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RECENT DEVELOPMENTS IN LIGNIN NANOPARTICLE-BASED ADSORBENTS FOR THE REMOVAL OF DYE, HEAVY METAL, AND PHARMACEUTICAL POLLUTANTS FROM WASTEWATER

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Abstract

Recent developments in lignin nanoparticle-based adsorbents for wastewater treatment have garnered significant attention due to their sustainability and effectiveness in removing diverse contaminants, including dyes, pharmaceuticals, and heavy metals. This review examines the advancements in the synthesis and application of lignin-based adsorbents, particularly focusing on their performance in the removal of organic dyes, pharmaceutical pollutants, and heavy metals from wastewater. Dye removal studies reveal that lignin composites exhibit high adsorption capacities, especially under neutral pH conditions, with a maximum of 1186 mg/g for methylene blue. Similarly, lignin-based adsorbents show remarkable efficiency for pharmaceutical pollutants under mildly acidic conditions, with adsorption capacities reaching up to 1396 mg/g, especially for tetracycline hydrochloride. Furthermore, heavy metal removal efficacy is significant in acidic environments, with lignin composites such as Alkali Lignin-derived Biochar demonstrating up to 1003.7 mg/g for Pb (II). The review also discusses the advantages of lignin's abundant functional groups and robust structure, contributing to its promising role as an adsorbent. However, future challenges remain, including the development of cost-effective synthesis methods, scalability, and the improvement of selectivity, stability, and regeneration properties. Advancements in composite materials combining lignin nanoparticles with other nanostructures hold great potential for further enhancing adsorption capacities and expanding their application in large-scale wastewater treatment systems.

Key words: dye removal, heavy metal removal, lignin composites, lignin nanoparticles, pharmaceutical pollutants, wastewater treatment

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