

SUPPLEMENTARY MATERIAL TO

**Removal of Fe<sup>2+</sup>, Zn<sup>2+</sup> and Mn<sup>2+</sup> ions from the mining wastewater by lemon peel waste**

SLADJANA MESELDZIJA<sup>1\*</sup>, JELENA PETROVIC<sup>1</sup>, ANTONIJE ONJIA<sup>2</sup>, TATJANA  
VOLKOV-HUSOVIC<sup>2</sup>, ALEKSANDRA NESIC<sup>1</sup> and NIKOLA VUKELIC<sup>3</sup>

<sup>1</sup>*University of Belgrade, Vinca Institute of Nuclear Sciences, Belgrade, Serbia*

<sup>2</sup>*University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia*

<sup>3</sup>*University of Belgrade, Faculty for Physical Chemistry, Belgrade, Serbia*

*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:<sup>1</sup>

$$\frac{1}{q_e} = \frac{1}{q_{\max}} + \left( \frac{1}{q_{\max} \cdot K_l} \right) \cdot \frac{1}{C_e} \quad (1)$$

where  $q_e$  (mg g<sup>-1</sup>) is the equilibrium metal ion sorption capacity,  $C_e$  (mg L<sup>-1</sup>) the equilibrium metal ion concentration in solution,  $q_{\max}$  (mg g<sup>-1</sup>) 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:<sup>2</sup>

$$\ln q_e = \ln K_f + \frac{1}{n} \cdot \ln C_e \quad (2)$$

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

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\* Corresponding author. E-mail: sladjja\_ms@yahoo.com

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 equation (2).

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:<sup>2</sup>

$$\ln q_e = \ln q_m - \beta \varepsilon^2 \quad (3)$$

where  $q_m$  (mg g<sup>-1</sup>) is Dubinin–Radushkevich monolayer capacity,  $\beta$  is parameter related to sorption energy  $E = \frac{1}{\sqrt{2\beta}}$  and  $\varepsilon$  is Polanyi potential, defined as  $\varepsilon = RT \ln(1 + \frac{1}{C_e})$ ,  $R$  (8.314 J mol<sup>-1</sup> K<sup>-1</sup>) is a universal gas constant,  $T$  (K) is absolute temperature, and  $C_e$  (mg L<sup>-1</sup>) 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<sup>-1</sup> describes physisorption, rather than ion-exchange 8 kJ mol<sup>-1</sup> <  $E$  < 16 kJ mol<sup>-1</sup> or chemisorptions  $E$  > 16 kJ mol<sup>-1</sup>.

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:<sup>2</sup>

$$q_e = B \ln K_t + B \ln C_e \quad (4)$$

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

#### REFERENCES

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