Hybrid magnetic core@shell@shell nanocomposites as efficient and reusable adsorbents for anionic dyes

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The activity of dye manufacturing, textile, and paper industries are one of the main sources of water pollution and it continues increasing year after year. A large amount of wastewater with hazardous chemical dyes has been continuously produced and discharged in water bodies, which represent a serious threat to several living forms due to their adverse effects. In this context, the present study addresses the application ferrite-based nanoparticles modified with cetyltrimethylammonium bromide (CTAB) as potential magnetic nanoadsorbents to remove anionic dyes from water. It is proposed an innovative nanomaterial architecture based on highly magnetic and stable core@shell nanoparticles covered by a surface bilayer of CTAB ($CoFe_2O_4$@γ-Fe_2O_3@CTAB). Samples of two different mean sizes were elaborated and characterized by XRD, TEM, FTIR, BET, zetametry, and SQUID magnetometry. Direct Yellow 12 and Remazol Brilliant Blue R dyes were used as target pollutants. The effect of pH, shaking rate, contact time, initial dye concentration and temperature were investigated from batch studies in standard dye solutions with 0.5 g/L of nanoadsorbent. The results were analyzed using the Langmuir and Freundlich models to evaluate the maximum adsorption capacity and the adsorption mechanism. The nanoadsorbents revealed to be more efficient in pH ≤ 5.0, for 30 min of contact time and under a shaking rate of 400 rpm. The kinetic data followed the pseudo-second-order model. The sample based on smaller nanoparticles exhibited higher adsorption capacity due to its larger surface area. Additionally, the adsorption capacity of the nanoadsorbents were also compared to that of uncoated precursor nanoparticles to emphasize the role of the CTAB layer in the removal efficiency. The adsorption process was spontaneous, exothermic, and characteristic of physical and chemical adsorption at the same time. The effect of competitive ions was also investigated. Lastly, the nanoadsorbents were recovered from wash cycles and reused in readsorption tests keeping a good removal efficiency.