

# The potential of *in natura* and magnetic nanomodified hydroponic lettuce roots for Cr(VI) removal in aqueous medium

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## Introduction

The increase in industrialization is an aggravating factor for environmental degradation, mainly due to the disposal of improperly contaminated effluents (Dhankhar and Hooda 2011). Among the most harmful contaminants are potentially toxic metals, which can pose severe risks due to their bioaccumulation and persistence in the environment. Several anthropogenic sources introduce Cr(VI), a toxic, carcinogenic metal, into effluents (Jobby et al., 2018). Among the methods for removing these contaminants from the environment, biosorption has been an attractive alternative. It is a process that uses biomasses, such as lettuce roots, which have low added value, for the adsorption of pollutants. Some modifications can be used to biomass to improve and facilitate the biosorption process, such as magnetic nanoparticles (Abilio et al., 2021; José et al., 2019). Thus, the objective of this work is to use biomass of hydroponic lettuce roots *in natura* and nanomodified, for removal of Cr(VI) species in an aqueous medium, aiming at the remediation of water and effluents.

## Methods

**Preparation of the biomass:** The hydroponic lettuce roots used in the present work were acquired from a greenhouse, cleaned, dried in an oven at 50 °C, and ground to a 0.12 nm particle size.

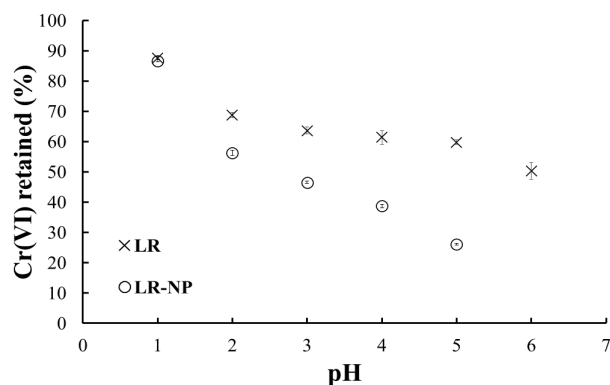
**Preparation of the magnetic materials:** Magnetite (Fe<sub>3</sub>O<sub>4</sub>) nanoparticles (NP) and the nanocomposite LR-NP were synthesized by employing the coprecipitation method (Panneerselvam et al., 2011). This method consists of the dissolution of Fe(II) and Fe(III) salts, at a molar ratio of 1:2, respectively, in an acid medium (HCl 1.0 mol/L). To this solution, 0.7 mol/L NH<sub>4</sub>OH was slowly added under constant stirring for 30 min. Thus, powdered LR biomass was added to this suspension to produce LR-NP in 5:1 LR:NP ratio, under continuous heating and stirring. All reagents (FeCl<sub>3</sub>·6H<sub>2</sub>O, FeSO<sub>4</sub>·4H<sub>2</sub>O, HCl, and NH<sub>4</sub>OH) were PA grade (LabSynth, São Paulo, Brazil).

**Point of zero charge (pH<sub>PZC</sub>) and pH study:** Initially, 0.1 mol/L NaCl solutions with initial pH values ranging from 2.0 to 12.0 were added to the biosorbents LR and LR-NP using 1.0 g/L dosage. The suspensions were left under constant stirring at 185 rpm for 24 hours. After the pH<sub>PZC</sub> determination, pH assessment was performed with 10 mg/L Cr(VI) solutions at pH values ranging from 1.0 to 6.0 adjusted with 1 mol/L HCl or NaOH, using biosorbents dosages of 10 g/L. The suspensions were kept under continuous stirring at 185 rpm for 10 min. The supernatant was separated and analyzed by Flame Atomic Absorption Spectrometry (FAAS). These assays were performed in triplicate.

**Kinetic studies and sorption capacity:** This experiment was conducted using 10 mg/L Cr(VI) solution at pH 1.0 and the biosorbents LR or LR-NP at a dosage of 10 g/L, under constant stirring at 185 rpm. Aliquots were taken at intervals of 5, 10, 30, 60, 90, 120, and 150 min and analyzed by FAAS for Cr determination. The sorption capacity of the biosorbents was determined using a batch procedure, and Cr(VI) solutions were used at increasing concentrations at pH 1.0. The suspensions were kept under constant stirring at 185 rpm for 30 min. The supernatants were analyzed by FAAS for Cr determination.

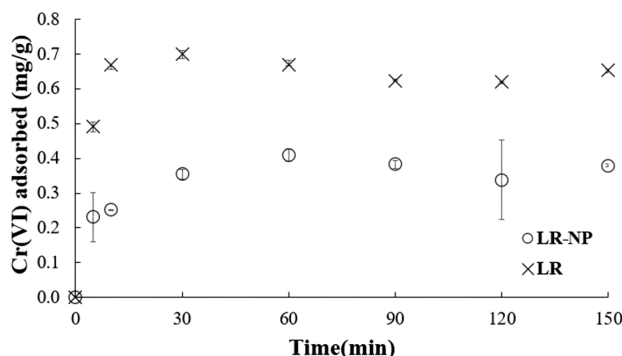
## Results and discussion

The pH<sub>PZC</sub> indicates the pH at which the surface charge of the biosorbent is electrically zero. The pH<sub>PZC</sub> of LR and LR-NP were 5.96 and 6.50, respectively. After the pH<sub>PZC</sub> evaluation, the procedure to determine the effect of pH on the sorption process, the values obtained indicate that the sorption of Cr(VI) by LR and LR-NP was favorable below the pH<sub>PZC</sub>, where the biosorbent surface is positively charged. Above it, the values decreased dramatically. At the lowest value, pH 1.0, both adsorbents showed 87.6% and 86.7% chromium removal by LR and LR-NP, respectively (Fig 1). This efficient sorption was due to the attraction of HCrO<sub>4</sub><sup>-</sup> ions by positively charged functional groups on the surface of the biosorbent.



**Figure 1.** The pH effect on Cr(VI) removal by *in natura* (LR) and nanommodified lettuce roots (LR-NP), using 10 g/L dosages of LR or LR-NP with 10 mg/L Cr(VI) solution. n = 3.

The results of the kinetic study are shown in Fig. 2. It is possible to verify that in the first 5 min of contact time, chromium retention occurs. The equilibrium was reached in 30 min for LR and LR-NP, demonstrating an advantage in using these biosorbents for water decontamination. Chromium sorption capacities for LR, LR-NP, and NP were  $4.51 \pm 0.04$  mg/g,  $3.84 \pm 0.08$  mg/g, and  $2.48 \pm 0.57$  mg/g, respectively.



**Figure 2.** Kinetics of Cr(VI) sorption by *in natura* (LR) and nanocomposite (LR-NP) with 10 g/L dosage, 10 mg/L Cr(VI) solution at pH 1.0. n = 3.

### Conclusion

This study of Cr(VI) sorption by LR and LR-NP proved to be more efficient with decreasing pH with maximum efficiency in pH 1. Among the isotherm models applied to experimental data, Freundlich was the model that best describes the sorption process of the materials LR, LR-NP, and NP. Therefore, the materials used in this work presented an efficient and low-cost alternative for removing Cr(VI) from water.

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