TECHNOLOGICAL INNOVATIONS AND NEW PRODUCTS OBTAINED FROM A VIRTUOSOS MANAGEMENT OF MINING WASTE

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Abstract

The mining industry (raw materials production and technologies connected to exploitation and dressing plants) is one of the most important for Italian economy The exploitation works, and the consequent waste production, represent an evident hazard for the population, as well as an important environmental and landscape impact for touristic areas. For those reasons a systematic reuse of the rock waste, as secondary raw materials (SRM), should be essential. To justify the construction of new treatment plants it is important to guarantee: a sufficient quantity of waste/resources, the constancy of their supply and the convenience of the transport system. An interesting example, connected to quarry waste valorisation as SRM, is the one of Montorfano and Baveno granite quarry disposal sites (Lake District, VCO – NE Piedmont and some analogue samples concerning Gruppo Minerali Maffei spa (GMM spa). The excavation technique produced, during the past, a huge amount of wastes, stocked on the lower hill side of the massifs. In 1995 a primary Italian company (Gruppo Minerali Maffei spa) invested in granite quarry waste valorisation as SRM. The technical principle and the project planning for such a recovery (dressing plant project) is based on physical-chemical characteristics of the rocks and on the quantity of waste to be treated and valorised (BOZZOLA ET AL., 1995). The new exploitation of the dumped materials is useful for the production, by specific mineral dressing treatment (crushing, sieving, magnetic separation, etc…) of SRM for ceramic industry (GP – Grès Porcelain stoneware production) (DINO ET AL., 2005). The main product coming from Montorfano quarry dumps (waste represented by 33% quartz and 62% feldspar) is F60P: 60% of feldspar, mostly K-feldspar, whose production is about **140.000 t/year**. The waste produced during the enrichment phase (powder granite, ferromagnetic minerals, etc..) are also treated to obtain by-products which are used in other applications. In fact to the F60P production, different by-products have to be added, commercially known as: SNS - sand (as pre-mix for building uses), NGA - coarse black sand (used for industrial sandblast), SF - wet feldspar (for ceramic industry) and SF100 and SF200 (used as filler in cement industries). The total amount of the by-products is about **70.000 t/year.** Nowadays, this is an interesting economic reality with a subsequent save in the raw material costs. In order to guarantee the highest safety in the superposed yards and the stability of the quarry fronts, the material layer is depleted exploited from the top to the base of the whole volume. The same Company (GMM spa) is also involved in different kind of mineral waste valorisation.

The paper wants to show interesting examples concerning waste recovery in order to let industrial companies, Public Administrations and citizen know that it is possible to treat and valorise waste with economic and environmental benefits (waste is a resource for the future).

Purpose

As exposed in the abstract the problem connected to quarry waste management is still actual, and interests both mine owners (economic and environment problems) and citizens (evident hazard for the population, as well as important environmental and landscape impacts for touristic areas). It has to be underlined that, thanks to the evolutions in quarrying techniques, the quantity of wastes produced in the last decades has been reduced, but the problems connected to the management of such a kind of materials is still unsolved. A possible way of solving the problem, with contemporary economic benefits, should be the new exploitation of the materials, stocked in dumps, for the production, by specific mineral dressing treatment, of secondary raw materials (SRM) for industry (mainly for the production of Grès Porcelain stoneware) through specific mineral dressing treatments. (DINO ET AL., 2005).

The Company (GMM spa) interested in such valorization is involved also in different kind of "mineral waste" recovery (from clay mines, quartzite quarry dumps, waste coming from glass and ceramic production, etc…)

The paper refers an interesting applicative sample of "quarry" waste valorization (both for quarry/mine rehabilitation and for SRM production), and some data about innovative treatment of mine and "inorganic waste", applying new technologies which derive from mineral dressing (sieving, crushing, floatation, magnetic separation, etc…).

