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Cellulose-Based Adsorbent for Selective Removal of Lead from Strongly Coordinated Waste Streams: Soil-Washing Effluents to Perovskite Leachates

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The efficient removal of toxic lead (Pb) from strongly coordinating matrices, including chelator-rich aqueous effluents and polar organic solvents, poses a formidable challenge for existing separation technologies. In such systems, metal ions are stabilized through strong multidentate complexation or persistent solvation shells, thereby rendering conventional precipitation and ion-exchange approaches largely ineffective. Here, we present a unified strategy using a biomass-based dithiocarbamate-functionalized cellulose sorbent (DPE6), designed to overcome the thermodynamic barriers associated with strong metal solvation and chelation, thereby enabling selective metal recovery. DPE6 demonstrates exceptional efficacy across two distinct and highly challenging systems. First, in chelator-laden aqueous environments, DPE6 selectively and quantitatively extracted Pb(II) from effluents containing up to a 100-fold excess of competing chelators, achieving near-complete recovery. Second, in non-aqueous media, DPE6 enabled rapid (<10 min) and high-capacity capture of Pb(II) from strongly solvating organic solvents, such as methanol (MeOH) and *N,N*-dimethylformamide (DMF). Advanced spectroscopic characterizations (XPS and XAS) confirm that chemisorption via sulfur-active sites governs metal uptake regardless of the solvent phase. Implementation in real-world waste streams, including soil-washing effluents and perovskite solar cell recycling solutions, validated the approach's and translational potential, demonstrating quantitative metal recovery (91–99%) even in highly complex matrices. The findings of this work establish bio-derived, functionalized cellulose as a transformative and sustainable platform for hazardous waste management across diverse chemical enviroments.