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Characterization of Pine Residues from Himalayan Region and Their Use as Copper Adsorbent

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Abstract In the present study, pine forest residues such as pine needle (PN-R), pine-cone (PC-R), and pine bark (PB-R) were characterized for their physico-chemical properties and then were utilized as adsorbents for removal of Cu(II) from synthetic wastewater simulating leachate from e-waste landfill sites. All the pine residues were comprised of cellulose (25–30%), hemicellulose (32–37%), and lignin (35–40%). PN-R had the highest lignin content of 40%. FTIR analysis of the pine residues confirmed the presence of functional groups such as C = O, C–N, and O–H on pine residue surface. Elemental analysis showed that O/C for PC-R, PB-R, and PN-R was 0.8, 0.7, and 0.6, respectively. The adsorption capacity (mg/g) and removal efficiency (%) of pine residue adsorbents were evaluated by conducting batch adsorption experiments as determined by response surface methodology (RSM). This was done by varying the pH (2.0–6.0), contact time (0.5–24 h), initial Cu(II) concentration (5–70 mg/l), and S:L (2–8 g/l). Analysis of variance (ANOVA) was used for analyzing the results of batch adsorption experiments. PC-R, PB-R, and PN-R were found to have maximum adsorption capacity of 11.4 mg/g, 10.45 mg/g, and 9.7 mg/g respectively at pH 6.0, S:L of 2 g/L, initial copper concentration of 70 mg/L, and contact time of 6–8 h. The study also revealed that the higher the lignin content in the pine residue is, the lower its adsorption capacity is. Likewise, the higher the O/C ratio in the pine residue is, the higher its adsorption capacity is. Langmuir isotherm model best fitted the adsorption data for PC-R, PB-R, and PN-R, confirming monolayer adsorption. The present study showed that pseudo-first-order best fitted the copper sorption kinetic data for PC-R, PB-R, and PN-R.

Keywords Pine forest residue · Physico-chemical properties · Functional groups · Response surface methodology · Metal adsorption capacity · Langmuir isotherm

1 Introduction

Pine tree belongs to the genus *Pinus* which is the largest family within the coniferous (Little & Critchefield, 1927). Pinus is a large genus with over 110 species worldwide (Richardson et al., 2007). Subtropical and temperate zones are suitable for the growth of pine trees. These can grow up to 80 m in height, with majority of species reaching 15–45 m tall (Dias et al., 2015). Pine trees are also found in abundance in the Himalayan range, covering an estimated area of

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