Methods

To opportunely valorize "mine waste", it is important to have some information about:

- chemical and physical characteristics;
- production of fluent waste (or quantity of waste disposed in "historical dumps");
- characteristics of mine/quarry dump: presence of polluted materials, concentration of inopportune minerals for the dressing plant (areal distribution of such concentrations), geometric characteristics of the dump (thickness and surface), etc…;
- localization of the mine and quarry dumps (or mine and quarry in the case of fluent waste) in order to program a logistic plan for selection, charge, transport, etc… to the treatment plant (still existing or to create, on the basis of a socio-economic analysis);
- law directive, in order to know how to manage such waste: as Waste, as By Products, as Secondary Raw Material (SRM). It has to be underline that in Italy there is a periodical regulatory update and in some case it is not so clear the way to follow to obtain the opportune quarry authorization/mine concession for "waste exploitation". (SERTORIO, 2008, MAGRI, 2009, DINO&FORNARO, 2010)

It has to be considered that, even if the data coming from an appropriate study are positive (proper characteristics, constancy of production, local/national/international market – it depends on the type of product produced in the dressing plant – ready for such product, etc…), the starting up of a new dressing plant is not guaranteed: es. Quartzite dumps valorization – Barge, CN. In that case the production never started because of problems connected to the authorization for "waste exploitation": they would have to follow Mine Legislation (Regio Decreto 1443/1927) and Quartzite Bargiolina would have to apply Quarry Legislation (L.R. 69/78 and L.R. 44/2000). (DINO ET AL., 2005).

Results

There is briefly summarized some interesting samples concerning mine waste and "inorganic waste" valorisation.

a. Ecomin - Verbania

The Montorfano and Baveno granite ore bodies are located in the *Lake District* (VCO – NE Piedmont). They were and are still quarried as dimension stones, with a consequent production of a huge volume of "waste".

The dressing plant (Ecomin S.p.A. in Verbania) has got the concession (in 1995, BOZZOLA ET AL, 1995) to exploit three granite quarry wastes dumps: Sengio and Ciana Tane-Pilastretto areas, for white granite recovering in Montorfano massif, and Braghini area, for the pink granite exploitation in Monte Camoscio (fig. 1). The Mottarone-Baveno pluton is mainly formed by two different varieties of granite: a pink granite (called "Rosa Baveno"), a historically famous ornamental stone. The Montorfano pluton is formed by a medium grained white granite and a small amount of a "green granite" (Verde Mergozzo) (BIGIOGGERO ET AL., 2004; BORIANI ET AL., 1988 A,B).

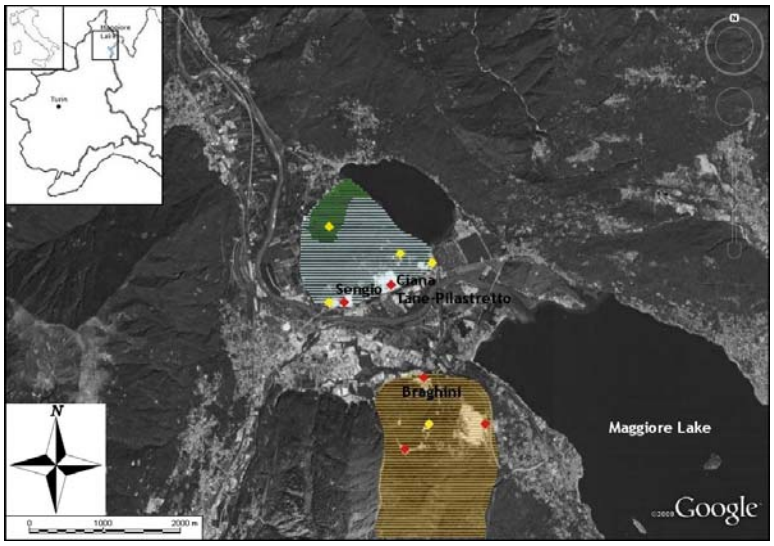

Figure 1: Geographic context of the studied area. The main image shows the satellite ortophoto of a portion of Massiccio dei Laghi batholith. In the northern part of the map (Montorfano area) it is possible to individuate both the White Granite (represented by grey stripes) and the Green Granite portion (Green Mergozzo type, represented by green stripes). The orange area defines the Baveno-Mottarone pluton. Furthermore in the image there are represented the exploited quarry dumps (red points) and the ancient quarry waste areas, potentially useful for a future valorisation (yellow points).(DINO ET AL, 2012)

In order to guarantee the highest safety in the superposed yards and the stability of the quarry fronts, the material layer is exploited from the top to the base of the whole volume: the quarried material is then loaded in dumper and transported to the dressing plant. The total recovery of the granite wastes exposes the underlying bedrock, to the purpose of minimize the conclusive hidro-geologic hazard of the areas.

