

Abstract

ADSORPTION ISOTHERMS FOR COPPER IONS BIOSORPTION ONTO GRAPE STALKS

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Abstract

The removal of heavy metals from wastewater is environmentally important due to their toxicity, persistence, and tendency to accumulate in living organisms. In this context, biosorption has emerged as a promising, cost-effective, and sustainable alternative to conventional treatment methods. This study investigates the potential application of grape stalks waste (*Vitis vinifera* L.) as a low-cost biosorbent for the removal of Cu(II) ions from aqueous solutions. Batch equilibrium experiments were conducted, and the adsorption data were analysed using Langmuir, Freundlich, and Temkin isotherm models, which are commonly used to describe adsorption mechanisms, surface heterogeneity, and adsorbate–adsorbent interactions. The experimentally determined equilibrium adsorption capacity ($q_{e,exp}$) was 5.01 mg g⁻¹. The Langmuir isotherm model yielded a maximum monolayer adsorption capacity (q_m) of 9.02 mg g⁻¹ and a Langmuir constant (K_L) of 2.966 dm³ mg⁻¹, with a correlation coefficient of $R^2 = 0.98$. These results suggest partial monolayer adsorption on a relatively homogeneous surface with a finite number of active sites. The Freundlich model provided the best fit to the experimental data ($R^2 = 0.99$), with $K_F = 9.08$ and $1/n = 0.637$, indicating favourable adsorption on a heterogeneous surface with a non-uniform distribution of adsorption energies and the possibility of multilayer formation. The value of $1/n < 1$ confirms favourable adsorption and strong interaction between Cu(II) ions and the biosorbent surface. The Temkin isotherm model also adequately described the system ($R^2 = 0.96$), with $K_T = 41.22$ dm³ g⁻¹ and $B = 1.65$ J mol⁻¹, suggesting that the heat of adsorption decreases linearly with increasing surface coverage and indicating the involvement of both physical and chemical interactions. Overall, grape stalks waste demonstrated good efficiency for Cu(II) removal from aqueous solutions. The dominance of the Freundlich model indicates that adsorption is mainly governed by heterogeneous surface interactions, including ion exchange and complexation with functional groups present in lignocellulosic biomass.

Keywords: biosorption, copper ions, adsorption isotherms, grape stalks

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