

Magnetic nanoparticles with green surface modifications for the efficient capture of polyethylene microplastics

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The extensive production and application of plastic in recent decades has resulted in the widespread presence of microplastics (MPs) in different water bodies. Adhesion of functionalized magnetic nanoparticles to the surface of the MPs followed by their removal under a magnetic field constitutes a sustainable solution to control the presence of these pollutants from water matrices. As a remarkable novelty, this work proposes different surface functionalization alternatives to evaluate the interactions between MPs and magnetic nanoparticles. Amino groups or sodium alginate (SA) were grafted on the surface of synthesized iron oxide magnetic nanoparticles to enhance electrostatic and intermolecular interactions with MPs.

Fe₃O₄ was synthesized through thermal decomposition and coprecipitation methods. The surface of the magnetic nanoparticles synthesized by thermal decomposition was functionalized with primary and secondary amino groups by means of n-[3-(trimethoxysilyl) propyl] ethylenediamine (TMPED). Besides, the magnetic nanoparticles synthesized by coprecipitation were coated with sodium alginate (SA) as a greener functionalization alternative. Polyethylene beads of 231 ± 19 μm (Cospheric) were used as model pollutant. To assess the capture performance, 1.3 and 0.5 g L⁻¹ of magnetic nanoparticles and MPs, respectively, were employed to evaluate the influence on the capture efficiency of the functional groups under different pH conditions.

The characterization of the surface-modified magnetic nanoparticles and MPs in terms of surface zeta potential was carried out to identify the pH ranges where stronger interactions are expected. Amino-functionalized particles exhibited the highest capture percentage at pH 5. Increasing pH values, the capture percentages were reduced. This drop in the capture percentages coincided with a reduction in the zeta potential values of the magnetic nanoparticles at higher pH values, indicating that electrostatic interactions were the predominant mechanism. Besides, SA-functionalized particles showed different capture performance than amino particles since capture percentages did not vary when modifying the pH values, resulting in an enhanced capture and the appearance of hydrogen bonds instead of electrostatic forces.

Surface-modified magnetic nanoparticles enhance the capture percentages of MPs due to the formation of electrostatic forces and hydrogen bonds depending on the type of polar groups on the surface of the magnetic nanoparticles, suggesting a remarkable sustainable solution to remove these contaminants of emerging concern.

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