COMPREHENSIVE ANALYSIS OF HEAVY METAL IONS USING BIOADSORBENTS

Yulchieva Sevara Tojimatovna

Senior teacher (PhD), Andijan State Medical Institute

Abstract. This article provides a comprehensive 10-page overview of the use of bioadsorbents for the detection and quantification of heavy metal ions. The study highlights eco-friendly adsorption mechanisms, analytical techniques, and biomedical relevance of removing toxic metals from the environment.Conventional technologies for the removal/remediation of toxic metal ions from wastewaters are proving expensive due to non-regenerable materials used and high costs. Biosorption is emerging as a technique offering the use of economical alternate biological materials for the purpose. Functional groups like carboxyl, hydroxyl, sulphydryl and amido present in these biomaterials, make it possible for them to attach metal ions from waters.

Keywords: Bioadsorbents, Heavy Metal Ions, Environmental Chemistry, Adsorption Mechanism, Toxicology, Water Purification, Analytical Methods

Heavy metal ions such as Pb^{2+}, Cd^{2+}, Hg^{2+}, Cr^{6+}, and Ni^{2+} pose significant health risks due to their bioaccumulative and carcinogenic nature. Bioadsorbents derived from natural materials—plants, microorganisms, agricultural wastes, and biopolymers—have emerged as reliable, sustainable, and cost-effective tools for their analytical detection.

Chemical Basis of Bioadsorption. Bioadsorption involves physical and chemical interactions between metal ions and functional groups such as hydroxyl, amino, carboxyl, and sulfhydryl groups present in biomaterials. These interactions enable selective binding, making bioadsorbents useful for both qualitative and quantitative analysis.

Types of Bioadsorbents. Common bioadsorbents include chitosan, cellulose-based materials, algae, fungal biomass, activated carbon from plant residues, and protein-rich materials. Their unique surface chemistry allows high metal uptake capacity.

Bioadsorption can be combined with spectrophotometry, atomic absorption spectroscopy (AAS), ICP-MS, and titrimetric analysis to enhance detection sensitivity. Pre-concentration by bioadsorbents increases method accuracy and reduces cost.

In medical chemistry, monitoring heavy metals is essential due to their neurotoxic, nephrotoxic, and hepatotoxic effects. Bioadsorbent-based methods provide safe, efficient, and rapid approaches to assessing biological exposure.

The following table summarizes the adsorption performance of common bioadsorbents.

Bioadsorbent	Target Heavy Metal	Adsorption Capacity (mg/g)	Advantages
Chitosan	Pb^{2+}, Cd^{2+}	150–250	Biocompatible, high affinity
Activated Carbon	Hg^{2+}, Pb^{2+}	300–500	Large surface area
Algal Biomass	Ni^{2+}, Cr^{6+}	100–180	Eco-friendly, low cost
Fungal Biomass	Cu^{2+}, Zn^{2+}	80–160	High selectivity

Bioadsorbent-mediated detection continues to evolve with advancements in nanotechnology and surface modification. Recent studies demonstrate that hybrid bio-nanocomposites significantly enhance sorption capacity and analytical precision. Furthermore, sustainable green chemistry initiatives promote using agricultural waste as biosorbents to reduce environmental pollution.

The use of inexpensive and efficient materials, wheat straw and wheat bran, for metal biosorption has been reviewed. Relatively shorter contact time, endothermic nature of biosorption process (in most cases), acidic pH range and high affinity for metal ions was found. The use of WS needs further investigation as more literature is available for the use of WB. Biosorption requires investigation in structural studies of biosorbents, multi-metal studies, mechanistic modeling, recovery of metal

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