



# Biochar: Heavy Metal Remediation, Mechanism, Current Status and Prospects

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## Abstract

Biochar has emerged as a promising material for heavy metal remediation because of its high surface area, porous structure, and functional groups that enable the effective adsorption and immobilization of contaminants. This study explored the mechanisms by which biochar interacts with heavy metals, including ion exchange, surface complexation, electrostatic interactions, and precipitation. The current status of biochar research highlights its successful application in treating heavy-metal-contaminated soils and water systems, demonstrating its potential for environmental restoration. Advances in biochar modification techniques, such as chemical activation and doping with nanoparticles, have further enhanced their remediation efficiency. Despite its advantages, challenges like limited scalability, variable performance in complex environments, and potential secondary pollution require further investigation. This popular article also discusses the prospects of biochar for sustainable heavy metal remediation, emphasizing the integration of biochar with circular economy principles, improved production methods, and

multifunctional applications. As biochar technology advances, it holds significant promise as a cost-effective and environment-friendly solution for addressing heavy metal contamination in diverse settings.

## Introduction

The contamination of water bodies by heavy metals has become a growing international issue due to the adverse effects of pollution on the environment and human health. Heavy metals are present with an atomic variety of over 20 and an elemental density exceeding 5 g · cm<sup>-3</sup>. Diverse anthropogenic activities such as industrial methods, agriculture and forestry, mining operations, fossil gas combustion, and waste disposal release heavy metals into water resources. These activities result in the entry of heavy metal pollutants into water resources through runoff or underground leaching.

## Mechanisms of Biochar Immobilizing Heavy Metal

The overall performance of the underlying mechanisms of BC-immobilizing metals relies on improving lower and more soluble species of HMs using soil amendments. To this point,



the complexity of soils, limitations of cutting-edge analytical strategies, and precise immobilization mechanisms in soils amended with BC have not been clarified. However, significant details are presented herein. The primary concept of the mobilization technique is the release of HMs into the soil pool so that deep-rooted flowers can take them up. In comparison, immobilization converts HMs from an inorganic to a natural form inside the soil pool through adsorption, CEC, pH, temperature, electrostatic attractions, precipitation, and complexation, thus rendering the metals unavailable to vegetation and humans or for motion to groundwater. Consequently, increasing the soil pH with the addition of alkaline amendments can reduce the solubility and mobility of soil HMs because the negative expenses of soil colloids increase with increasing pH, resulting in the extended sorption of definitely charged steel cations. In addition, it has been reported that dissolution-precipitation is the main remediation mechanism of Pb in soil via n-HAP. This procedure causes the formation of pyromorphite, which has a lower solubility and bioavailability than Pb. However, conventional solidification or stabilization (S/S) is an emerging and promising remediation era for HM-polluted soils and hazardous wastes in numerous international locations (GWRTAC, 1997). Moreover, in an S/S manner, soluble HMs are converted into stable or physiochemically stable paperwork through binders or interactions between HMs and soil

particles. Over the previous few years, different forms of inorganic and organic binders, which includes clay minerals (bentonite and kaolinite), rock phosphate, lime, cement, fly ash, blast furnace slag, Fe/Mn oxides, charcoal, zeolite, bitumen, composts, and manures, had been broadly used for the immobilization of metals the usage of BC as a amendment of different concentrations and feedstocks has been pronounced both to mobilize or immobilize HMs in polluted soils. recently, numerous scientists have proposed that BC is commonly an alkaline and carbon, and naturally be counted-rich cloth that could efficiently modify the solubility of HMs by converting soluble metals into the insoluble bureaucracy that bind with organic count number, oxides, or carbonates and are constant in croplands

#### **Biochar modification**

The use of unmodified or pristine biochar has several limitations. Pristine biochar is less effective at removing water pollutants than activated carbon because it has a lower surface area and fewer functionalities. Usually, unmodified biochar has a low specific surface area and pore volume, resulting in low adsorption capacity. The stability of biochar under certain conditions such as elevated temperature, pressure, and pH can limit its application. Typically, unmodified biochar exhibits limited effectiveness, but various activation techniques increase the surface functional groups, leading to heightened reactivity toward contaminants. It is also

ineffective at removing particular contaminants. Generally, biochar displays good dispersion in water; however, in some instances, certain types of biochar can display limited dispersibility for intended applications. Owing to their high buoyancy, Liu et al. (2019) also drew attention to the formidable challenge of utilizing biochar for Cd removal. Despite the numerous benefits associated with biochar, there are concerns about its long-term potential environmental implications and safety. Biochar is prone to physical and chemical degradation, reducing its effectiveness over time and potentially generating undesirable residues that are a safety concern. These factors may influence the utilization and efficiency of biochar for removing heavy metal ions from aquatic systems.

### Conclusion and Future Prospects

The long-term accumulation of HMs in the soil environment is a significant problem because of their effects on the meal chain, plant growth, and soil microbial methods. BC modification has widespread potential as a value-powerful and surroundings-pleasant remediation tool. However, in maximally evolved nations, it has been commercialized and with no trouble in contrast to developing nations, where insufficient awareness, inherent benefits, and concepts of operation far hinder it. Moreover, HM immobilization in soil contaminated with BC depends on the nature of the raw fabric, porosity, composition, pyrolysis temperature, and pyrolysis duration. Consequently, BC properties exchange after addition to the soil

over time, which might result from exceptional biogeochemical exchanges in the soil. Biochar mixed with inorganic additives may want to immobilize or mobilize the HMs in contaminated soils. moreover, all forms of BC are not alkaline in reaction, and yield depends at the biomass kind, pyrolysis temperature, and house time of pyrolysis.

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