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Review

Magnetic nanostructured adsorbents for water treatment: Structure-property relationships, chemistry of interactions, and lab-to-industry integration

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ABSTRACT

Toxins released due to rapid industrialization and urbanization have significantly polluted the world's water resources. Current remediation technologies remain inadequate in terms of cost and effectiveness in removing low concentration pollutants. Nanomaterials have unique properties, such as precisely controllable surface areas, biocompatibility, and durability, and their surface properties can be easily modified to increase their specificity. Considering the variety of nanosorbent materials, creating economic and efficient adsorbents that could easily remove toxic pollutants from environmental water is one of the current challenges. Magnetic nanoparticles (MNPs) offer a low-maintenance and straightforward alternative to conventional adsorbents for the removal of contaminants from wastewater. This review critically evaluates recent advances in the use of magnetic materials for a variety of pollutants (anions, cations, organics, radioactive elements, and pathogens). Also, the technology developed using magnetic adsorbent for the treatment of large-scale wastewater treatment processes as magnetic separators have been reviewed in detail. The structure–property relationships between the MNPs and the pollutants were revealed based on the results of theoretical models. The challenges in developing highly stable MNPs and improvements in their practical use for the removal of toxic pollutants are also discussed in detail. Further, potential modeling for water pollutant removal, economic evaluations, toxicity and legality, and further research direction on MNPs for on-site remediation and pilot scale application are emphasized. The review bridges adsorption research and engineering science to facilitate efficient approaches for adsorption of various toxic pollutants on MNPs from wastewater.

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