

Yeast-Based Magnetic Bionanocomposite for the Removal of Zn(II) in aqueous medium

J.C. José¹, T.E. Abilio¹, B.C. Soares¹, G. Labuto², E.N.V.M. Carrilho^{1,3}

¹Laboratory of Polymeric Materials and Biosorbents, Federal University of São Carlos, Araras – SP, 13604-900 – Brazil

²Department of Chemistry – Federal University of São Paulo, Diadema – SP, 09913-030 – Brazil

³Department of Natural Sciences, Mathematics and Education – Federal University of São Carlos, Araras – SP, 13604-900 – Brazil

Keywords: biosorption, zinc, ferromagnetic nanoparticles, *Saccharomyces cerevisiae*.

Presenting author email: elma.carrilho@gmail.com

1. Introduction

Biosorption has been considered an economical and environmentally viable alternative for the remediation of contaminated aquatic environments due to its high metal ion removal capacity (Volesky, 2004). It is a process that uses biomasses from biological waste, such as yeasts (*Saccharomyces cerevisiae*) discarded by the sugar-alcohol industries. The process occurs by the interaction between the biomass and the metal ions, due to the active sites available in the cell wall of the biosorbent (Fomina and Gadd, 2014). Therefore, due to the amount of this residue generated and its high capacity as biosorbent, this work proposes the use of yeast biomass (YB) (Debs et al., 2019). In addition, there was the impregnation of YB with ferromagnetic nanoparticles due to the superparamagnetic properties that it offers (Carantu et al., 2007), making the materials feasible for effluent decontamination. In this work, a composite was synthesized by impregnation of Fe₃O₄ to the yeast biomass, in order to test the sorption capacity of the biosorbent for Zn(II). *In natura* and nanomodified materials were used to investigate the effect of the magnetization of the biomass on the sorption efficiency.

2. Material and Methods

Synthesis of the yeast bionanocomposite: The yeast biomass was acquired as a byproduct from a sugarcane and alcohol industry (Biorigin Company-São Paulo, Brazil). This material was used as *in natura* and nanomodified with magnetite. The reagents used for the synthesis of the magnetic materials and the preparation of the Zn(II) solution were HCl, NH₄OH, FeCl₃·6H₂O, FeSO₄·4H₂O and ZnSO₄·7H₂O (LabSynth-São Paulo, Brazil). The magnetite nanoparticles (MNP) were synthesized by the coprecipitation method (Labuto et al., 2018; Panneerselvam et al., 2011). For this purpose, solutions of Fe(II) and Fe(III) were prepared in 1.0 mol L⁻¹ HCl medium and mixed. To this solution, NH₄OH 0.7 mol L⁻¹ was added slowly under constant stirring. The synthesis of the yeast bionanocomposite (YB-MNP) was performed by adding yeast biomass (YB) into the MNP suspension, kept under heating and constant stirring, and the resulting material was dried before use.

Point of zero charge (pH_{PZC}) and pH assessment: The preliminary study of the biomass surface characterization was determined by the pH at the point of zero charge (pH_{PZC}). This test was performed using 10 mL of 0.1 mol L⁻¹ NaCl solution at initial pH values ranging from 2.0 to 12.0, adjusted with 0.1 mol L⁻¹ HCl or 0.1 mol L⁻¹ NaOH solutions. The saline solution containing 10 mg of the adsorbent (YB or YB-MNP) was kept under constant stirring at 185 rpm for 24 h. The pH value corresponding to the pH_{PZC} was determined by the graphical representation of the initial pH variation as a function of the final pH. Sorption of metal ions at pH values higher than the pH_{PZC}, such as 5.5, 6.0, and 6.5, was evaluated by mixing 0.5 g of YB or YB-MNP with 10 mL solution of 100 mg L⁻¹ Zn(II). These mixtures were kept under stirring for 10 min at 185 rpm and the supernatant was analyzed for zinc determination by Flame Atomic Absorption Spectroscopy (FAAS, AAnalyst 400, PerkinElmer, USA). With this, it becomes possible to note the pH at which the adsorption process occurs most efficiently. This experiment was performed in triplicate.

Kinetics of sorption: The equilibrium time was determined by assessing the kinetics of Zn(II) sorption mixing 1 g of YB or YB-MNP and 40 mL of 100 mg L⁻¹ Zn(II) solution at pH 6.0 under constant stirring at 185 rpm. Aliquots of 5 mL were taken at intervals time of 5, 10, 30, 60, 90, and 120 min for further determination of the remaining zinc content by FAAS. The tests were performed in triplicates.

3. Results and Discussion

The pH_{PZC} for YB and YB-MNP was 5.7 and 6.0, respectively (Fig. 1), and above this pH value the surface of these adsorbents shows negative charges, which would favor the adsorption of Zn(II). Therefore, the best adsorption pH is expected to be at values higher than the pH_{PZC}.

