metal ions adsorbed on the biomass (mg/g dry weight of fungal pellets).Co and C are the concentrations of the metal ions in the solution (mg/l) initially and after biosorption.V is the volume of the medium (ml) and M is the dry weight of fungal biomass.

3. Results and Discussion

3.1 Effect of contact time on biosorption

Fig. 1 shows the effect of reaction time on the biosorption of Cu(II) and Cr(VI) by biosorbent from aqueous solutions. The rate of metal biosorption by the living biomass was rapid in the first 30 min of contact, accounting about 80.4% and 77.3% of sorption for Cu(II) and Cr(VI), respectively. Time required for attaining equilibrium for both metal ions was about 120 min.

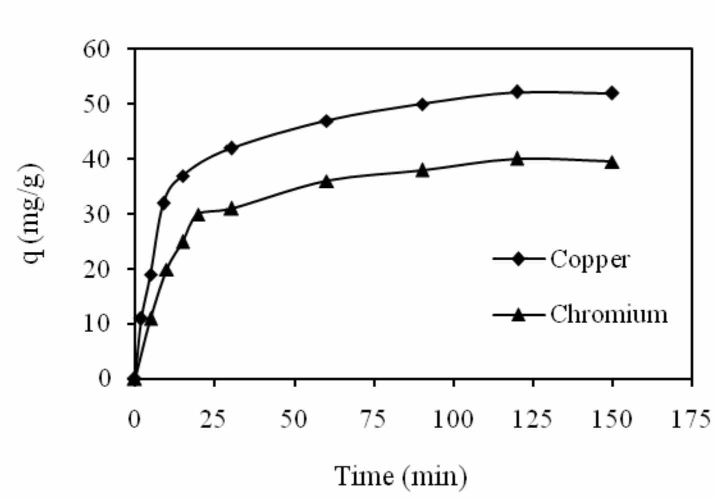


Fig. 1. Time-course profiles for Cu(II) and Cr(VI) biosorption by fungal pellets.

3.2 Effect of initial metal ion concentration on biosorption

Heavy metal ion biosorption capacities of fungal biomass are presented as a function of the initial concentration of Cu(II) and Cr(VI) ions within the aqueous solution in Fig. 5. These experiments were performed using single solutions (20-500 mg l^{-1}) of the metal ions at optimum pH. The amount of metal ions adsorbed per unit mass of biosorbent increases with an increase in initial metal ion concentration. This could be due to an increase in electrostatic interactions (relative to covalent interactions), involving sites of progressively lower affinity(Iqbal, M., Edyvean, R.G.J.(2004)). Moreover, higher initial concentration provides increased driving force to overcome all mass transfer resistance of metal ions between the aqueous and solid phases resulting in higher probability of collision between Cu(II) and Cr(VI) ions and sorbents. This also results in higher metal uptake.

