

Abstract

**MECHANISMS AND CHALLENGES OF PHOTOCATALYTIC NANOMATERIALS
IN HEAVY METAL REMOVAL**

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Abstract

Water pollution by heavy metals and metalloids is a serious environmental and health issue due to their toxicity, persistence, and tendency to bioaccumulate. Conventional methods for removing these pollutants have limitations, including high costs and reduced efficiency at low concentrations. This paper provides an overview of the application of photocatalytic nanomaterials as a modern approach to removing heavy metals from wastewater. Various types of nanomaterials were analyzed, including carbon-based, metal oxide, graphitic carbon nitride, and zero-valent metal materials, as well as their mechanisms of action through adsorption, photocatalysis, and redox reactions. Graphitic carbon nitride was identified as the most economical, while solar-driven zero-valent metal systems demonstrated greater efficiency than those not exposed to radiation (the removal efficiency of Cr⁶⁺ ions with these systems was 78.5%). A synergistic removal effect was also observed by combining graphitic carbon nitride and nano zero-valent iron, achieving 98% Cr⁶⁺ removal within 60 minutes under visible light, significantly faster than with the individual nanomaterials. Special attention was given to integrating nanomaterials with conventional treatment methods to increase the efficiency and sustainability of the process.

Key factors affecting the performance of these systems were also considered, including pH, which critically affects the surface charge of the particles, catalyst dose, temperature, initial pollutant concentration, and potential nanotoxicity. It was observed that the adsorption capacity for heavy metal ions increases with the catalyst dose up to an optimal value, after which efficiency decreases due to light scattering.

The paper concludes that photocatalytic nanomaterials represent a promising solution for improving water purification technologies, but also addresses the challenges they face for broader practical application.

Keywords: heavy metals, photocatalytic nanomaterials, graphitic carbon nitride, conventional methods, synergistic effect

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