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Preliminary investigations on stone cutting sludge processing for a future recovery

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A B S T R A C T

Solid waste management is a key component for the natural stone industry. In recent years, multiwire machines have been overtaking stone gang saw cutting technology. The advantages of these new cutting-edge technologies are high efficiency and performance, flexibility of use, high quality of the cut surfaces, very low environmental impact (low energy consumption, lowest concentration of heavy metals in the sludge, less waste) and lowest noise levels. There are many studies on the separation and recovery of sludge from cutting with the gang saw, but very few on diamond cutting sludges.

In accordance with the European Commission's Thematic Strategy on the Prevention and Recycling of Waste (EC raw material strategies), it is important to perform a correct characterization of sludge from cutting with the new technologies, in order to investigate its possible recovery.

This paper presents a preliminary investigation of the sludge resulting from different types of silicatic stones with the aim of their valorization. The investigation was conducted on sludge from cutting with diamond wire, diamond saw blades, and mixed sludge resulting from the filter press.

The following tests have been performed to characterize the sludge properties: chemical analysis on the solid fraction of sludge, particle size distribution, evaluation of the metals content through image analysis for each particle size, and leaching tests. To assess the possible recovery of the sludge, wet magnetic separation tests with a high gradient magnetic separator were performed in order to obtain two types of secondary materials, namely the mineral fraction and metals fraction. The separation efficiency has been evaluated through DRX and SEM analysis on the two fractions. The results obtained for the different particle size classes have been compared. The magnetic separation of the size class <0.038 mm has a low separation efficiency because of the phenomenon of grain capture by metallic granules: for this reason the metallic fraction of this class must be further processed if it is to be considered as a secondary raw material. On the other hand, the magnetic separation of the other granulometric classes is characterized by good separation efficiency. A good efficiency of the process is a key factor in order to optimize the recovery process and to increase the economic advantages. The study performed is useful for evaluating the possible reuse of both the metal and the mineral parts, through the implementation of a proactive waste management strategy in order to avoid a subsequent environmental degradation.

1. Introduction

The vast quantity of natural stone products used in the construction industry generates significant amounts of slurry deposits, estimated at 5 million tons per year in Europe (Graziani and Giovannelli, 2015). The rapid development of new cutting technologies in the stone industry has resulted in an increased production of hazardous materials and, at the same time, an increasing need for an eco-sustainable process. The production of hazardous materials has a big impact on issues related to the management of non-renewable resources and protection of the landscape, as well as on the management of waste. Reducing the generation or utilization of these materials at source or recycling waste on site are

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primary pollution prevention goals. This aspect not only has an effect on the environment with respect to the reduction of hazardous materials disposal, but also has economic benefits for industry.

The European Community through the Directive 2006/21/EC (Management of waste from extractive industries – Mining waste), the Directive 2008/98/EC (Waste Framework) and the Directive 1999/31/EC (Landfill Waste) provides guidelines for its member countries on how to handle the wastes in view of a future sustainable development of the sector, especially with regard to the critical raw material (CRM) (EU Conference, 2016). The Italian implementation of the European Directives is shown in Fig. 1.

The Italian legislative decree of April 3, 2006, n. 152, *Regulations on environmental matters Part IV*, the implementation of Directive 2008/98/CE, refers to the 'rules on waste management and remediation of contaminated sites', outlines the prevention of (art. 180) and reduction in the production of dangerous waste and encourages the use of recycling, energy recovery (art. 181), disposal (art. 182), landfilling and incineration. This decree assigns each waste a CER (the corresponding EWC, European Waste Catalogue) code of six numbers: the sludge is identified with the waste code 010413, 'wastes from stone cutting and sawing'. According to the current legislation there are many gaps in the use of residues from mining and processing lithoids (gravel and rock dust in the form of sludge), such as 'by-products'. The European Directive and its Italian implementation, cited above, provide guidance on requirements to be fulfilled for classifying a substance as a by-product. The substance will be used directly without any further treatment outside of normal industrial practice (Annex 3 of D.M. 161 of 2012 which includes the following activities: granulometric selection with possible elimination of anthropic materials, volumetric reduction by grinding, drying and maturation of the soil and rocks from excavation to foster the natural biodegradation of the additives used); the substance is produced as an integral part of a production process; and further use satisfies the requirements for health and environmental protection. The European Commission in a note of

