

SUPPLEMENTARY MATERIAL TO

Magnetic *Ambrosia artemisiifolia*-based biosorbent for Congo red removal from water: A circular economy approach

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J. Serb. Chem. Soc. 91 (7–8) (2026) 823–838

RESULTS AND DISCUSSION

Biosorption kinetics

Table S-I. Kinetic models applied to analyze CR biosorption with Fe₃O₄/MB.¹

Model	Equation	Plot	Parameter
Pseudo-first-order (PFO)	$\log(Q_e - Q_t) = \log(Q_e) - \frac{k_1}{2.303}t$	$\log(Q_e - Q_t)$ vs. t	Q_e, k_1
Pseudo-second-order (PSO)	$\frac{t}{Q_t} = \frac{1}{k_2 Q_e^2} + \frac{t}{Q_e}$	$\frac{t}{Q_t}$ vs. t	Q_e, k_2
Elovich	$Q_t = \frac{1}{\beta} \ln(\alpha\beta) + \frac{1}{\beta} \ln(t)$	Q_t vs. $\ln(t)$	α, β
Intra-particle diffusion (IPD)	$Q_t = k_3 t^{0.5} + C_{id}$	Q_t vs. $t^{0.5}$	k_3

where Q_e and Q_t (mg g⁻¹) are the adsorption capacity's at equilibrium and at time t , k_1 (min⁻¹) and k_2 (g mg⁻¹ min⁻¹) are the rate constant; α (mg g⁻¹) is the initial adsorption rate, β (g mg⁻¹) is related to the extent of surface coverage; k_3 (g mg⁻¹ min⁻¹) is intra-particle diffusion rate constant

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*Biosorption isotherms***Table S-II.** Isotherm models applied to analyze CR biosorption with Fe₃O₄/MB.^{2,3}

Model	Equation	Plot	Parameter
Langmuir	$\frac{C_e}{Q_e} = \frac{1}{k_L Q_{\max}} + \frac{C_e}{Q_{\max}}$	$\frac{C_e}{Q_e}$ vs. C_e	$Q_{\max}, k_L$
Freundlich	$\log Q_e = \log k_F + \frac{1}{n} \log C_e$	$\log Q_e$ vs. $\log C_e$	k_F, n
Temkin	$Q_e = \frac{RT}{b_T} \ln A_T + \frac{RT}{b_T} \ln C_e$	Q_e vs. $\ln C_e$	A_T, b_T
Elovich	$\ln \frac{Q_e}{C_e} = \ln K_E Q_m - \frac{Q_e}{Q_m}$	$\ln \frac{Q_e}{C_e}$ vs. Q_e	Q_m, K_E
Dubinin-Radushkevich	$\ln Q_e = \ln Q_{D-R} - K_{D-R} \epsilon^2$ $\epsilon = RT \ln \left[1 + \frac{1}{C_e} \right]$ $E = \left[\frac{1}{\sqrt{2K_{D-R}}} \right]$	$\ln Q_e$ vs. ϵ^2	Q_{D-R}, K_{D-R}

where Q_e (mg g⁻¹) and C_e (mg L⁻¹) are the adsorption capacity at equilibrium and adsorbate equilibrium concentration respectively; k_L (L mg⁻¹) is Langmuir constant; Q_m (mg g⁻¹) is the maximum monolayer adsorption capacity; n and k_F (L g⁻¹) are Freundlich constants related to adsorption and intensity of adsorption driving force or surface heterogeneity, respectively; A_T is Temkin constants (L mg⁻¹), T is the temperature (K), R is the gas constant (8.314 J mol⁻¹ K⁻¹); K_E (L g⁻¹) is Elovich equilibrium constant. Q_{D-R} is the Dubinin-Radushkevich maximum adsorption capacity (mg g⁻¹), K_{D-R} is the activity coefficient (mol² kJ⁻²), ϵ is the Polanyi potential, R is the gas constant (8.314 J mol⁻¹ K⁻¹), and E is adsorption energy (kJ mol⁻¹).

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