SS8

# Resource Recovery from Water and Wastes: Grand Challenges and Opportunities for Circular Economy and Carbon Neutrality

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**Abstract** Continuing global growth in electric vehicles, artificial intelligence-assisted supercomputing, and energy generation from renewable sources (including solar and wind) leads to significant demand for scarce and expensive materials (e.g., rare earth elements (REEs) and high-cost catalysts). For example, global REE production reached 210,000 tons in 2019, with an 11% increase compared to 2018, and it is expected to grow at an annual rate of 13.7% during the period 2017–2021. Practical recovery of the scarce and expensive materials from various water and waste streams can obviate environmental pollution, saves resources, and boosts sustainability. In recent decades, academia has elaborated a wide range of technological solutions to recover materials, energy, nutrients, and other products from water and waste. However, traditional pyrometallurgy and hydrometallurgy technologies are not considered economically sustainable, and emerging direct recycling has been confirmed only at laboratory-scale, with attendant uncertainties for scale-up. This paper critically assesses grand challenges and opportunities of resource recovery from various wastes (including (lithium-ion) batteries, e-wastes, photovoltaic modules, polymeric wastes, municipal solid wastes) and water streams (including seawater, groundwater, produced water, acid mine drainage, and municipal wastewater) for circular economy and carbon neutrality.

**Keyword(s)**
Scarce and expensive materials, Resource recovery, Water and wastes, Sustainability and carbon neutrality

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