Master's Thesis Engineering Technology

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Optimization of aquatic Cu(II) removal within a competitive metal ion sorption against Cd(II) and Pb(II) on low-cost biomass of artichoke

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Introduction

Cu(II), Pb(II) and Cd(II) are the most abundant heavy metal ions found in industrial wastewaters. Through water streams, they are capable of migrating into ecosystems and accumulate in the human body where their carcinogenic and toxic properties may express. This research on the removal of metal ions from water streams is commissioned by QUIMYTEC and focusses on the optimization of the competitive aquatic Cu(II) sorption against Cd(II) and Pb(II) on low-cost lignocellulosic biomass of artichokes. The sorption mechanism is of high complexity and consist of physio-chemical processes such as surface precipitation, complexation, ion exchange, adsorption and diffusion. The overall ion uptake is mainly generated by the chemical sorption due to a rich variety of functional groups on lignin, cellulose and hemicellulose structures in artichoke biomass as represented in Figure 1.

Materials & Methods

Based on *Taguchi's OA design* methodology, the influence of pH, initial metal concentration and biomass dosage on the sorption mechanism was evaluated. These parameters were selected from the *system* and *parameter* design after preliminary study and subsequently tested at 3 different levels in a 25 °C isothermally performed batch experiment for 24 h. Furthermore, the sorption capacity was introduced as the performance characteristic to be maximized in the Taguchi analysis. Subsequently, the process capacities were calculated from *ICP-OES* responses of the analysed batch sequence and lastly evaluated by the *MiniTab* software. For the equilibrium modelling experiment, the suggested optimal parameter settings from the Taguchi analysis were applied. The experiment was performed in a 1 L batch at room temperature (25 °C). The Cu(II) concentrations before and after equilibrium were determined by using ICP-OES analysis. In this way, linear equilibrium expressions of the Langmuir, Freundlich and Temkin isotherms, as well as pseudo-first and –second order kinetecs, could be set up in order to trace the unknown sorption constants.

Figure 1 – Lignin, cellulose and hemicellulose structures

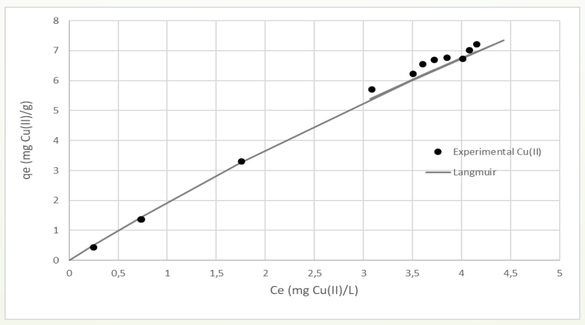

Figure 2 – Langmuir isotherm

Results & Discussion

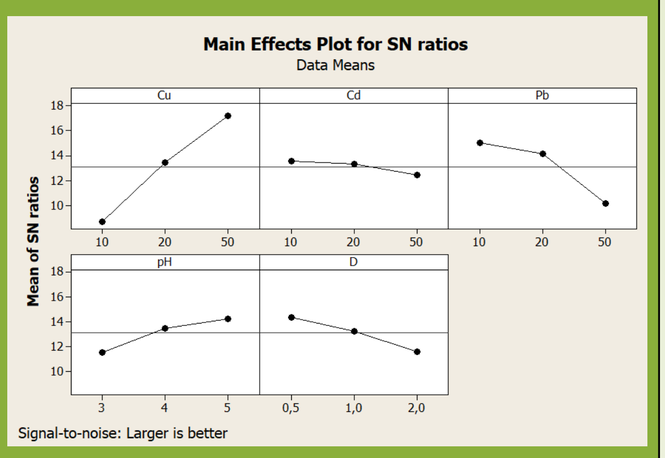

Figure 3 – Main effects plot for SN ratios

Optimal parameter settings, in order to maximize the S/N ratio, were found to be at pH 5, [Cu (II)] 50 mg/L, [Cd (II)] 10 mg/L, and [Pb (II)] 10 mg/L as represented in Figure 3. Only the initial concentrations of Cu (II) and Pb (II) appear to cause a significant main effect on the overall sorption capacity. Moreover, two-factor interactions are not significantly present within the process.

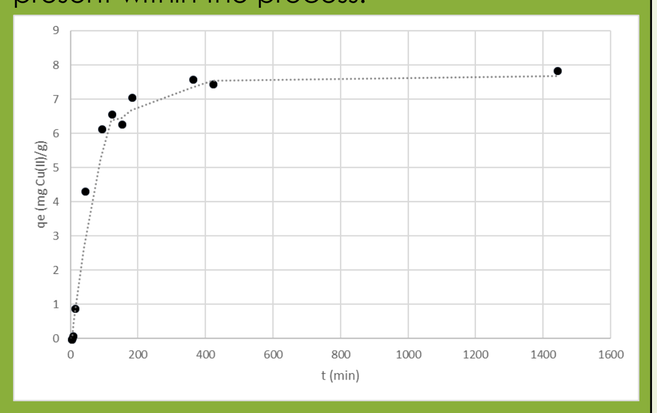

Figure 4 – Pseudo-Second-Order approach

Sorption isotherm models are essential in establishing the most suitable sorption equilibrium behaviour, which is indispensable for a reliable estimation of the sorption parameters. The most accurate approach for the equilibrium conditions was obtained by the Langmuir Isotherm, as shown in Figure 2, followed by the Freundlich and Temkin isotherm. At last, the kinetics of the process were described well by using the pseudo-second-order approach as shown in Figure 4.

Conclusion

From the analysis, it appears that the initial Cu(II) and Pb(II) concentration exert the most import main effects, whilst two-factor interactions between Cu-Cd and Cu-Pb appear to be non-existing. A maximum Cu(II) sorption capacity of 6.77 mg/g was obtained by adding 0.5 g/L biomass and adjusting the pH to 5 in an ionic solution which contained 50 mg/L of Cu(II) and 10 mg/L of Cd(II) and Pb(II). Based on these settings, a kinetic experiment was conducted in order to modulate the evolution towards equilibrium by *Langmuir, Freundlich and Temkin isotherm,* of which the first one fits most precisely, based on its correlation coefficient of 0.967. Furthermore, the evolution towards equilibrium over time was described by pseudo-first and pseudo-second order, of which the pseudo-second order fits the most acucrately due to its correlation coefficient of 0.999.

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