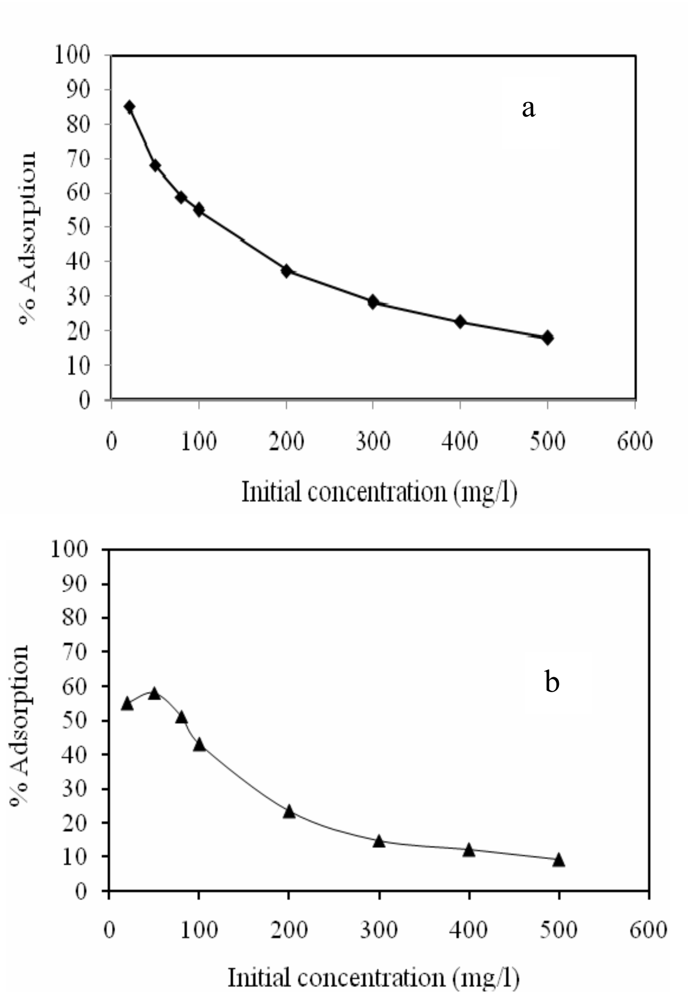


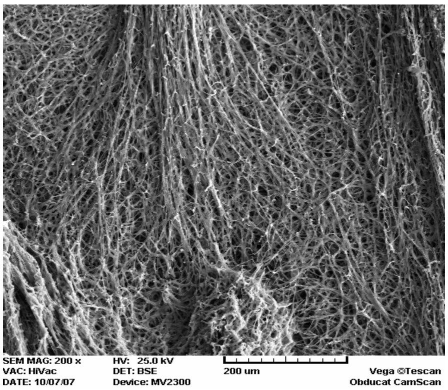
Fig. 2. Effect of initial metal on concentration on percentage adsorption of (a) Cu (II) and (b) Cr (VI).

3.3 SEM studies results

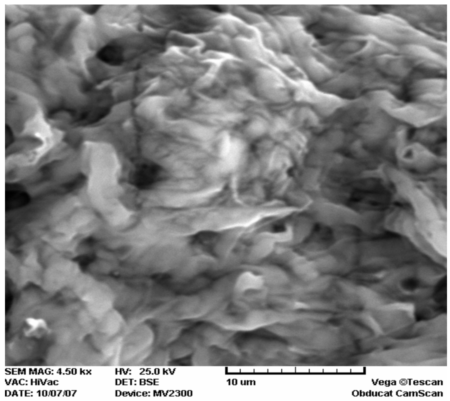
SEM micrographs of the hyphae of fresh pellets and Cu (II) and Cr(VI) loaded pellets are compared in Fig. 3. The fresh pellets had a highly porous mycelium matrix and their large surface areas were clean for metal uptake.

In living cells the sorption mechanisms include both metabolism dependent and independent processes. Metabolism independent uptake process essentially involves cell surface binding through ionic and chemical interaction, while dependent process deals with the binding of both the surfaces followed by intracellular accumulation.

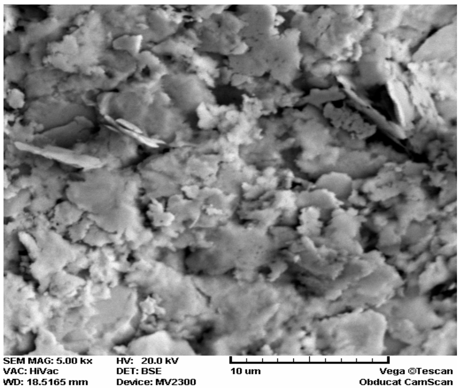
The appearance of the hyphae loaded with chromium is completely different from that of copper implying different biosorption mechanism such as complexation and precipitation in addition to ion exchange.



(a)



(b)



(c)

Fig. 3. Scanning electrn micrographs of fungal hyphae; (a) fresh pellets, (b) copper loaded pellets, (c) chromium loaded pellets.

4. Conclusions

The experiments conducted with the biosorption showed that *Phanerochaete chrysosporium* can remove Cu (II) and Cr (VI) by biosorption. Living mycelium of white-rot fungus exhibited the highest copper and chromium adsorption capacity of 90.6 and 48.6 mg/g. The sorption capacity was found to increase with increase of solute concentration. The biosorbent has the potential to be used in industrial wastewater treatments, since the fouling and structure damage are not problems of the living fungal mycelium (Sing, C., Yu, J (1998)).

5. References

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