

# Competitive adsorption of Cr(VI) and Zn(II) ions in aqueous medium applying a biosorbent based on *Saccharomyces cerevisiae* residues and ferromagnetic nanoparticles

J. C. José<sup>1</sup>, G. Z. Beretta<sup>1</sup>, E. N. V. M. Carrilho<sup>1,2\*</sup>

<sup>1</sup>Laboratório de Materiais Poliméricos e Biossorbentes, Universidade Federal de São Carlos, 13600-970 Araras, SP, Brazil.

<sup>2</sup>Departamento de Ciências da Natureza, Matemática e Educação, Universidade Federal de São Carlos, 13600-970 Araras, SP, Brazil.

Keywords: biosorption; water treatment; magnetite; chromium, zinc; yeast biomass

\*Presenting author e-mail: [elma.carrilho@gmail.com](mailto:elma.carrilho@gmail.com)

## Introduction

The term “biosorption” indicates the occurrence of an adsorption mechanism using biomasses from microbial organisms, plants, animals, or their derivative products. *Saccharomyces cerevisiae* from the sugar and alcohol industry is a biomass of significant potential for biosorption (JOSÉ et al., 2019; DEBS et al., 2019), low added value, and great availability in nature. Such residues are favorable for the process because they contain active sites that can perform the adsorption process of pollutants in contaminated environments. Due to the importance of water resources, pollution in aqueous matrices stands out due to the highly adverse impacts. Emerging pollutants, such as heavy metals, dyes, drugs, and pesticides, are primarily responsible for effluent contamination since they cannot be degraded naturally, becoming harmful to living beings when they accumulate (GEISSEN et al., 2015). Thus, this work proposes the use of yeast biomass (YB), its magnetic nanomodified form (YB-MNP), and magnetite (MNP) for comparison purposes. All materials were tested for Cr(VI) and Zn(II) simultaneous adsorption in aqueous medium.

## Methods

**Synthesis of magnetite (MNP) and nanomodified yeast biomass (YB-MNP):** By applying the coprecipitation method (Panneerselvam et al., 2011), a solution prepared from FeSO<sub>4</sub> and FeCl<sub>3</sub> was used to synthesize the magnetic nanoparticle (MNP), after which powdered yeast biomass (YB) was added to the this suspension in a 5:1 YB:MNP ratio. The mixture was heated to 80 °C under constant agitation to form the magnetic bionanocomposite YB-MNP.

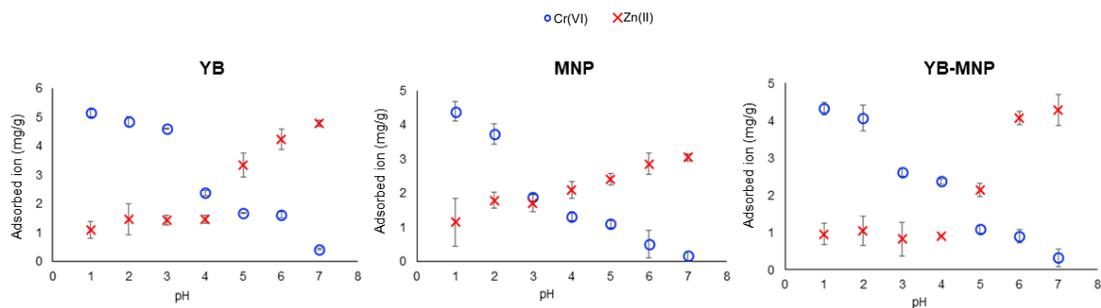
**pH assessment:** Based on previous studies on sorption pH for Cr(VI) and Zn(II), it was decided to adjust the pH values of a bielement solution containing both 100 mg/L of Cr(VI) and Zn(II) for 1, 2, 3, 4, 5, 6 and 7, to evaluate competitive sorption at pHs favorable to the removal of Cr(VI) (below pH<sub>PZC</sub>) and suitable to the removal of Zn(II) (above pH<sub>PZC</sub>). For this, YB, MNP, or YB-MNP were used in a dosage of 2.5 g/L. Then, supernatants were analyzed by Flame Atomic Absorption Spectrometry – FAAS.

**Kinetic study:** To evaluate the competitive sorption kinetics, 2.5 g/L YB, MNP, or YB-MNP dosage was mixed with 100 mg/L Cr(VI) and Zn(II) bielement solutions at pH 2 and 6. After increasing contact times (5, 10, 30, 60, 90, 120, and 150 min) between adsorbent and adsorbate, the supernatants were collected and analyzed by FAAS.

**Sorption capacity (SC<sub>exp</sub>):** In the sorption capacity competitive tests of Cr(VI) and Zn(II), 2.5 g/L dosage of YB, MNP, or YB-MNP were used. The pH of the bielement solutions at increasing concentrations (25, 50, 75, 100, 125, 150, 175, and 200 mg/L of each ion) was adjusted to 2 and 6. Thus, the suspensions were kept under constant agitation until the time previously determined by the kinetic (10 min). After that, the supernatants were removed and analyzed by FAAS. All tests (pH, kinetic, and SC<sub>exp</sub>) were performed in triplicates.

