

An Integrated Approach in Metal Recovery for E-Waste: Process Chains, Advanced Systems, and Circular Economy Perspectives

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Abstract

E-waste has been one of the rapidly growing waste streams due to shorter product lifecycles and increased consumption. Particularly in developing countries, E-waste is informally processed and dumped into landfills. Leaching activities of the metals will then cause both environmental and health hazards. Simultaneously, E-waste is also a valuable secondary resource rich in critical and precious metals such as copper, gold, cobalt, lithium, palladium, and rare-earth elements. The study evaluates the complete process chain for resource recovery by pre-processing and mechanical separation, thermal pretreatment, pyrometallurgical processing, hydrometallurgical extraction, bioleaching systems, electrochemical recovery, and emerging approaches such as ionic liquids, deep eutectic solvents, and supercritical fluid technologies. Process integration, recovery efficiency, selectivity, environmental impacts, and scalability have been emphasised while proposing an integrated system for the heterogeneous nature of E-waste. With comparative analysis, it is evident that no individual technology can achieve complete and efficient recovery of metals from the e-waste stream. To build a comprehensive recovery system, technologies must be combined and integrated. This paper emphasises the importance of a scalable, integrated recovery system that considers feedstock composition and curbs secondary pollution. Constructing these technologies is an important step towards transforming e-waste from an environmental burden into an urban resource reservoir and completing the loop of the circular economy.

Keywords

E-waste, metal recovery, hydrometallurgy, circular economy, sustainable resource management, Metal recovery.