SPIONs doped with cobalt from the Li-ion battery acid leaching waste as a photocatalyst for tetracycline degradation – synthesis, characterization, DFT studies, and antibiotic treatment

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ABSTRACT

This work demonstrates the removal of cobalt-containing liquid waste recovered from spent lithium-ion battery waste in the context of the synthesis of superparamagnetic particles and their application for tetracycline photodegradation. First, the spent lithium-ion battery waste was treated with H₂SO₄, glutaric acid and H₂O₂ to release heavy material from the graphite electrodes, and then the post-acid leaching solution was used as a source of Co²⁺ ions in the wet co-precipitation synthesis of superparamagnetic co-doped iron oxide nanoparticles. Scanning electron microscopy and transmission electron microscopy revealed the spherical morphology of nanoparticles with a size of 15 ± 4.80 nm. Fourier-transform infrared spectroscopy and X-ray diffraction confirmed the formation of iron oxide doped with Co, while the particles obtained have a polycrystalline structure. Magnetometric measurements prove the superparamagnetic properties of the obtained material with saturation magnetization (Mₛ) of about 91 emu/g. The band gap energy estimated from Tauc plot for obtained nanoparticles is about 1.6 eV, while the flat band potential calculated from Mott–Schottky’s plot is about –0.18 V vs. SHE. The experimental studies conducted with UV-Vis show the highest efficacy in pH 7 degradation of tetracycline (TC) of about ~84.42%, with the process undergoing first-order kinetics. The addition of H₂O₂ improves the effectiveness to reach about 92.2% TC degradation. It turned out that magnetic nanoparticles from waste battery waste have catalytic properties and can be considered efficient catalysts in various fields, including environmental studies. The material obtained provides reuse for 5 operating cycles and can be easily removed from aqueous media after effective treatment.

Keywords: Spent lithium-ion batteries; LiBs; Acid leaching; SPION; Magnetic nanomaterials; Metals recovery; Superparamagnetic; Waste management; Functional materials

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