

Abstract

The increasing demand for critical raw materials driven by energy transition policies and technological development is posing important challenges to raw materials supplies in Europe and worldwide, while stimulating interest in alternative sources. Accordingly, abandoned and historical mine waste represents a promising secondary source to be considered. However, the assessment of their recovery potential for obtaining critical and strategic raw materials is often limited by data availability, partial characterisation, and the lack of large-scale applicable evaluation methodologies.

This Doctoral Thesis develops and applies a data-driven methodological approach for the assessment of mine waste deposits as potential secondary sources of valuable raw materials. In particular, the proposed methodology merges together information screening, site-specific characterisation, and laboratory-scale recovery trials, providing a structured pattern from preliminary evaluation to technical application of recovery solutions. International guiding case studies are included as procedural benchmarks, such as the Finnish national mine waste database for prioritisation of actions and characterisation methodologies applied on Kanmantoo mine (Australia) for secondary prospectivity of tailings materials.

The proposed framework is applied to selected Italian case studies (Traversella, Libiola and Fenice-Capanne), representing different historical mining districts, site characteristics and mine waste typologies. Site investigations, including sampling and geophysical surveys, were combined with geochemical and mineralogical analyses to assess the occurrence, distribution and concentration of critical minerals and elements. Subsequently, laboratory-scale recovery trials, including mineral processing and hydrometallurgical methods, are performed to preliminarily evaluate the technical feasibility of recovering critical and strategic elements while validating the assessment outcomes.

Results demonstrate that bulk geochemical characterisation should be coupled to detailed mineralogical and geometallurgical information for guiding the selection of applicable processing methodologies and for defining a recovery potential of critical and strategic raw materials from mine waste. Additionally, real-case applications proposed through the Italian case studies, confirm that mine waste may be recovered according to solutions tailored to the specific conditions of each site, such as mine waste type, materials characteristics and accessibility of the areas.

Overall, the proposed methodology describes a transferable scheme for supporting the evaluation of mine waste sites that could be implemented in wider

protocols for developing data-driven protocols to assess potential exploitation of mine waste in Italy.

The outcomes of this Thesis could contribute to advancing sustainable approaches for mine waste valorisation according to circular economy principles and create opportunities for resource recovery and environmental restoration.