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

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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 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.

Point of zero charge (pH\textsubscript{PZC}) and pH assessment: The preliminary study of the biomass surface characterization was determined by the pH at the point of zero charge (pH\textsubscript{PZC}). This test was performed using 10 mL of 0.1 mol L\textsuperscript{-1} NaCl solution at initial pH values ranging from 2.0 to 12.0, adjusted with 0.1 mol L\textsuperscript{-1} HCl or 0.1 mol L\textsuperscript{-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\textsubscript{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\textsubscript{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\textsuperscript{-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\textsuperscript{-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\textsubscript{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\textsubscript{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.
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.

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


