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Editorial

Advances in Recycling of Valuable Metals—2nd Edition

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1. Introduction and Scope

The demand for critical raw materials is increasing for energy transition. For instance, metals such as Li, Ni, Co, Fe, and Mn are the key raw materials for current technologies of cathode Li-ion batteries; Ga and Y are important for illuminations (e.g., LED lamps); and rare earth elements (REEs) such as Y, La, Nd, Sm, Eu, Gd and Tb are necessary for magnetics production used in electric vehicles and wind turbines. As a consequence, the mining activities to meet the demand are increasing yearly. Due to the geographical locations of the mining sites, the recycling of industrial wastes and electronic waste are an alternative for domestic production with a substantially lower environmental impact, which meets the definition for sustainable mining, which is *a set of mining processes and activities related to producing raw minerals from primary and secondary sources with near- to-zero waste generation* [1]. The recovery of metals involves metallurgical routes, such as hydrometallurgy, pyrometallurgy, pyro-hydrometallurgy, and biohydrometallurgy. New routes such as electrohydrometallurgy and solvometallurgy contribute new strategies for a circular economy and the critical metals supply chain [1].

However, recycling valuable metals (mostly critical metals) still faces several challenges, including theory and applied processes. It requires investigation to understand the reactions and extraction/separation mechanism due to the complexity, high concentration of contaminants, and similar chemistry proprieties [2–11]. This Special Issue aimed to address the most recent developments in recycling processes to obtain critical and valuable metals from secondary sources by traditional and novel technologies including a new understanding of the separation of critical metals, representing excellent contributions in the area.

2. Contributions

Solvent extraction is the main separation technique for REE processing. In Contribution 1, the extraction mechanism and structure of organic phase-REE were investigated for La, Y, Nd, and their mixtures to elucidate the organometallic complexation between phosphine oxide, phosphinic acid, and amine extractants. This work presents important insights for future separation processes of REEs from primary and secondary sources. Segala et al. investigated Ga separation using polyacrylonitrile nanofibers loaded with di-(2-ethylhexyl) phosphoric acid (D2EHPA), which combines a high specific surface area, simple regeneration, and a regular pore structure with a high selective solvent extraction process. The authors demonstrated high adsorption capacity (33.13 mg/g, at pH 2.5 and 45 °C) that could be used in the future for recycling LEDs (Contribution 2).

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For the separation of metals, Zheng et al. synthesized and evaluated zirconium phosphate supported on biochar for the recovery of REEs, which demonstrated strong selectivity for La ions and stronger selectivity than other materials reported in the literature (Contribution 3). Braz et al. also evaluated nanocellulose (carboxylate and sulfonated) for metal adsorption. In this case, the authors evaluated the adsorption of metallic ions commonly found in industrial and mining wastewater such as Hg, Na, and Mg reaching 89–100% removal (Contribution 4). The extraction of critical metal waste or non-explored streams from primary sources is relevant to promote a circular economy and resource valorization. Liang et al. studied the extraction of REEs from ion adsorption ore using $(NH_4)_2SO_4$ solution, where a higher ionic strength raises the NH^+ activity, thus increasing the exchange-site occupancy for REE^{3+} displacement (Contribution 5). Han et al. also studied the leaching of ion adsorption ore but using Mg sulfate as leaching agent, which is another potentially cheaper alternative; column experiments demonstrated leaching efficiencies of 90–98% REEs (Contribution 6).

Another important topic for the recycling of valuable metals is the recycling of batteries. Hoof et al. compared pyrometallurgy and hydrometallurgy as Li-ion battery recycling routes and demonstrated that a combination of both leads to the lowest overall carbon footprint with higher opportunities for improvements towards decarbonization (Contribution 7). Beyond Li-ion batteries, Lv et al. evaluated Zn-Mn recycling via reduction roasting followed by acid leaching to produce valuable nanomaterials as the product, reaching a recovery rate of 99.8% for Mn and Zn (Contribution 8).

Stopic et al. recovered Ti and Al using novel ultrasonic spray pyrolysis, which involves ultrasonic waves that can impede the removal of droplets from the gas phase, due to their collision with the reactor walls and between the droplets themselves. According to the authors, the integration of electrostatic precipitators increases the scalability and contributes to a lower environmental impact (Contribution 9). In this Special Issue, we also accepted literature review articles that addressed an analysis of the most recent publications, as shown by Efstratiadis et al., with their analysis of e-waste recycling and reuse of REEs products in additive manufacturing applications. This literature review demonstrates the importance of analyzing previous works to address the challenges of recovery metals towards sustainable mining (Contribution 10).

3. Conclusions and Outlook

Sustainable mining is needed to support the demand for critical raw materials for energy transition. This Special Issue contributes with excellent work on this topic and introduces new theories and applications. Future work could focus on the challenge to transform the knowledge of laboratory experiments into pilot and industrial scale worldwide.

Data Availability Statement: No data were used in this paper.

Conflicts of Interest: The authors declare no conflict of interest.

List of Contributions

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