The assessment of pH effect in the sorption process were carried out at pH 5.5, 6.0 and 6.5 for both materials (YB and YB-MNP) and the results are shown in Fig. 2.

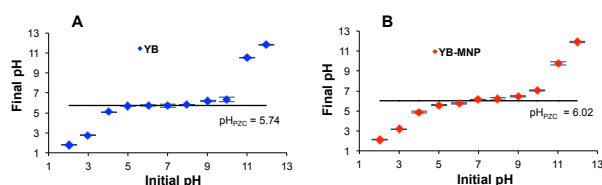


Figure 1. Point of zero charge (pH_{PZC}) of YB, yeast biomass (A) and YB-MNP, yeast bionanocomposite (B). The mass of biomass was 10 mg mixed with 10 mL of 0.1 mol L^{-1} NaCl.

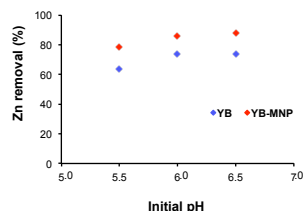


Figure 2. Effect of pH on Zn(II) sorption efficiency by YB (yeast biomass) and YB-MNP (yeast bionanocomposite), using 0.5 g of YB or YB-MNP with 10 mL solution of 100 mg L^{-1} Zn(II).

According to the results shown in Fig. 2, pH 5.5 was slightly less favorable for Zn(II) sorption by YB and YB-MNP (63.6% and 78.2%, respectively), which was expected since the pH_{PZC} was higher. Thus, the best pH values for sorption should be those above 5.7 for YB and 6.0 for YB-MNP, as observed in Figure 1. At pH 6.0 and 6.5 the percentages of Zn(II) sorption by these materials were 73.4% and 73.6% for YB, and 85.9% and 87.6% for YB-MNP, respectively. Therefore, the chosen pH was 6.0 in order to avoid metal precipitation as hydroxides and also due to the fact that contaminated effluents is more likely to show acidic pH. Therefore, sorption tests should be carried out under the lowest pH possible.

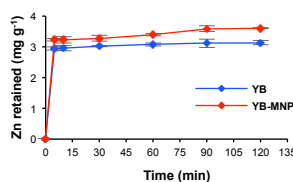


Figure 3. Kinetic of Zn(II) sorption by YB (yeast biomass) and YB-MNP (yeast bionanocomposite) using 1 g of YB or YB-MNP and 40 mL of 100 mg L^{-1} zinc solution at pH 6.0.

According to Fig. 3, it can be observed that the sorption efficiency remained practically constant after the first 5 min of contact, showing 2.94 and 3.23 mg Zn(II)/g biomass for YB and YB-MNP, respectively, presenting fairly similar results for 120 min of contact time (3.14 mg g^{-1} for YB and 3.62 mg g^{-1} for YB-MNP).

4. Conclusion

This study on zinc adsorption was favorable for both materials (YB and YB-MNP), showing higher sorption for YB-MNP at all pH tested. At pH 6.0, the percentage of Zn(II) removal by YB-MNP was 85.9% while 73.4% was found for YB. In addition, the kinetics studies showed a rapid equilibrium for both materials, indicating their promising use in the treatment of effluents contaminated with metal ions.

5. References

- Caruntu, D.; Caruntu, G.; O'Connor, C. J. Magnetic properties of variable-size Fe_3O_4 nanoparticles synthesized from non-aqueous homogenous solutions of polyols. *J. Phys. D: Appl. Phys.*, 40, 5801-5809, 2007.
- Debs, K. B.; Cardona, D. S.; Silva, H. D. T.; Nassar, N.; Carrilho, E. N. V. M.; Haddad, P. S.; Labuto, G. Oil spill cleanup employing magnetite nanoparticles and yeast-based magnetic bionanocomposite. *J. Environ. Manage.*, 230, 405-412, 2019.
- Fomina, M.; Gadd, G. M. Biosorption: current perspectives on concept, definition and application. *Bioresour. Technol.*, 160, 3-14, 2014.
- Labuto, G.; Cardona, D. S.; Debs, K. B.; Imamura, A. R.; Bezerra, K. C. H.; Carrilho, E. N. V. M.; Haddad, P. S. Low cost agroindustrial biomasses and ferromagnetic bionanocomposites to cleanup textile effluents. *Desalin. Water Treat.*, 12, 80-89, 2018.
- Panneerselvam, P.; Morad, N.; Tan, K. Magnetic nanoparticle (Fe_3O_4) impregnated onto tea waste for the removal of nickel (II) from aqueous solution. *J. Hazard. Mater.*, 186, 160-168, 2011.
- Volesky, B. *Sorption and biosorption*. BV-Sorbex, Inc., St. Lambert, Quebec, 2004.