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"Gheorghe Asachi" Technical University of Iasi, Romania

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

Khalid A. Alkhuzai[1], Hijran Sanaan Jabbar[2], Harikumar Pallathadka[3*], Teku Kalyani[4], Vikasdeep Singh Mann[5], Hameed Ghazy[6], Usama S. Altimari[7], Nahed Mahmood Ahmed Alsultany[8], Carlos Rodriguez-Benites[9], Merwa Alhadrawi[10,11,12]

[1]*Civil Engineering Department, Faculty of Engineering, Al-Baha University, Al-Baha, Saudi Arabia*
[2]*Department of Chemistry, College of Science, Salahaddin University-Erbil, Kurdistan Region, Iraq*
[3]*Manipur International University, Imphal, Manipur, India*
[4]*Department of Mechanical Engineering, Raghu Engineering College, Visakhapatnam, India*
[5]*Department of Mechanical Engineering, Chandigarh College of Engineering, Chandigarh Group of Colleges, Jhanjeri, Mohali-140307, Punjab, India*
[6]*Department of Pharmacy, Al-Manara College for Medical Sciences, Maysan. Iraq*
[7]*Department of Medical Laboratories Technology, AL-Nisour University College, Baghdad, Iraq*
[8]*Collage of Dentist, National University of Science and Technology, Dhi Qar, 64001, Iraq*
[9]*Universidad Nacional de Ingeniería, Lima, Peru*
[10]*Department of Refrigeration and air Conditioning Techniques, College of Technical Engineering, the Islamic University, Najaf, Iraq*
[11]*Department of Refrigeration and air Conditioning Techniques, College of Technical Engineering, the Islamic University of Al Diwaniyah, Al Diwaniyah, Iraq*
[12]*Department of Refrigeration and air Conditioning Techniques, College of Technical Engineering, the Islamic University of Babylon, Babylon, Iraq*

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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* Author to whom all correspondence should be addressed: e-mail: harikumarpallathadka6@gmail.com; Phone: +911211984091