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Sustainable Recovery of Graphitic Carbon from Spent LIBs and Its Application in Mercury Removal from Aqueous Media

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ABSTRACT

The exponential growth in the use of lithium-ion batteries (LIBs) has resulted in an alarming accumulation of end-of-life battery waste, posing environmental risks and resource challenges. However, this waste also represents a significant urban mine for critical raw materials. While significant efforts have been made to extract critical metals such as lithium, cobalt, nickel, and manganese from spent LIBs, the recovery of graphitic carbon remains largely overlooked. Graphite is a vital anode material due to its high energy density, structural stability, and cost-effectiveness, but its conventional production is both high-energy and cost-intensive. Therefore, recovering graphite from battery waste enhances material circularity and reduces the ecological footprint of battery production.

This study proposes an integrated, environmentally conscious process for recovering and valorizing graphitic carbon from the industrially sourced black mass. Following the selective extraction of metal values, a secondary acid leaching step was employed to remove residual metallic contaminants like aluminium and copper followed by controlled pyrolysis at moderate temperatures to eliminate organic binders such as polyvinylidene fluoride (PVDF), without degrading the graphite structure. The black mass, its leach residue and the pyrolyzed residue were thoroughly characterized using ICP-OES, FESEM-EDS, XRD, TG-DTA, Raman spectroscopy, and CHNS elemental analysis to confirm its purity and structural integrity.

The recovered graphitic carbon was evaluated as an adsorbent for mercury (Hg(II)) ions in aqueous media to extend its functionality. Mercury is a persistent and highly toxic pollutant, and its removal from water sources is critical for public health and ecological protection. The recovered graphite demonstrated promising adsorption potential, highlighting its applicability beyond energy storage.

This approach advances sustainable waste management and exemplifies the circular economy by transforming battery waste into value-added materials for environmental remediation, thereby promoting a dual-benefit strategy that integrates critical material recovery with pollutant mitigation and paves the way for a more sustainable model of LIB recycling.

KEY WORDS

Graphitic carbon recovery; Lithium-ion batteries (LIBs); Circular economy; Waste valorisation; Mercury adsorption

BIOGRAPHY

Include a short biographical (100 words) for the presenting author

Dr. M.G. Sujana is Chief Scientist at the Environment and Sustainability Department of CSIR-Institute of Minerals and Materials Technology (CSIR-IMMT), Bhubaneswar, India. Her research focuses on water and wastewater treatment, with notable contributions to environmental materials. Using synthetic and geo-materials, she has extensively studied fluoride and arsenic removal from potable water. Dr. Sujana has also contributed to developing nanomaterials for optical and energy applications. Her core interests include treating and reusing industrial effluents, valorising industrial residues, and promoting a circular economy through sustainable material utilization and waste-to-resource innovations.

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