

The Role of Microalgae in Heavy Metal Removal from Wastewater: A Review

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Structured Abstract

Background: The excessive discharge of heavy metals (HMs) into water bodies exerts significant threat to the environment, specifically the aquatic ecosystems, and human health. Microalgae-based technology has emerged as a promising eco-friendly alternative to conventional treatment methods for wastewater management owing to microalgae's cost-effectiveness, pollutant removal capacity and high adaptability to varying conditions. Adopting microalgae for wastewater treatment has been found to support the principles of circular economy by valorising its biomass into various value-added products. This critical review delves into the mechanisms of HM removal by microalgae and explores the potential contribution of their biomass in circular economy.

Objective: This review seeks to critically describe the role of microalgae in removing heavy metals from wastewater, highlighting the underlying mechanisms, cultivation methods and biomass valorisation pathways. It also focuses on the main challenges hindering real-world applications and examines recent technological advances and potential strategies for enhancing system efficiency.

Literature Review: Numerous studies have extensively demonstrated microalgae's ability to remove heavy metals through different mechanisms such as biosorption, bioaccumulation and biotransformation while accumulating significant amount of biomass. These processes are facilitated by various components which includes transporter and metal-binding proteins. Species such as *Chlorella vulgaris*, *Scenedesmus obliquus* and *Spirulina sp.* have been extensively studied due to their high tolerance and uptake capacities. The harvested biomass has potential for further use in other applications, presenting a combined solution for pollutant control and sustainable development. Nonetheless, issues related to biomass harvesting, environmental fluctuations and risks of biomass contamination are several barriers to the use of microalgae-based wastewater treatment system at a larger scale.

Conclusion: Microalgae serve as a dual-purpose approach for sustainable wastewater treatment strategy and biomass valorisation, supporting the principles of circular economy. Existing challenges of this technology necessitate more large-scale or pilot studies, cost-effective harvesting methods and solid safety assessments of products derived from wastewater-grown microalgae to ensure successful real-world implementation.

Keywords: Microalgae, Wastewater Treatment, Heavy Metals, Biomass Valorisation, Circular Economy

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