INTERNATIONAL SEVEN JOURNAL
OF MULTIDISCIPLINARY
ISSN: 2764-9547

RECYCLING OF RARE EARTH ELEMENTS USING IONIC LIQUIDS FOR REGENERATIVE MANUFACTURING

10.56238/isevmjv2n5-037
Receipt of originals: 09/26/2023
Acceptance for publication: 10/262023

Eduardo Nunes da Silva

ABSTRACT
The growing demand for rare earth elements (REEs) in high-technology applications has intensified the need for sustainable recycling methods. Ionic liquids (ILs) have emerged as a promising tool for selective recovery of critical metals from post-consumer products such as magnets and batteries. This article explores the use of ILs in regenerative manufacturing, highlighting their high selectivity, recyclability, and operation under mild conditions. Recent industrial applications, including processes developed at Queen's University Belfast and Ionic Technologies, demonstrate the feasibility of IL-based recovery of high-purity REEs. Integrating IL-mediated recycling into circular value chains supports sustainable, secure, and low-impact production of critical metals.

Keywords: Ionic liquids. Rare earth elements. Recycling. Regenerative manufacturing. Circular economy. Critical metals. Post-consumer recovery. Sustainable materials. High-tech production. Industrial application.

1 INTRODUCTION

The escalating demand for rare earth elements (REEs) in high-tech applications has underscored the necessity for efficient recycling methods. Ionic liquids (ILs), as environmentally friendly solvents, have emerged as promising agents for the selective recovery of REEs from post-consumer products such as magnets and batteries. The use of ILs offers advantages such as high selectivity, recyclability, and the ability to operate under mild conditions, making them suitable for regenerative manufacturing processes (Iravani et al., 2021; MDPI, 2025a). Case studies, including the work of Ionic Technologies in Belfast, demonstrate the practical implementation of IL-based processes in the recovery of high-purity REEs, contributing to the establishment of circular value chains in high-technology production (Ionic Technologies, 2025; Chemistry World, 2025).

The rapid advancement of technology has increased reliance on REEs in electronics, renewable energy systems, and electric vehicles. However, extraction from primary sources is environmentally detrimental and geopolitically sensitive. Consequently, recycling REEs from post-consumer products has become a critical component of sustainable manufacturing. Ionic liquids, a class of solvents composed entirely of ions, have garnered attention for their potential in selective recovery due to properties such as tunable solubility, high thermal stability, and low volatility (ScienceDirect, 2025a; MDPI, 2025b).

ILs have been extensively studied for extraction and separation of REEs from waste streams. Their ability to dissolve a wide range of compounds and selectively extract target metals makes them ideal candidates for recycling processes. Recent research has demonstrated the efficacy of ILs in leaching REEs from end-of-life magnets and batteries, with high selectivity and minimal environmental impact (ScienceDirect, 2025b; ACS Publications, 2025). For instance, work at Queen's University Belfast's QUILL (Queen's University Ionic Liquid Laboratories) developed an environmentally benign, IL-based method to separate rare earth metals from end-of-life magnets, recovering pure metals while minimizing the use of hazardous solvents (Queen's University Belfast, 2025).

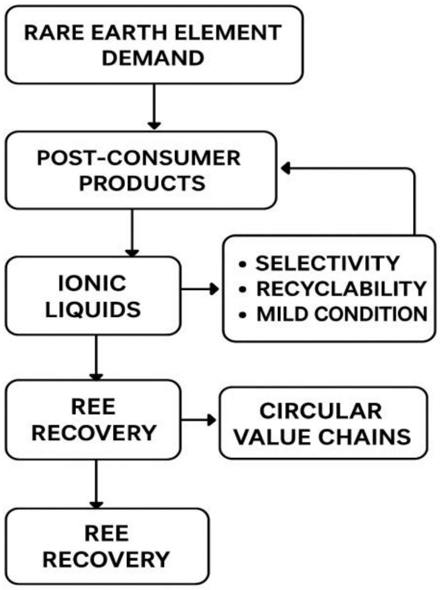
Practical application of IL-based recycling processes has been exemplified by Ionic Technologies, a Belfast-based start-up. The company developed a patented method for extracting high-value rare earth oxides from industrial magnets, reducing dependence on traditional supply chains and producing high-purity elements such as praseodymium, neodymium, terbium, and dysprosium (Ionic Technologies, 2025). This approach aligns with the growing demand for sustainable and secure sources of critical materials (Chemistry World, 2025).

Despite these promising applications, challenges remain in the widespread adoption of IL-based recycling methods, including scalability, economic viability compared to traditional methods, and the need for standardized protocols to ensure consistent quality of recovered materials (MDPI, 2025c; ResearchGate, 2025). Future research should focus on optimizing IL formulations for specific applications, improving recycling efficiency, and developing comprehensive life-cycle assessments to evaluate environmental and economic impacts (MDPI, 2025a; ScienceDirect, 2025a).