The ore, conveyed from the quarry wastes areas to the plant, is successfully treated by crushers, roller mills, etc… in order to reduce each grain size class and to obtain 1,25 mm as maximal grain size dimension. Subsequently it is selected, by means of sieves, to obtain different grain size materials and to separate the raw powder granite from the other products. Finally this material passes through electromagnetic separators to select ferromagnetic minerals from the final product, in order to obtain an excellent product, characterized by the correct physical-chemical properties. The wastes produced during the enrichment phase (powder granite, ferromagnetic minerals, filler < 100μm) are also treated to obtain by-products which are used in other applications. A simplified Flow-Chart of Ecomin dressing Plant is reported in fig. 2.

In particular, the main product, output from the plant, is a mixture of quartz and feldspar, commercially known as F60P (quartz feldspar mixture: 60% of feldspar, mostly K-feldspar), whose production is about 140.000 t/year. To the F60P production, it has to be added different by-products, commercially known as: SNS - sand (as pre-mix for building uses), NGA - coarse black sand (used for industrial sandblast), SF - wet feldspar (for ceramic industry) and SF100 and SF200 (used as filler in cement industries). The total amount of the by-products is about 70.000 t/year. Nowadays, this is an interesting economic reality with a subsequent save in the raw material costs. The domestic market of feldspars, as industrial minerals, is increasing year after year in Italy: from 200.000 t in 1975 to 2,5 Mt in the last years (2005 data); to these amounts it have to be added the imported natural resources (about 2,0 Mt). It

has to be noticed that in 2009 there was an important decrease in feldspar production and utilization (- 30%), caused by the Global Economic Crisis.
Thanks to a detailed study of the *Graniti dei Laghi* area (Baveno and Montorfano), it has been possible to:

- calculate the quantity of material available for the treatment plant (2,9 Mtons);
- assess the quality of these materials in order to select what to send to the treatment plant and what to keep separate, because of their poorer quality;
- evaluate the reserves available in dumps, added to a fluent waste from the quarry, which will ensure the productivity of the treatment plant for 15 years.

In particular to update the information about the "dump-ore body", an in situ geomineral survey of the three mining areas was carried out in order to evaluate the characteristics of the material and the thickness and volume of the useful disposal sites that could be used (by means of geophysical surveys). The research described the structural, size distribution and stability properties of the waste deposits, and, at the same time, conducted a petrologic characterization of the bedrock, with the purpose of underlining the general characteristics (petrology, size distribution, morphology of the bedrock and stability of the slopes) of the three deposits. The granite waste are composed of > 30 mm material (70 – 75%), < 30 mm (20 %) and metric rocks (5 to10 %): it is classifiable as a granitic gravel sand, with a small percentage of silt and absence of clay. As a consequence of the field works, the amount of quarry waste was estimated as nearly **2 Mm^3**. (DINO ET AL., 2012)
Chemical analysis was carried out on 75 granite samples (characterizing the whole surface of the three investigated areas), in order to individuate the Fe_2O_3 grade: from **1.321-2.593%** of the **original waste** to **0.160-0.228%**. after the "**dry process**" treatment in Minerali Industriali pilot plant. Three different detailed maps (an example is reported in Fig. 3) that show the typology, the locations and the quality distribution of the material in the dumping areas have been drawn up (DINO ET AL., 2012).

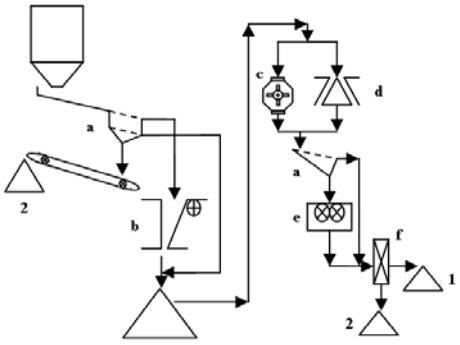

Figure 2: simplified flow-chart of Ecomin transformation plant

a: sieves
b, c, d: crushers
e: mill crushers
f: magnetic separation (different steps)
1: main product (F60P)
2: by-products

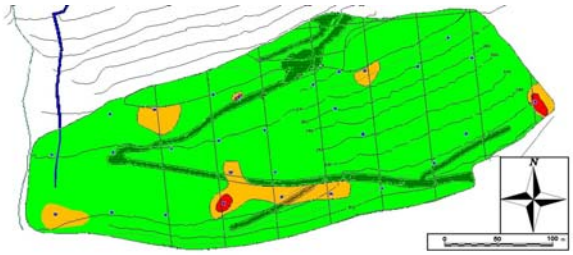

Figure 3: Braghini Area. It is possible to notice, in the middle of the map, a rockfall protection embankments (wire netting area), the Rio Cavallaccio stream just above the rockfall protection embankments (blue line) and the concession area borders (red lines)..(DINO ET AL, 2012)

