

# Removal of Heavy Metals from Contaminated Water Using Low-Cost Adsorbents: A Comprehensive Review

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**Abstract:** Heavy metal contamination of water is a significant environmental concern because many metal ions are toxic, persistent, and capable of accumulating in living organisms. Industrial activities such as electroplating, mining, metal processing, battery manufacturing, tanning, and fertilizer production can introduce metals into aquatic environments. Conventional water-treatment technologies, including chemical precipitation, ion exchange, membrane filtration, and coagulation, can be effective, but their cost, sludge generation, operational complexity, or sensitivity to water chemistry may limit their application in certain settings. Adsorption has therefore received considerable attention as a relatively simple and potentially economical method for removing dissolved metals from contaminated water.

This review examines research published up to 31 December 2021 on the use of low-cost adsorbents for heavy metal removal. Materials considered include agricultural residues, fruit and vegetable wastes, sawdust, rice husk, tea waste, natural clays, zeolites, industrial by-products, microbial biomass, chitosan, activated carbon, and biochar. The principal adsorption mechanisms—including ion exchange, electrostatic attraction, surface complexation, physical adsorption, and precipitation—are discussed. The effects of pH, adsorbent dosage, contact time, initial metal concentration, temperature, and competing ions are also examined. Particular attention is given to adsorbent modification, regeneration, disposal of metal-loaded materials, and the challenges of translating laboratory findings into practical water-treatment systems. Studies available by 2021 demonstrate the potential of waste-derived adsorbents, while also highlighting the need for standardized testing, realistic wastewater trials, and comprehensive cost and environmental assessments..

**Keywords:** Heavy metals, contaminated water, wastewater treatment, low-cost adsorbents, adsorption, biosorption, agricultural waste, biochar, activated carbon, water purification.