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Towards sustainable mining: exploiting raw materials from extractive waste facilities

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The incremental amount of needed Raw Materials (RM) and Critical Raw Materials (CRM) cannot be totally supplied by recycling activities, and mining activities are growing more and more at global level, requiring more modern and efficient technologies and mining techniques to guarantee a sustainable mining. To reach a sustainable mining, an interdisciplinary approach, which consists in considering economic, environmental and social impacts together with new processes implementation, is needed. The focus of the present research is the exploitation of extractive waste (EW) to recover RM and CRM, considering the technological and economical factors, together with the environmental impacts, associated to EW quarrying and dressing activities.

The present study, based on a case history from Northern Italy (Montorfano and Baveno granite quarrying area), was intended to validate the presented interdisciplinary approach for evaluating economic and environmental impacts associated to EW facility exploitation (from granite EW facility to products for ceramic industry and by products for building industry and infrastructures). Two different surveys were carried out: in 2009 and 2016, investigating four different EW facilities (Braghini, Ciana-Tane Pilastretto, Sengio, and Montorfano).

A shared methodology was applied to determine EW characteristics (geochemical, petrographical and mineralogical), EW facility volume (geophysical and topographic and morphologic 3D characterisation) and potential exploitable products, by-products (and CRM). Meanwhile, the Life Cycle Assessment (LCA) was applied to determine environmental impacts associated to extraction and processing phases.

The sampled materials from the EW facilities, sampled in 2009 and 2016, show highly homogeneous geochemical features (Al_2O_3 : 13.02-14.65; Fe_2O_3 : 1.40-2.41, TiO_2 : 0.10-0.26, CaO : 0.54-2.01, MgO : 0.14-0.45, K_2O : 4.49-5.18, Na_2O : 3.08-3.64) for major elements. The alkalis ($\text{K}_2\text{O}+\text{Na}_2\text{O}$) and Fe_2O_3 tot content of all samples are extremely important for the feldspar (l.s.) industry, and the samples obtained after magnetic separation show a decrement of Fe_2O_3 passing from > 1.4% (not good for ceramic industry) to < 0.2% (good for ceramic industry). Moreover, a wider range of geochemical analysis was carried out in 2016 and an interesting fractionation in the

treatment process is observed when considering the REE concentration: all samples of the magnetic fraction are much more concentrated than in the feeding material and can be up to one order of magnitude more concentrated than in the upgraded amagnetic portion. The total volume of dumps was estimated in about 2.1 Mm³.

The LCA reports that main environmental loads were due to the dressing plant, including climate change and freshwater eutrophication ones. Despite landfilling shows minor impacts, it has significant impact in terrestrial eco-toxicity. While climate change indicators show significantly higher loads than savings, savings and loads in freshwater eutrophication indicator are balanced. The avoided phosphate and phosphorous release to water results in high ratio of savings in freshwater eutrophication. As for environmental impacts, the SRM recovery activities are favourable for the environment compared to the use of primary sources.

The presented interdisciplinary approach is in line with the will of going towards a sustainable mining, which has to consider, together with economic and environmental factors, also social impacts and risks mitigation instruments.