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Response surface modelling and optimization for copper removal from acid mine drainage using oxidized Himalayan pine needle biochar

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ABSTRACT

This study aims to investigate and compare the adsorption behaviour of pine needle biochar (PNB) and H_2O_2-oxidized PNB (OPNB) in eliminating Cu(II) from acid mine drainage. The PNB and OPNB adsorbents undergo comprehensive characterization through various techniques (BET, FTIR, SEM, and pH_{PZC}). A central composite design was employed for designing experiments and optimizing the impact of process factors (metal concentration, adsorbent doses, contact time, and pH) on adsorption capacity. Pseudo-first-order, pseudo-second-order, and intra-particle diffusion kinetics models as well as Langmuir, Freundlich, and Temkin isotherm models were used to analyze the experimental data. Langmuir isotherm best fit ($R^2 > 0.99$) the experimental data and adsorption capacities of 29.49 and 102.04 mg/g, were determined for PNB and OPNB, respectively. Under optimized experimental conditions, desorption studies revealed the reusability of OPNB about 80% even after four cycles. Fixed-bed column experiments were conducted at ambient temperature with an initial Cu(II) concentration of 125 mg/L and 5.0 g of adsorbent, utilizing a flow rate of 1 mL/min for both PNB and OPNB. These results indicate that oxidized biochar, synthesized for Cu(II) remediation, not only addresses Himalayan pine needle concerns sustainably but also exhibits potential applicability for removing other metal ions from aqueous environments.

Key words: acid mine drainage, copper removal, optimization, oxidized pine needle biochar, response surface methodology, reusability

HIGHLIGHTS

- Resource in the form of biochar can be generated from Himalayan Forest waste pine needles.
- The application of H_2O_2 oxidation resulted in an increment of oxygen content in the Himalayan pine needle biochar.
- The adsorption isotherm of the H_2O_2-modified pine needle biochar exhibited the best fit with the Langmuir model.
- H_2O_2-oxidized pine needle biochar demonstrates efficacy as an effective adsorbent for the removal of copper.