

Nanotechnology at the interface of medicine and environment: functional applications of SPIONs

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Nanotechnology plays an important role in modern science. It enables designing of nanoparticles and nanocomposites with tunable physicochemical properties to make them valuable in various fields including medicine and environmental applications. In nanomedicine, their small size, large surface area, and ease of functionalization make them functional as effective theranostic agents, integrating diagnostic and therapeutic functions on a molecular level. Among many different nanomaterials the superparamagnetic iron oxide nanoparticles (SPIONs) exemplify this potential to be used in theranostics. Their unique magnetic properties enable facile and precise drug delivery, real-time imaging with magnetic resonance imaging, and localized mild hyperthermia under alternating magnetic fields. Additionally, SPIONs can be coated with various biologically active compounds like cytostatic drugs, photoactive molecules for photodynamic therapy, or biocompatible polymers that enhance colloidal stability and enable controlled drug release. Depending on the compounds to be used as the shell that coats SPIONs, the SPION-based hybrid offers multifunctionality that can improve the treatment efficacy with reduction of the side effects.

Beyond healthcare, the physicochemical characteristics of SPION-based nanomaterials extends to environmental applications. These nanoparticles occur high reactivity and depending on the outer shell they can bind various chemicals making them attractive for water pollution treatment including emerging contaminants removal through adsorption and degradation of organic compounds through photocatalysis, as well as sensing of hazardous substances. Incorporation of SPIONs into composite can enhance the effectiveness of the water pollution removal and facilitate the adsorbent/photocatalyst with magnetic separation.

By combining tunable functionality with responsiveness to external stimuli, nanoparticles—especially SPIONs - provide sustainable solutions for different applications to deal with medicine and environmental challenges.