

Abstract

PHOTOCATALYTIC NANOMATERIAL FOR HEAVY METAL REMEDIATION

DOI: 10.5937/EcoTER26634N

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Abstract

The paper presents an overview of modern methods for removing heavy metals and metalloids from wastewater, with a particular focus on the use of nanomaterials and their hybrid systems in combination with conventional treatment technologies. Heavy metals pose a serious environmental problem due to their toxicity, bioaccumulation, and long-term persistence. The study examines the main sources of pollution, including industrial activities, agriculture, and municipal wastewater, as well as their negative impacts on human health and ecosystems.

The paper gives special attention to conventional removal methods such as adsorption, membrane filtration, chemical precipitation, ion exchange, electrochemical processes, and advanced oxidation processes. It also discusses the application of nanomaterials such as TiO₂, ZnO, graphene-based materials, and magnetic nanomaterials. Due to their large specific surface area and high reactivity, these materials enable more efficient removal of metal ions.

For example, the use of Fe₃O₄ magnetic nanoparticles for arsenic removal from groundwater is described, achieving removal efficiencies greater than 90%, along with simple magnetic separation and adsorbent reusability. The factors influencing process efficiency are also analyzed, showing that increasing temperature enhances heavy metal removal by intensifying ion diffusion and improving interaction with the active sites of nanomaterials. It is also observed that lowering the initial pollutant concentration increases the removal percentage, as more active sites are available for metal ion adsorption.

The integration of nanomaterials with adsorption, membrane, electrochemical, and biological processes is emphasized to achieve a synergistic effect and improve treatment efficiency. Finally, the advantages, limitations, and future development directions of nanomaterials in environmental protection and wastewater treatment are discussed.

Keywords: pollutants, heavy metals, removal methods, nanomaterials, synergistic effect

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ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for financial support according to the contract with registration No. 451-03-34/2026-03/ 200131

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