EXPLOITING SECONDARY RAW MATERIALS FROM EXTRACTIVE WASTE FACILITIES: A CASE STUDY

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INTRODUCTION

In recent years, resource scarcity has emphasised a need to transition from a linear to a circular flow of resources [1]. Securing supplies of critical and secondary raw materials (CRM/SRM) for the manufacturing industry is at the forefront of industrial challenges, especially in Europe, USA and Asia [2; 3; 4; 5]. A key step towards achieving resource efficiency, is to recover these materials from anthropogenic waste deposits, such as urban landfill sites and extractive waste facilities [6]. This means breaking away from the traditional linear use of resources to a closed-loop approach that allows maximum recovery of resources from waste [7]. The management of extractive waste deposits and resource recovery is closely linked to the concept of urban mining [8]. In this paper, we present a case study illustrating the feasibility of recovering SRM from EW facilities and discuss the pros and cons of undertaking such activities.

MATERIALS AND METHODS

Pilot site description

Montorfano granite extractive waste (EW) facilities, subject of the present study, are in the Montorfano and Verbania territories, Verbano-Cusio-Ossola district (VCO, NE Piedmont Region, Italy). The VCO area is characterised by high tourism and is one of the most important quarrying districts in Italy, thanks to the vital dimension stones quarried, such as *Serizzo* and *Beola* (orthogneisses), granites and marbles. Specifically, the granites occur in the southern Verbano area, close to the entrance of the Ossola Valley, between Cusio and Verbano Lakes. They are typically pink (*Rosa Baveno*), white (*Bianco Montorfano*) and green (*Verde Mergozzo*) in colour.

The investigated area is part of a wider EW area, interested in granite exploitation present in Montorfano (Sengio and Ciana Tane-Pilastretto waste facilities –

Montorfano massif) and Baveno (Braghini waste facilities – Monte Camoscio) territories (Fig. 1).

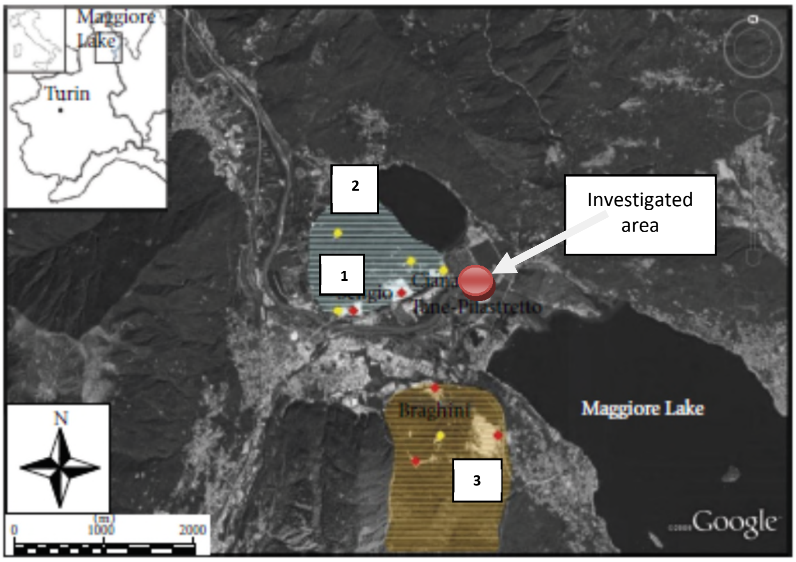

Figure 1 : Geographic context of the studied area. In the northern part (Montorfano area), it is possible to individuate both white granite (1) and green granite 2). The orange area defines the Baveno-Mottarone pluton (3). Furthermore, in the image the exploited quarry dumps are represented (red points) and the ancient quarry waste area, potentially useful for a future exploitation (yellow points). [9]

In the past, large amounts of EW have been produced and stocked on the lower side of the hill (Montorfano and Baveno), forming EW facilities of differing shapes (Fig. 2, 3). The large volume of waste rock is a clear example of the problems connected to mining activities: exploitation in this territory have caused, and are causing, an evident hazard for the population, as well as significant environmental and aesthetic impacts on this tourist area.

