

1. Kinetics models

Sorption kinetics were investigated to evaluate both the rate of U(VI) sorption and the equilibrium time required for the sorption isotherm. Three adsorption kinetic models, namely pseudo-first-order, pseudo-second-order and intra particle model have been chosen to describe the kinetic data. The pseudo-first-order model is expressed in the following equation:

$$\ln(q_e - q_t) = \ln q_e - k_1 t$$

The pseudo-second-order model is described in the following equation:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e}$$

where q_t and q_e (mg g^{-1}) stand for the amount of U(VI) ions adsorbed on the adsorbents at time t (min) and equilibrium, respectively. $k_1(\text{min}^{-1})$ is the rate constant of the pseudo-first-order model, while k_2 ($\text{g mg}^{-1} \text{min}^{-1}$) is the pseudo-second-order rate constant.

Intra-particle diffusion model was further tested as follows:

$$q_t = k_i t^{1/2} + C$$

where $k_i(\text{mg g}^{-1} \text{min}^{-1/2})$ is the intra-particle diffusion rate constant and C is the thickness of the boundary layer and q_t (mg g^{-1}) stands for the amount of metal ions adsorbed on the adsorbents at time t (min).

2. Isotherm models

The Langmuir isotherm assumes that monolayer adsorption takes place on an adsorbent that have a structurally homogeneous surface, on which the binding sites have the same affinity for the adsorption, and no interaction occurs between adsorbates. The Langmuir model can be represented as:

$$q_e = \frac{q_{max} K_L C_e}{1 + K_L C_e}$$

where C_e is the equilibrium concentration of the adsorbate (mg L^{-1}), q_e is adsorption capacity at equilibrium (mg g^{-1}), q_{max} is the maximum adsorption capacity of the adsorbent (mg g^{-1}) and K_L is the Langmuir adsorption constant related to the energy of adsorption (L mg^{-1}).

The well-known Freundlich isotherm is an empirical equation predicting that the adsorption occurs on an energetically heterogeneous surface, on which the adsorbed molecules are interactive and adsorption capacity is related to the concentration of

adsorbate at equilibrium. The Freundlich model is expressed as:

$$q_e = K_F C_e^{\frac{1}{n}}$$

where K_F and n are the Freundlich constants related to adsorption capacity and intensity, respectively, q_e and C_e are the adsorption capacity at equilibrium (mg g^{-1}) and equilibrium concentrations of adsorbate in liquid phases (mg L^{-1}), respectively.

The Temkin isotherm is based on the assumption that the free energy of adsorption is a function of the surface coverage and takes into account the interactions between adsorbents and adsorbates. The isotherm model is written as

$$q_e = \frac{RT}{b_T} \ln(a_T C_e)$$

where R is the ideal gas constant ($8.314 \text{ J mol}^{-1} \text{ K}^{-1}$), T is the absolute temperature (K), a_T is the equilibrium binding constant corresponding to the maximum binding energy and b_T is the Temkin isotherm constant.