The flowchart illustrates the process of rare earth element (REE) recycling using ionic liquids (ILs). It begins with the growing demand for REEs, which drives the recovery of materials from post-consumer products such as magnets and batteries. Ionic liquids are then applied as selective, recyclable, and environmentally friendly solvents that operate under mild conditions. This enables efficient REE recovery while reducing reliance on primary extraction. The recovered elements are reintegrated into production systems, supporting circular value chains and advancing sustainable high-technology manufacturing.

Figure 1

Flowchart of Rare Earth Element Recycling Using Ionic Liquids



Source: Created by author.

The integration of ionic liquids into REE recycling represents a significant advancement toward regenerative manufacturing. By enabling the efficient recovery of critical metals from post-consumer products, ILs contribute to circular value chains in high-technology production. Continued research and development are essential to overcome existing challenges and fully realize the potential of IL-based recycling processes in sustainable manufacturing (MDPI, 2025b; ACS Publications, 2025).

INTERNATIONAL SEVEN JOURNAL OF MULTIDISCIPLINARY
ISSN: 2764-9547

REFERENCES

1. ACS Publications. (2025). Separation of Rare Earths and Transition Metals Using Ionic-Liquid-Based Solvent Extraction.
2. Chemistry World. (2025). Ionic liquid a perfect fit for rare earth recycling.
3. Ionic Technologies. (2025). Belfast magnet recycling start-up offers rare earth promise. *Financial Times*.
4. Iravani, S., Korbekandi, H., Mirmohammadi, S. V., & Zolfaghari, B. (2021). Synthesis of silver nanoparticles: chemical, physical and biological methods. *Green Synthesis and Applications*.
5. MDPI. (2025a). Recent Uses of Ionic Liquids in the Recovery and Utilization of Rare Earth Elements.
6. MDPI. (2025b). Recovery of Rare Earth Elements with Ionic Solvents.
7. MDPI. (2025c). Recent Work on the Recovery of Rare Earths Using Ionic Liquids.
8. Queen's University Belfast. (2025). Using Ionic Liquids in the Transition to Renewable Energies.
9. ResearchGate. (2025). Application of Ionic Liquids for the Recycling and Recovery of Rare Earth Metals.
10. ScienceDirect. (2025a). Ionic liquids-mediated recovery of metals from spent batteries.
11. ScienceDirect. (2025b). Selective recovery of rare earth elements from e-waste via ionic liquids.
12. Pessoa, E. G. (2024). Pavimentos permeáveis uma solução sustentável. *Revista Sistemática*, *14*(3), 594–599. https://doi.org/10.56238/rcsv14n3-012
13. Pessoa, E. G. (2024). Pavimentos permeáveis uma solução sustentável. *Revista Sistemática*, *14*(3), 594–599. https://doi.org/10.56238/rcsv14n3-012
14. Eliomar Gotardi Pessoa, & Coautora: Glaucia Brandão Freitas. (2022). ANÁLISE DE CUSTO DE PAVIMENTOS PERMEÁVEIS EM BLOCO DE CONCRETO UTILIZANDO BIM (BUILDING INFORMATION MODELING). Revistaft, 26(111), 86. https://doi.org/10.5281/zenodo.10022486
15. Eliomar Gotardi Pessoa, Gabriel Seixas Pinto Azevedo Benittez, Nathalia Pizzol de Oliveira, & Vitor Borges Ferreira Leite. (2022). ANÁLISE COMPARATIVA ENTRE RESULTADOS EXPERIMENTAIS E TEÓRICOS DE UMA ESTACA COM CARGA HORIZONTAL APLICADA NO TOPO. Revistaft, 27(119),

67. https://doi.org/10.5281/zenodo.7626667

16. Eliomar Gotardi Pessoa, & Coautora: Glaucia Brandão Freitas. (2022). ANÁLISE COMPARATIVA ENTRE RESULTADOS TEÓRICOS DA DEFLEXÃO DE UMA LAJE PLANA COM CARGA DISTRIBUÍDA PELO MÉTODO DE EQUAÇÃO DE DIFERENCIAL DE LAGRANGE POR SÉRIE DE FOURIER DUPLA E MODELAGEM NUMÉRICA PELO SOFTWARE SAP2000. Revistaft, 26(111), 43. https://doi.org/10.5281/zenodo.10019943

17. Pessoa, E. G. (2025). Optimizing helical pile foundations: a comprehensive study on displaced soil volume and group behavior. *Brazilian Journal of Development*, *11*(4), e79278. https://doi.org/10.34117/bjdv11n4-047