Figure 2: Example of EWfacilities present in the Montorfano area.

Figure 3: Southern side of Montorfano Massif.

In 1995, Minerali Industriali Group invested in a dedicated dressing plant to exploit and convert granite waste rock, present in the Sengio and Ciana-Tane-Pilastretto (Montorfano) and Braghini (Baveno-Mottarone) EW facilities, into new ore-deposits for feldspar and quartz exploitation. Such deposits are being progressively exhausted as a result of continuous exploitation.

The feeding material is treated by crushers) and mills (to reduce each grain size class to 1.25 mm as the maximum grain size dimension. This is then sieved to both obtain different grain size materials and to separate powder granite from other products. Finally, the material passes through electromagnetic separators, which select the ferromagnetic minerals from the final product by appropriate physical-chemical properties. The main product is commercially known as F60P (quartz feldspar mixture), produced at around 65.000 t/year. By-products, obtained after the enrichment of produced "waste" (mainly powder granite and fractions enriched in ferromagnetic minerals) commercially known as SNS-sand (premix for building uses), NGA-coarse black sand (used for industrial sandblasting), SF-wet feldspar (for the ceramic industry), and SF100 and SF200 (used as fillers in cement industries), are added to the F60P production. The total amount of by-products is about 110.000 t/year.

Field survey and characterisation

The Montorfano pilot site field activity focused on the new EW facilities NE of the Ciana-Tane-Pilastretto and Sengio mining areas (Fig. 1, 4). Samples were collected using a hammer and chisel due to block size (Fig. 2). The sampling area for each sample is around 10 m^2. Each sample constituted of small pieces of chips rock from different blocks.

Figure 4.a: Location of the samples in the new investigated area. The dot points represent the samples location

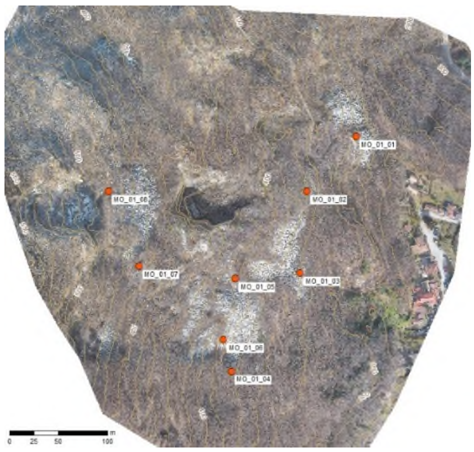

Figure 4.b: Locations of sampling points on top of orthophoto with contour lines.

During the sampling campaign (summer 2016), other samples from the treatment plant (Minerali Industriali) were collected in order to characterise the feeding material (from Sengio, Ciana-Tane-Pilasteretto and Braghini areas) and the product and by-products in order to understand if and where an enrichment in CRM (eg. REE) is possible. A total of 16 samples were collected: 8 samples from Montorfano EW facilities and 8 samples from the treatment plant. All samples were prepared at the Mineral Dressing and Sampling Laboratory (Earth Sciences Department, University of Torino) and characterised (geochemical analysis) at an external certified laboratory. For the Montorfano material, the main geochemical features (alkalies, Fe2O3tot, etc.) are extremely important for the feldspar industry; moreover, REE concentrations can be potentially important, as SRM.

RESULTS AND DISCUSSION

Geochemical characterisation

The sampled materials show highly homogeneous geochemical features (Al_2O_3: 13.38-14.65; Fe_2O_3: 2.09-2.41, TiO_2: 0.21-0.23, CaO: 1.33-2.01, MgO: 0.29-0.45, K_2O: 4.49-5.18, Na_2O: 3.26-3.51) for major elements. The alkalies (K_2O+Na_2O) and Fe_2O_3tot content of all samples are extremely important for the feldspar (l.s.) industry, are shown as histograms in Fig. 5.

