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Kinetic Aspects of the Adsorption of Copper onto Bio-waste Adsorbents

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ABSTRACT

Adsorption kinetics is one of the main factors that must be understood before the applicability of any adsorbent. However, a large majority of the work done in adsorption studies just describe the macroscopic trend of adsorption uptake by using common models, often without careful appraisal of the adsorbent characteristics and validity of the model. Furthermore, adsorption is dependent on factors such as adsorbent and adsorbate type, their properties and operating conditions. Therefore, the aim of this work was to compare and thus, understand the mechanisms and kinetic aspects of copper adsorption using banana and orange peels as adsorbents for future modeling purposes. Furthermore, in order to have insight into and evaluate the kinetics, initial metal concentration, adsorbent dosage, temperature, adsorption type and shaking speed were examined.

The banana and orange peels were characterized by various techniques such as Brunauer-Emmett-Teller (BET), scanning electron microscope (SEM), X-ray diffraction, Fourier transform infrared spectroscopy (FTIR), and titration methods. The results showed that both peels have heterogeneous structures, mesoporous pores and contain different functional groups, with orange peels being acidic and amorphous, whereas banana peels were crystalline and basic. After characterization analysis, the design of experiments (DOE) methodology using two-level five-factor full factorial (2^5) was used in order to determine the relationship between factors affecting the process and the amount of copper adsorbed. In this study, the temperature, initial metal concentration, bio-adsorbent dosage, type of adsorbent and agitation rate were investigated. Furthermore, the significance of each factor and associated interactive effects were evaluated using DOE and percent copper removed was used as the measured response. From the results, initial copper concentration, adsorbent dosage and shaking speed were found to be statistically significant.

These parameters were further optimized using response surface methodology (RSM). Experiments were designed and carried out at various conditions according to the central composite rotatable design (CCRD). The results of the response surface methodology showed that the theoretical optimum conditions for the maximum copper recovery of 84.3% within the range of conditions studied were found to be at an initial metal concentration of 51.3 mg/L, shaking speed at of 146 rpm and adsorbent dosage of 3.5g/L.

The data from RSM was fitted to the Freundlich and Langmuir isotherms. The data of both the orange and banana peels fitted the Langmuir isotherm well with correlation coefficient factors (R^2) greater than 90%. Furthermore, to confirm and support the best fitting model as indicated by R^2, the error statistics were calculated. The highest R^2 values and the lowest values for Chai-square test, sum of squares of the errors and Marquardt's percentage standard deviation were found when modeling the equilibrium data using the Langmuir isotherm. The kinetics of Copper (Cu) ions onto

banana and orange peels were evaluated using reaction-based models namely, pseudo-first- and pseudo-second-order models, and diffusion-based models such as the Weber-Morris, Banghan's pore diffusion model, Boyd model, and Film diffusion model. The results obtained revealed that banana peels showed stronger conformity to both reaction models. The data were further evaluated using diffusion models. The models confirmed the existence of both pore and film diffusion. Lastly, possible governing mechanisms were evaluated. The fitting of the models revealed that there is more than one mechanism responsible for the uptake of copper. Ion-exchange was identified as the dominant mechanism in the copper uptake by both banana and orange peels. Some other types of interactions, like complexation and electrostatic interactions, were also proven to be involved in the adsorption process.