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SUPPLEMENTARY MATERIAL TO

Removal of Fe^{2+}, Zn^{2+} and Mn^{2+} from the mining wastewater by lemon peel waste

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SORPTION ISOTHERMS

Langmuir's isotherm model describes the chemisorption on the homogeneous surface of the sorbent as monolayer sorption without the interaction between the sorbed ions. The linear form of the Langmuir isotherm equation is given in the following equation:[1]

$$\frac{1}{q_e} = \frac{1}{q_{max}} + \left(\frac{1}{q_{max} K_l}\right)\frac{1}{C_e} \tag{S-1}$$

where q_e (mg g^{-1}) is the equilibrium metal ion sorption capacity, C_e (mg L^{-1}) the equilibrium metal ion concentration in solution, q_{max} (mg g^{-1}) is the maximum amount of sorbate sorbed per unit mass of sorbent, and K_l Langmuir sorption constant related to the free energy constant. Higher K_l indicates a higher affinity of sorbent for sorbate.

Freundlich isotherm is an empirical model that describes physisorption on the heterogeneous surface of sorbent, forming of multilayers. A linear form of Freundlich equation is expressed by the following equation:[2]

$$\ln q_e = \ln K_f + \frac{1}{n}\ln C_e \tag{S-2}$$

where K_f is Freundlich sorption constant and n is parameter related to the intensity of adsorption, which varies with the heterogeneity of sorbent. The greater the value of the n, the more favorable is the sorption. The value of K_f and n can be calculated from the intercept and slope of the plot of ln q_e versus ln C_e derived from Eq. (S-2).

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Dubinin–Radushkevich sorption model is usually employed for the description of sorption processes on porous sorbents. The linear form of Dubinin–Radushkevich isotherm is given as following equation:[2]

$$\ln q_e = \ln q_m - \beta\varepsilon^2 \quad \text{(S-3)}$$

where q_m / mg g^{-1} is Dubinin–Radushkevich monolayer capacity, β is parameter related to sorption energy $E = 1/\sqrt{(2\beta)}$ and ε is Polanyi potential, defined as $\varepsilon = RT \ln(1+1/C_e)$, R (8.314 J mol^{-1} K^{-1}) is a universal gas constant, T / K is absolute temperature, and C_e / mg L^{-1} is residual sorbate concentration. The use of this model allows the evaluation of the mean free energy of sorption per molecule of the sorbate. Mean free energy lower than 8 kJ mol^{-1} describes physisorption, rather than ion-exchange 8 kJ mol^{-1} < E < 16 kJ mol^{-1} or chemisorptions E > 16 kJ mol^{-1}.

The Temkin isotherm can give details about the distribution of the binding energies. It is assumed that the heat of sorption of all the molecules in the layer decreases linearly with coverage due to sorbent – sorbate interactions. A linear form of Temkin isotherm can be expressed by the following equation:[2]

$$q_e = B\ln K_t + B\ln C_e \quad \text{(S-4)}$$

where K_t and B are Temkin constants, which correspond to the sorbate–sorbent interactions and the heat of sorption, respectively ($B = -RT / \Delta H$).

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