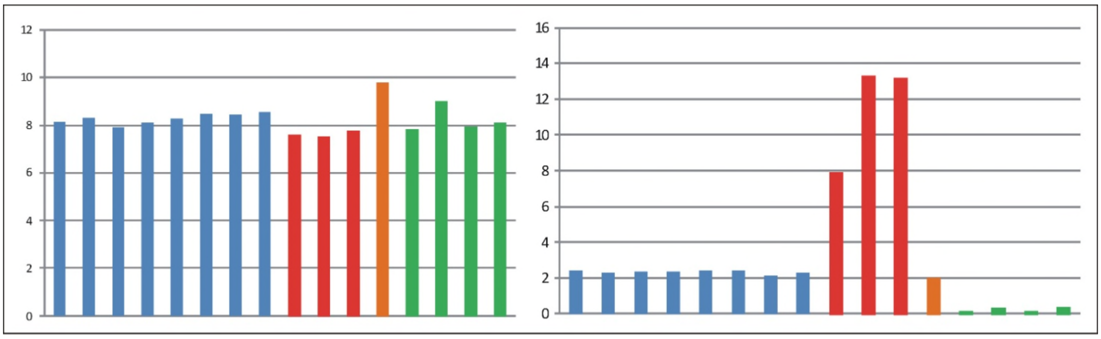

Figure 5: Concentration of alkalies (left) and Fe_2O_3tot (right) in the Montorfano pilot (all samples; values in wt.%). Blue: rock waste; red: treatment plant, magnetic fraction; green: treatment plant, amagnetic fraction, orange: feeding material.

For minor and trace elements concerning waste rock and feeding material, a relatively high REE content was found, typical of felsic, strongly differentiated magmatic rocks. In particular, the chondrite-normalised REE diagram (Fig. 6) shows a strongly coherent pattern characterised by strong enrichments in Light REE (LREE: especially La, Ce, Pr, Nd, Sm: up to 100 times chondrite), and slight enrichments in Heavy REE (HREE: Gd to Lu, relatively flat patterns with up to ca. 10 times chondrite values).

As for the enriched fraction (output from processing) there are strong differences concerning the absolute concentrations: all samples from the magnetic fraction show LREE enrichments up to almost 1000 time chondrite, i.e., 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 (Figs. 6, 7). Considering La+Ce, the average concentration ranges from 164 ppm (waste rock) to 585 ppm (magnetic fraction), down to 45 ppm (amagnetic fraction; 63 ppm also considering the strongly anomalous MO_02_04 sample). Y and Sc are also enriched in the magnetic fraction.

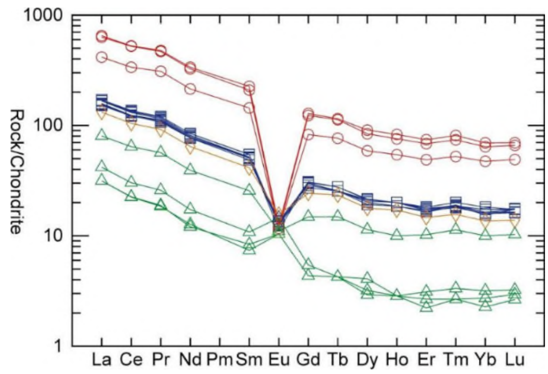

Figure 6: REE pattern for all samples, normalized to chondrite, logarithmic scale (chondrite values from Nakamura, 1974). Blue: waste rock; red: treatment plant, magnetic fraction; green: treatment plant, amagnetic fraction, orange: treatment plant, feeding material.

