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Silica and Polyphenol-Based Adsorbents of Heavy Metals Fabricated by Enzymes

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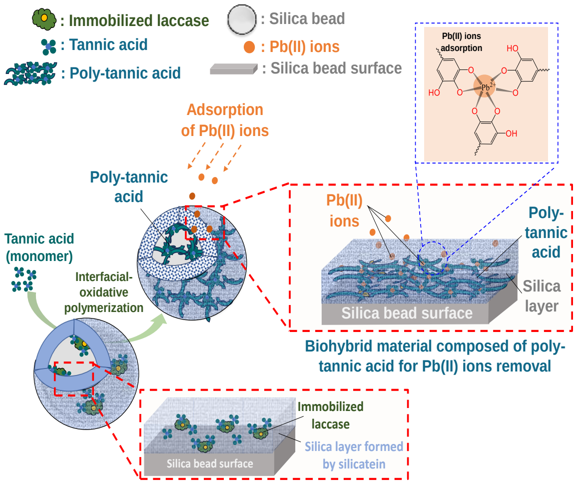
Abstract

Lead (Pb) contamination in water sources poses severe health risks to both humans and ecosystems. Conventional methods for Pb removal often rely on chemical treatments or expensive filtration systems, which can be economically burdensome and environmentally hazardous. In response to this pressing issue, this study presents a novel approach leveraging biologically inspired fabrication techniques by using enzymes for the development of an efficient and eco-friendly silica-based biosorbent incorporating poly-tannic acid for efficient Pb (II) ion removal from aqueous solutions. The process involves the biological immobilization of laccase enzyme on the bead's surface via a protective silica layer formed by the functional silica-polymerizing enzyme, silicatein. Silica beads were chosen as the support material for enzyme immobilization due to their favourable chemical and physical properties and natural compatibility with the silicatein enzyme. This innovative method prevents the immobilized enzyme from leaching and enhances laccase immobilization on the beads, ensuring the enzyme thermostability, and maintains its activity even under harsh conditions such as at an acidic-alkaline pH. Furthermore, poly-tannic acid was formed on the bead surface through oxidative polymerization mediated by immobilized laccase. Successful coverage of poly-tannic acid polymerized by laccase on the beads was confirmed by using SEM-EDS and FTIR spectra. The silicatein-treated biosorbent exhibited high laccase loading capacity and retained about 48% of its initial activity when tested under alkaline conditions. Additionally, it showed a remarkable enhancement compared to the biosorbent treated without silicatein in activity across varying temperatures which indicated favourable thermostability properties. The silicatein-treated biosorbent revealed its effectiveness in removing Pb(II) ions from aqueous solutions with a maximum adsorption capacity of 52.4 mg/g, a threefold increase compared to that of the biosorbent without silicatein. This silica-based biohybrid material presents advantages over conventional methods, including higher adsorption capacity and enhanced stability, offering a promising environmentally friendly solution for heavy metal bioremediation in water sources.

Graphical Abstract



Keywords: Bioremediation; Laccase-mediated polymerization; Poly-tannic acid; Silica-polymerizing enzyme; Surface immobilization