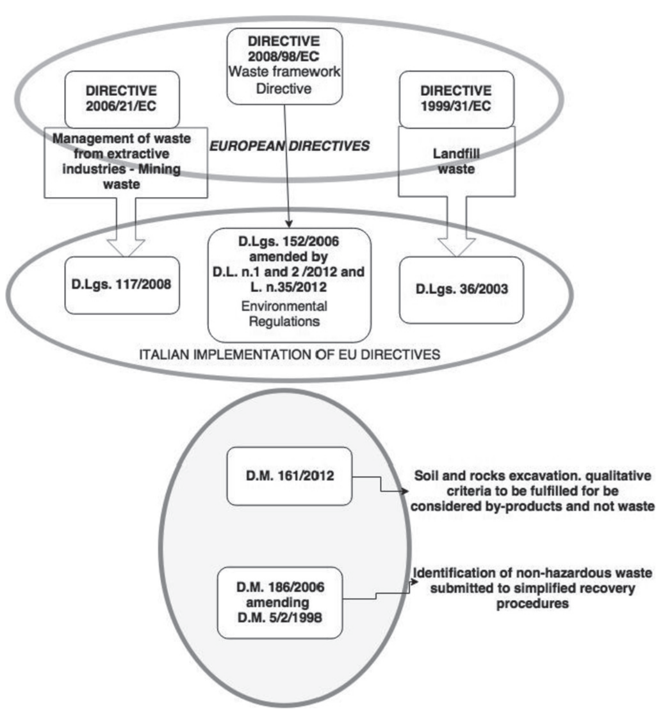

Fig. 1. Italian regulatory framework, on the basis of European Directives.

09/01/2015 confirms that the classification of soil and rock excavation as by-products must be conducted case by case. The important thing is that they contain a concentration of pollutants under the CSC (Contamination Threshold Concentration) limit with reference to the specific target use (Italian implementation: Decree of April 3, 2006, n. 152, Table 1 Annex 5). The D.M. 161 of 2012, following what is prescribed by Law 221 of December 28, 2015 Art. 53, excludes the residues of processing stone materials from the discipline of earth and rock excavation. This exclusion should be a simplification because it allows operators to qualify such residues as by-products in accordance with the regulations governing mining activities. Fig. 3

The management and disposal of sludge resulting from silicate and carbonate rocks has long been the subject of research (Uliana et al., 2015; Careddu et al., 2014; Uygunoglu et al., 2014; Papantonopoulos et al., 2007), although a suitable solution has not yet been found on how to recover this waste (CER 010413) or where it can be disposed of other than in authorized landfills for inert waste, which are often far away from the place of production of the sludge.

The sludge produced is composed of water, rock residues and metal parts resulting from the cutting tools. According to several studies, these sludges have a moisture content of around 35%–45% (Mancini et al., 2005). For the purposes of disposal in landfills, sludge must be dewatered until reaching a percentage of humidity of less than 25%. The estimated minimum amount of waste produced from the extraction and processing of granites and marbles is 40% of the worked stone volume. The processing waste contributes 20% of the total. So, for example, a production of 5.8 million tons and an estimated minimum of 40% of waste leads to 2.3 million tons of total waste of which (20%) 1.2 million tons is from processing (Salah el-Haggar, 2015; Celik and Sabah, 2008). This would mean a very high cost for disposal, as well as environmental issues.

With new cutting technologies, different from the gang saw, such as diamond disks and diamond wires, the amount of processing residues also decreases, as does the amount of hazardous substances present in the sludge.

According to a sector study carried out by the Fillea Observatory (Graziani and Giovannelli, 2015; Serra et al., 2014), in Italy the extraction and processing of stone materials in 2012 cost about 7.7 billion €, that is 0.34% of the total national economy and 0.88% of all manufacturing industry, and only 9% of the sludge from processing stone is recovered (Fig. 2).

The recovery of sawing sludge is characterized by several issues due to:

– fine particle size. The sawing sludge represents the finer part of the waste produced by the cutting and processing. This material arises because almost all of the machines of the production cycle operate wet, subjecting the cutting zone to a continuous jet of water to cool the tools and to remove the powder produced. Usually the particle size of the sludge is $<$ 25micron, like a silt-clay soil with low permeability characteristics if compacted. In the case of environmental restoration of quarries it creates stability problems.
– metals content. The sludge obtained from the extraction and processing of stones contains both removed stone material and residue from the tools. The presence of heavy metals, such as Cr, Ni, and Mn, associated with the Fe in the metallic grit of sludge from gang saw cutting, as well as the Co and Cu generally resulting from diamond disk cutting tools. Following further studies (Dino et al., 2006), it is clear that there are obvious problems (high shipping and landfill fees) linked to the presence of cobalt in the alloys of the diamond disks.