Legend (fig. 3)

Fe_2O_3 oxide < 0,19 %
Fe_2O_3 oxide: 0,19 - 0,22%
Fe_2O_3 oxide > 0,22%
sampling points

The "waste" resulting from the production of F60P, the so-called "magnetic scrap", is treated to obtain new marketable products for the ceramics industry and for other applications concerning construction sector. The magnetic scrap waste, characterized by an initial Fe_2O_3 content close to 3%, are treated by mean of appropriate sieving, in order to select the 0.1-0.5 mm fraction in which the feldspar is still present in large quantities. It is not possible to separate this fraction during the first step of the magnetic separation (the one to produce the F60P), because the material presents larger particle size (0.1 to 1.2 mm) that affects the ability of magnetic separators. Thanks the sieving of the magnetic scrap waste it is possible to obtained: a 0.5 to 1.2 mm product suitable for industrial applications such as sand blast and other building products; a 0.1-0.5 mm product which, by means of another magnetic separations, guarantee enough feldspar content for ceramic industry (Fe_2O_3 shall swing between 0.15% and 0.3%, depending on the sector's commercial interests). Waste coming from this treatment is used as premixed material for building, in brick kilns and chimneys.

c. Enhancement of SF (fine product from grinding and dedusting)

The fine product coming from granite grinding and from the dedusting system presents initial particle size of about 0 - 0.3 mm (most of them < 0.1 mm). This filler, appropriately selected at 0.15 mm, is interesting for bituminous sheaths. Furthermore, thanks to the mixing with the powders coming from glass waste treatment, it can be used in the ceramics production. In fact the very fine particle size is important to guarantee considerable savings in terms of energy (the necessity of a material grinding is inferior of first raw material).

d. Washing sludges

The washing sludge, if dried thanks to filter press system (moisture content < 25%) and furthermore in a natural way, find a collocation in kilns market. Alternatively, it can be successfully used in quarries and mines rehabilitation.

e. Glass Waste

During the last 7 years more than 200,000 tons/year of glass waste, coming from glass recovery, have been valorised as secondary raw material in SASIL in Brusnengo dressing plant. Thanks to the contribution of Geom. Ramon and to financed LIFE projects, which topics were environmental protection and natural resources preservation, it was possible to apply mineral dressing knowledge for turning such "urban waste" into new resources..

After an appropriate treatment of such waste it is possible to obtain secondary raw materials for glass industry without the exploitation of "virgin" ore bodies, guaranteeing a significant reduction of thermal energy and of CO_2 atmosphere emission.

The new target of GMM group is the recovery of other kinds of glass waste, such as: standard PC monitor, mosaic-glasses, art-glasses, TV screens, lamps, glass fibre, solar and photovoltaic panels.

Low density, high mechanical resistance, high fire resistance and low thermal transmittivity, which characterise such "ex-waste", allow to use the "new products", coming from dressing plant, as insulating agents for the production of innovative light concrete to employ for the construction of eco-susteinable buildings.

Main conclusions

The importance of such a treatment is that, at first, it is possible to valorize quarry wastes as Secondary Raw Material (SRM), but, secondary, it is possible to achieve the goal of a zero waste volume production, with a consequential cost decrease for quarry enterprises and indisputable, environmental advantages for the territory.

The old dumps can be considered as "new mines". A wise and planned mining activity is important for the defence of the territory, as well as for the production of SRM, which are profitable for the company and for the Country. As already mentioned, the exploitation of the

quarry wastes ensures often a correct environment recovery and the safety of slopes affected by the dumps.
The valorisation of the material stocked in the dumps, guarantees positive results, both for the company and the community at large. The systematic exploitation of the "waste" accumulated during the years and/or actually produced, is the basic condition for:

- the safety of the landfill areas. The exploitation of these materials is truly favourable for slopes stability and for the safety of the roads and infrastructure near the quarries
- the impacts reduction (dust, etc …);
- a positive economic return (exploitation of the material placed in the dumps.

The research points out that it is possible to ensure sustainable development for mining activities, guaranteeing, at the same time, profit for the virtuous companies involved in the exploitation, valorisation and recovery of the "new ore-bodies".
Quarry waste represent, therefore, an important alternative (integrating) source, as a substitute to the exploitation of "virgin" material from the primary mines.
To fully exploit the resource from the dumps it is still essential to conduct a complete investigation in order to estimate the volumes, size distribution and chemical and mineralogical characteristics of the material.

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