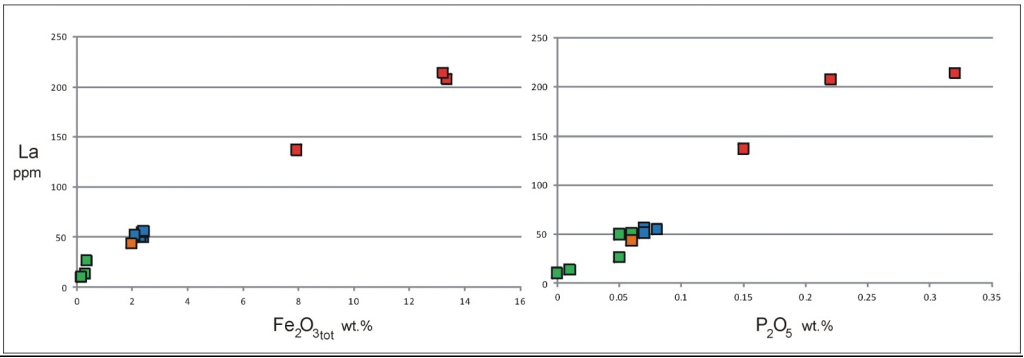

Figure 7: La-Fe_2O_3 and La-P_2O_5 correlations. La as ppm, Fe_2O_3 and P_2O_5 as wt.%. Blue: rock waste; red: treatment plant, magnetic fraction; green: treatment plant, amagnetic fraction; orange: feeding material.

Volume of the raw materials on the site

The total volume of the Montorfano pilot site was calculated at about 560.000 m^3 (about 1.008 Mt). Assuming that about 20 % must be subtracted from this volume to be treated in Sasil treatment plant, it is possible to estimate that the resources directly treatable in the Minerali Industriali plant should be about 0.8 Mt. Considering a feeding amount to the plant of nearly 175 t/year, it is possible to estimate 4.5 years (at least) for the production lifetime. The data, given by the company, in regards to the main products and by-products from the treatment plant are reported in Tab. 1.

Table 1: Yearly quantity and values connected to products and by-products arising from the treatment plant (value from Minerali Industriali documents)

Main Product And BY-PRODUCTS	Production (t/y)	Value (€)
F60P (Main Product)	65.400	1.430.800
F60-40 (feldspar concentrate with Fe<0.4%. Class <500 µm)	21.000	526.500
Gravel and sand	61.500	615.700
SF and SF- 100 (fine sands, magnetic concentrate, from dust aspiration; SF100 refers to class: <100 µm)	5.800	79.500
SN (black sand; magnetic concentrate)	1.800	16.500
SNG (black sand, magnetic concentrate. Class >600 µm)	6.900	102.500
SNS (black sand, magnetic concentrate, coming from the production line for F60-40	1.950	19.400
Type A (filler)	11.500	NO INFO
TOTAL	175.850	2.822.900

Main applications include: F60P: feldspar for ceramic industry, F60-40: feldspar for ceramic industry, Gravel and sands: for buildings and infrastructures; SF and SF100: for bituminous concrete; SN: for brick production; SNG: for external pavement and industrial surface treatments and SNS: for external pavement.

CONCLUSIONS

This paper presents the results connected to the site characterisation of EW and EW facilities, focusing on an Italian case study (Montorfano quarrying area). The wastes are stored in EW facilities, which need to be monitored for environmental and health impacts, but which can also be considered as potential new mining areas: e.g. for industrial mineral (feldspar) production. The Montorfano case study is a paradigm for how the recovery of EW from EW facilities can be economically sustainable (22 years of working activity). Minerali Industriali exploits granite waste to produce main products for ceramic industry and several by-products (for other applications) coming from the advanced treatment of the waste produced during the dressing activity. The results from the characterisation phase demonstrate that the investigated area (not yet mined) can guarantee feeding material to Minerali Industriali dressing plant for other 4.5 y after the recovery of all the materials present in the still exploited EW facilities. Furthermore, the presence of REE in the magnetic by-products suggests the potential exploitation of CRM, to be confirmed after a focused characterisation and treatment.

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Exploiting secondary raw materials from extractive waste facilities: A case study

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