

Utilization of Microbial Bioindicators in the Monitoring of Polluted Ecosystems

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Received: 7.08.2025; Accepted: 21.09.2025; Published: 16.11.2025

Abstract: The presence of heavy metals in ecosystems, especially soils and aquatic environments, represents a significant threat to biodiversity and ecosystem services. Microbial bioindicators have proven to be effective tools for monitoring the extent of heavy metal contamination due to their sensitivity to such pollutants and their ability to exhibit rapid physiological responses. According to recent literature, microbial strains such as *Pseudomonas*, *Bacillus*, *Arthrobacter*, *Corynebacterium*, and *Alcaligenes* have shown strong resistance mechanisms to metals, like lead (Pb), cadmium (Cd), and mercury (Hg). Metagenomic and molecular techniques, such as 16S rRNA sequencing and functional gene analysis, have enabled a more detailed understanding of microbial community shifts in response to heavy metal contamination. Studies indicate that heavy metal pollution leads to a decrease in microbial diversity, with an enrichment of metal-tolerant or metal-resistant populations. This microbial adaptation serves as a direct bioindicator of environmental quality, offering an early warning system for ecosystem stress [1,2]. Furthermore, microbial bioindicators can complement traditional monitoring methods by providing a dynamic and more sensitive approach to assessing pollution levels. The integration of microbial bioindicators into environmental monitoring programs is thus an essential step toward developing sustainable strategies for heavy metal pollution management and remediation.

Keywords: heavy metals; microbial bioindicators; environmental monitoring.

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Acknowledgments

This work was supported by a grant from the Ministry of Research, Innovation, and Digitization, CCCDI-UEFISCDI, project number PN-III-P2-2.1-PED-2021-3528, 731PED/2022, within PNCDI III, and was carried out with the support of the National Institute for Chemical-Pharmaceutical Research and Development-ICCF Bucharest, Romania.

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