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Poly(methacrylic acid) surface modified magnetite nanoparticles for dispersive solid-phase adsorption of chlorpyrifos pesticide from aqueous solutions

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ABSTRACT

Population growth and the increasing need for agricultural and food products, enhance usage of pesticides, which are special water pollutants. In this study, we synthesized poly(methacrylic acid) modified magnetite nanoparticles (Fe_3O_4@PMA MNPs) to remove chlorpyrifos organophosphate pesticide from aqueous samples. The structure of synthesized MNPs was characterized by vibrating sample magnetometer, field-emission scanning electron microscopy, Fourier-transform infrared spectroscopy, X-ray diffraction, and dynamic light scattering. Effective operational parameters such as pH, adsorbent mass, contact time and ionic strength were evaluated at four levels by Taguchi fractional factorial design method (OA_{16}). Under the optimum conditions (pH = 5, adsorbent content = 2 g·L^{-1}, ionic strength = 0.005 mol·L^{-1} and 30 min contact time), the removal efficiency of 89.8% was obtained. The kinetic studies at two concentrations of 5 and 25 mg·L^{-1} showed that chlorpyrifos removal followed the pseudo-second-order kinetic model (R^2 = 0.99, q_{eq} = 11.31 mg·g^{-1}) confirming diffusion plays a key role in determining the rate of adsorption process. The adsorption equilibrium data were investigated by linear and non-linear forms of four isotherm models, and the results showed good accordance with the Dubinin–Radushkevich isotherm model (R^2 = 0.99). From the thermodynamic studies, $\Delta H°$, $\Delta S°$, $\Delta G°$, and E_a of adsorption process were obtained as 9.665 kJ·mol^{-1}, 40.25 J·mol^{-1}·K^{-1}, –2.326 kJ·mol^{-1} and 8.677 kJ·mol^{-1}, respectively. The results revealed that the adsorption process was endothermic ($\Delta H° > 0$) and spontaneous ($\Delta G° < 0$). The obtained values of $\Delta H°$, $\Delta G°$ and E_a confirmed the physisorption nature of interaction. The calculated E_a and sticking probability (S^*) showed the endothermic adsorption process and high probability of sticking to the surface, respectively. This study showed that Fe_3O_4@PMA MNPs are suitable adsorbents for removing chlorpyrifos pesticide from aqueous solutions.

Keywords: Magnetite; Nanoparticles; Methacrylic acid; Chlorpyrifos; Adsorption; Removal

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