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RESEARCH ARTICLE

Investigations on adsorptive removal of PVC microplastics from aqueous solutions using *Pinus roxburghii*–derived biochar

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Abstract

This study investigates the adsorption mechanisms of pine bark biochar (BC) and modified pine bark biochar (MBC) in the removal of polyvinyl chloride (PVC) microplastics from aqueous solutions, with a significant focus on resource recovery from pine residues which is one of the key Himalayan Forest byproducts. The research findings highlighted the optimal adsorption capacity of biochar at 131.5 mg/g achieved after 6 h of contact time, with a pH of 10 and a PVC microplastic concentration of 200 mg/L. The primary mechanisms of PVC microplastic adsorption involved ion exchange and physical adsorption, driven by forces such as Vander-Waals, London forces, and electrostatic forces. Thermodynamic analysis showed the exothermic nature of the PVC and BC/MBC interaction, with spontaneous adsorption occurring within the temperature range of 10 to 40 °C. Isotherm and kinetic models fit well with Temkin model and PSO kinetics, as indicated by R^2 values exceeding 0.9. Particularly, MBC exhibited superior removal efficiency and adsorption capacity compared to its precursor, reaching an optimum adsorption capacity of 156.08 mg/g with a removal efficiency of 78%, surpassing the performance of BC. This research contributes valuable insights into potential applications of BC for PVC removal and underscores the effectiveness of MBC in achieving enhanced adsorption outcomes.

Keywords Adsorption capacity · Biochar · Pine residue · PSO kinetics · PVC microplastics · Temkin model

Introduction

With the onset of the industrial revolution, exponential population growth, rapid urbanization, and the modern life style surrounded with technological growth, the widespread production of plastic goods has become a common practice. Consequently, mass manufacturing processes have triggered a substantial accumulation of plastic waste, giving rise to universal environmental and health problems due to their non-biodegradable and persistently lasting characteristics (Abuwatfa et al. 2021). A significant impact of plastic pollution on aquatic ecosystems is the formation of microplastics in water bodies. While plastics are durable and persist in the environment, they can break down into smaller fragments known as microplastics, primarily due to exposure to ultraviolet (UV) light and natural weathering. These microplastics have become one of the primary emerging contaminants (Padervand et al. 2020).

Microplastics, including polyethylene, polypropylene, PVC, polyester, acrylic, and polyamides, are prevalent in the environment. Their abundance results from various pathways, primarily linked to human activities in households, industries, and sewage systems. Wastewater has been identified as a major contributor to microplastics in aquatic environments. A single wash of 6 kg of synthetic clothing can discharge approximately 700,000 microplastic fibers. Furthermore, the utilization of pellets in industrial applications as a feedstock for plastic goods introduces additional microplastics into the environment (Sharma & Chatterjee 2017). Microplastics, especially PVC, have low bond energy and greater surface area which makes it ideal for microbial adhesion. The high chloride and additive content of PVC induces the production of dioxins during the manufacturing

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