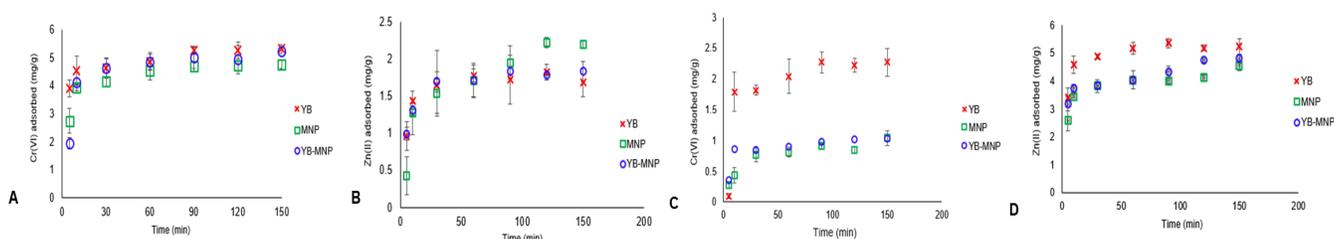
## Results and discussion

From Figure 1, it is possible to notice that, in competitive sorption, the pH values with the best results for Cr(VI) are the ones with the lowest Zn(II) sorption. Similarly, Zn(II) best sorption pH resulted in less efficiency for Cr(VI) removal. This behavior is in accordance with the results obtained for monoelement solutions of Cr(VI) and Zn(II). Since Cr(VI) is present in anionic forms (CrO<sub>4</sub><sup>2-</sup>, Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup> e HCrO<sub>4</sub><sup>-</sup>), it is adsorbed at more acidic pHs. Thus, with the increase in H<sup>+</sup> ions concentration, the surface of the adsorbent is neutralized, reducing the obstacle to the diffusion of the chromium anions in solution (ALOMÁ et al., 2013). On the other hand, with the increase in the pH value, OH<sup>-</sup> concentration is higher, which results in negative charges on the adsorbent surface, causing repulsion against the negative charge of Cr(VI) species (ABILIO et al., 2021). Thus, for Cr(VI), adsorption is favored in more acidic pH. By knowing that, as the pH increases, the material's surface becomes more negatively charged, favoring attraction for Zn(II) ions in its cationic form.



**Figure 1.** Effect of pH on the sorption efficiency of Cr(VI) and Zn(II) by yeast biomass (YB), ferromagnetic nanoparticles (MNP), and magnetic bionanocomposite (YB-MNP) using a dosage of 2.5 g/L of YB, MNP, or YB-MNP and a 100 mg/L Cr(VI) and 100 mg/L Zn(II) solution. n = 3.

After the competitive pH test, it was observed that it would be more interesting to perform the adsorption kinetics at both pH values to favorable adsorption of Cr(VI) and Zn(II) for both, respectively at pH 2 and 6. From Figure 2, it can be seen that after 10 min, sorption remains practically constant for all materials. The choice of an adsorbent highly depends on the adsorption kinetics since the faster the removal of pollutants from the medium, the more favorable the process will be.



**Figure 2.** Experimental data of adsorption kinetics of Cr(VI) at pH 2 (A), Zn(II) at pH 2 (B), Cr(VI) at pH 6 (C) and Zn(II) at pH 6 (D). The adsorbents used were yeast biomass (YB), ferromagnetic nanoparticles (MNP) and magnetic bionanocomposite (YB-MNP) at 2.5 g/L dosage and 100 mg/L Cr(VI) or Zn(II) solution. n = 3.

Chromium(VI) sorption capacity for all materials, at pH 2, was higher ( $6.07 \pm 0.24$  mg/g for YB,  $5.04 \pm 0.05$  mg/g for MNP and  $5.37 \pm 0.43$  mg/g for YB-MNP), showing a decrease at pH 6 ( $1.93 \pm 0.49$  mg/g for YB,  $1.58 \pm 0.16$  mg/g for MNP and  $1.32 \pm 0.31$  mg/g for YB-MNP). As for Zn(II) at pH 2, a decrease in the sorption capacity was observed for all materials ( $2.33 \pm 0.23$  mg/g for YB,  $2.86 \pm 0.28$  mg/g for MNP, and  $2.05 \pm 0.12$  mg/g for YB-MNP), increasing dramatically at pH 6 ( $11.42 \pm 0.49$  mg/g for YB,  $9.54 \pm 0.77$  mg/g for MNP, and  $12.86 \pm 0.06$  mg/g for YB-MNP).

### Conclusion

It is possible to conclude that all investigated materials exhibit promising results for decontamination of aquatic environments, mainly YB-MNP, under the studied conditions. As a modified biological residue, the incorporated magnetic properties allow the easier removal of the material from the medium after sorption.

### Acknowledgments

Authors are grateful to Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP, Grants# 2016/06271-4 and 2019/08335-8) for the financial support provided. We thank Dr Geórgia Labuto for providing the yeast biomass.

### References

- Abilio, T. E. et al. Hexavalent chromium removal from water: adsorption properties of *in natura* and magnetic nanomodified sugarcane bagasse. *Environ Sci Pollut Res*. <https://doi.org/10.1007/s11356-020-11726-8>. 2021.
- Alomá, I. C et al. Biosorption of  $\text{Cr}^{6+}$  from aqueous solution by sugarcane bagasse. *Desalin Water Treat*, v. 52, p. 31–33, 2013.
- Debs, K. B. et al. Oil spill cleanup employing magnetite nanoparticles and yeast-based magnetic bionanocomposite. *J Environ Manage*, v. 230, p. 405-412, 2019.
- Geissen, V. et al. Emerging pollutants in the environment: A challenge for water resource management. *Int Soil Water Conserv Res*. v. 3, n. 1. p. 57–65, 2015.
- José, J. C., Debs, K. B., Labuto, G., Carrilho, E. N. V. M. Synthesis, characterization and application of yeast-based magnetic bionanocomposite for the removal of Cu(II) from water. *Chem Eng Commun* 206(11): 1581–1591, 2019.
- Panneerselvam, P., Morad, N. Tan, K. Magnetic nanoparticle ( $\text{Fe}_3\text{O}_4$ ) impregnated onto tea waste for the removal of nickel(II) from aqueous solution. *J Hazard Mater* 186:160–168.