Chapter 3
Factors Affecting Biosorption Efficiency:
Process Optimization and Performance Evaluation

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ABSTRACT

Biosorption, an eco-friendly, cost-effective method for removing heavy metal pollutants from the environment, gained great attention. This utilizes biological sources such as microbial and agricultural biomass for the removal of heavy metals and other hazardous materials from industrial effluents and other wastes that directly come into the environment. The efficiency is influenced by factors such as temperature, pH, biomass concentration, initial ion concentration, contact time, agitation rate, type of biosorbent, competing ions. The source of biosorbents ranges from microbial sources to plant biomass following different mechanisms. In this chapter, the influencing factors are examined widely, and it spotlights optimization by modifying the parameters. The outcomes hold implications for designing an effluent removal process with the right process factors for maximum efficiency. The findings provided give valuable insight to the researchers, industrial experts, students, policy makers, and academicians who are seeking sustainable solutions to reduce heavy metal pollution.

DOI: 10.4018/979-8-3693-1618-4.ch003

1. INTRODUCTION

The industrialization era changed the world from an agro-based economy to an industry-based economy that utilizes large quantities of mineral and human resources. This significantly increased the use of resources, leading to the generation and accumulation of industrial waste in the environment. The industrial waste more commonly pollutes water, air, and land. Apart from the common pollutants from the industries, the heavy metal pollutants which include arsenic, mercury, lead, phosphates, nitrates, sulfur, cadmium, nickel, copper, zinc, cobalt, magnesium, chromium, selenium, and other metalloids (Sedlakova-Kadukova et al., 2019) leave an irreversible impact on the ecosystem. The discharged heavy metal pollutants into the ecosystems are difficult to assimilate and remove, leading to major environmental modification in biomagnification. Heavy metal contamination is noticeable in the environment due to sources like metal processing industries, mining industries, dying industries, agricultural processes, and waste generated from medical applications. Environmental poisoning by heavy metals has gone over the allowed level, threatening all forms of life. According to the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) of the United States of America, the maximum allowable concentration of certain heavy metals in water is 0.01 mg/L for Ar, 0.05 mg/L for Cd, 0.01 mg/L for Cr, 0.015 mg/L for Pb, 0.002 mg/L for Hg, and 0.05 mg/L for Ag, respectively. On the other hand, according to the Indian standards for heavy metals, the standard for soil is 3–6 mg/kg for Cd, 135–270 mg/kg for Cu, 75–150 mg/kg for Ni, 250–500 mg/kg for Pb, and 300–600 mg/kg for Zn, respectively (Ayangbenro et al., 2019). Heavy metals are carcinogenic and cause permanent damage to the skin, kidneys, blood, and irregularity in blood pressure, and retardation in cognitive skills of children. The heavy metals have prolonged effects on the environment since their half-life is comparatively longer and removing them is difficult.

1.1 Heavy Metal Removal

The removal of heavy metals from the contaminated sources is termed as heavy metal removal. The heavy metals are removed by different means of methods that can be classified into conventional methods and modern methods. The conventional methods employed for the removal of heavy metals are ion floatation (Hoseinian et al., 2020), filtration, and ion-exchange process (Bashir et al., 2019), evaporation, chemical precipitation process (Wang et al. 2019), electrochemical precipitation, catalysis (Gupta et al., 2021), Chemical coagulation/flocculation (Zou et al., 2021), reverse osmosis (Sunil et al., 2018), membrane separation, chemical oxidation, adsorption, and reduction (Shahrokhi-Shahraki et al., 2021). The segregation of heavy metal through the above conventional methods is not efficient in terms of cost, substrate efficiency, recovery, need for advanced equipment, maintenance of equipment, and application for low-concentration solutions.

On considering the downsides of the above-mentioned existing methods, the biosorption process stands out in the positive aspects of recycling and recovery of heavy metals. The first study on bio-sorption was reported in 1951 and due to its captivating properties and environment friendliness, it has gained more interest from the researchers and industries. In 1970, the awareness of environmental pollution and wastewater treatment led to the search for new techniques that landed on biosorption technique due to the advantages over the conventional sorption techniques such as cost-effectiveness, ability to apply for different materials, less or no sludge formation, and high adsorption performance.