Valorization of chestnut shell for the removal of heavy metals under real conditions

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Introduction: Sediments as the source and storage of heavy metals plays a significant role in their migration and as well transformation [1]. Heavy metals pollution is a worldwide problem through their migration and hazardous effect on the normal functions of rivers and lakes.So, it is of great importance to find suitable method for their removal from contaminated waters. The current study aimed to investigate removal of Cu(II), Cr(III, Pb(II) and U(VI) by means of biosorption. As a medium from which removal of metal ions was performed was used modelled solution to mitigate real conditions. As a novel biosorbent was used chestnut shellwhich characherization was performed by FTIR, EDXRF, physico-chemical analysis, Boehm's titration and determination of point of zero charge (pHpzc). Experimentally obtained data were analysed using Langmuir's, Freundlich's and Temkin's isotherm models. Used kinetics models were: pseudo-first order, pseudo-second order and interparticle model of diffusion.

Methods: Individual and simultaneous removal of heavy metal ions (Pb^{2+}, Cu^{2+}, Cr^{3+}andUO_2^{2+})using chestnut shellwere investigated in stationary conditions by batch method. The selected process parameters were optimized: pH values, sorbent mass, contact time, and initial metal concentration. Concentration of U(VI) was determined by UV-Vis spectrophotometric method and of other heavy metals by FAAS method. Removal efficiency (R_e) were determined by Eq.(1) [3]:

$$R_e = \frac{c_i - c_f}{c_i} \times 100\ \% \qquad (1)$$

Results: Point of zero charge was determined with the value of 4.64 and pH value of the powdered chestnut shell suspension was 4.49. Boehm's titrations showed that total content of acidic and basic functional groups was 2.91 mmol/g and 0.12 mmol/g. By EDXRF analysis, it was determined that chestnut shell contains heavy metals such as Mn, Fe, Ni, Cu, Zn and Pb, with the highest concentration of Fe (243.40 ppm). Optimal conditions for the removal of heavy metal ions with chestnut shell-based biosorbent were pH 5, sorbent mass 100 mg, contact time 30 minutes and initial concentration of each of the analyzed metals 20 mg/L. Adsorption isotherm models showed the best agreement with the Langmuir model for all metals.

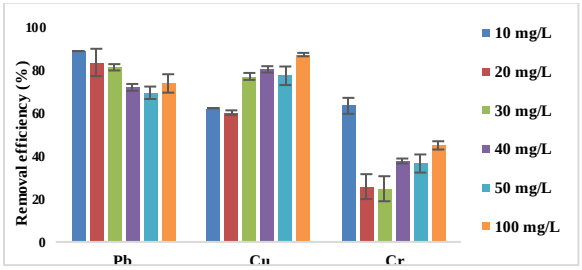

Fig. 1: Change in the value of removal efficiency with the initial concentration of Pb, Cu and Cr ions from a multicomponent solution during the biosorption process on the chestnut shell biosorbent.

Discussion: Analysis of the structural composition of chestnut showed that biosorbent is mainly composed of cellulose and lignin, which provides mechanical and chemical stability to its structure biosorbents. The cellulose content was 18.66% and lignins 36.20%. According to the pHpzc value obtained for chestnut shell (4.64), it can be concluded that it has a cation exchanger properties in a wider pH range.Additionally, characterization by FTIR spectroscopy revealed characteristic bands (C-O, O-H,C-H) attributed to cellulose, lignin and phenolic compounds [5]. Through kinetic modeling of the adsorption process, it was established that the sorption mechanism of the mentioned ions is based on a chemical reaction.The addition of U(VI) in a concentration of 10 to 50 mg/L shows an inhibitory effect on the removal efficiency of Cr ions. Chestnut shell proved to be an excellent biosorbent for the removal of Pb ions from a monocomponent solution, and for the removal of Pb and Cu from a multicomponent system, while it does not show significant affinity for Cr and U ions for investigated process parameters.

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