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## EVALUATION OF ADSORPTION PERFORMANCE OF MALACHITE GREEN USING PINE NUT (*Pinus pinea*) SHELLS AS AGRICULTURAL WASTE ADSORBENT

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### Abstract

In this study, we investigated the adsorption of malachite green (MG) from synthetic wastewater using pine nut shells as a nature-friendly and economical adsorbent. The maximum MG adsorption capacity of pine nut (*Pinus pinea*) shells was calculated to be 25.641 mg/g at pH 10. SEM images revealed significant porosity, confirming the adsorption of malachite green on the surface of the shells. Post-adsorption SEM analysis showed that the surface of pine nut shells was covered by MG molecules. We evaluated the effect of various adsorption parameters, including initial dye concentration, thermodynamic parameters, and pH. Furthermore, we determined that the Langmuir isotherm provided a better fit to the equilibrium data, while the pseudo-second-order model accurately described the kinetics. The Gibbs free energy change value was calculated to be 6.041 kJ/mol (298 K). Our findings suggest that pine nut shells can serve as an eco-friendly, economical, and promising adsorbent for MG removal from synthetic wastewater.

**Key words:** adsorption, agricultural waste, isotherm, malachite green, SEM

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