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REUSE AND VALORIZATION OF SILT FROM AGGREGATES CRUSHING OF ALLUVIAL GRAVEL AND SAND, FOR THE MANUFACTURING OF CEMENT BASED BUILDING ELEMENTS

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Abstract

The development of Multi-Energy Systems (MES) or District Energy Systems (DES) requires suitable design and operation optimization tools, in order to assess their feasibility and economic profitability. These tools can be helpful in choosing the proper technologies and also in the perspective of defining proper incentive or taxation schemes. A critical result of the analysis of MES is that, when optimizing their design, the operation strategy and the part load behavior of the units must be considered in the optimization model. This way, the model is to be formulated as a two-stage problem, where the design and the operation variables are optimized in the first and in the second stage, respectively. In order to guarantee the computational tractability, the scheduling/operation problem is solved for a limited set of typical and extreme periods. We have developed a Mixed Integer Linear Programming model to solve this design optimization problem, for which we have linearized the off-design and the size effects of performances and costs for the technologies considered in the case study. The model has been applied to optimize the design of a district energy system for the University of Parma Campus in Northern Italy.

Key words: carbon tax, design optimization, district energy systems, tri-generation

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1. Introduction

The materials studied in this paper are the "silt washing", that represent the residues from the processing of aggregates (extracted from alluvial sand and gravel quarries), conduct in some production centers defined crushers. In these production centers different processes are carried out on quarry aggregates: crushing, mechanical screening (winnowing), decanting and washing with water (Fig. 1).

The aggregates "silt washing", byproduct of these processes, show up in the form of aqueous suspension containing clay, silt and fine sand in different grain sizes. Currently, the silt resulting from washing

phase of the aggregates production process, represents a good product suitable for environmental requalification or for other purposes. Obviously for the activation of a systematic recovery, it is essential to observe the provisions of the rules relating to the recycling of waste (Decree in Force of Law, 1997, 2006). However, although there is a tendency to consider the silts washing as wastes, there are different interpretations that, according to their origin, agree with their definition as byproducts of processing. The Court of Cassation in its judgment of 2 March 2015 # 8982 clarifies that to the waste from mining activities should not be applied the discipline of General waste, but the special discipline referred to Decree in Force of Law (2008).

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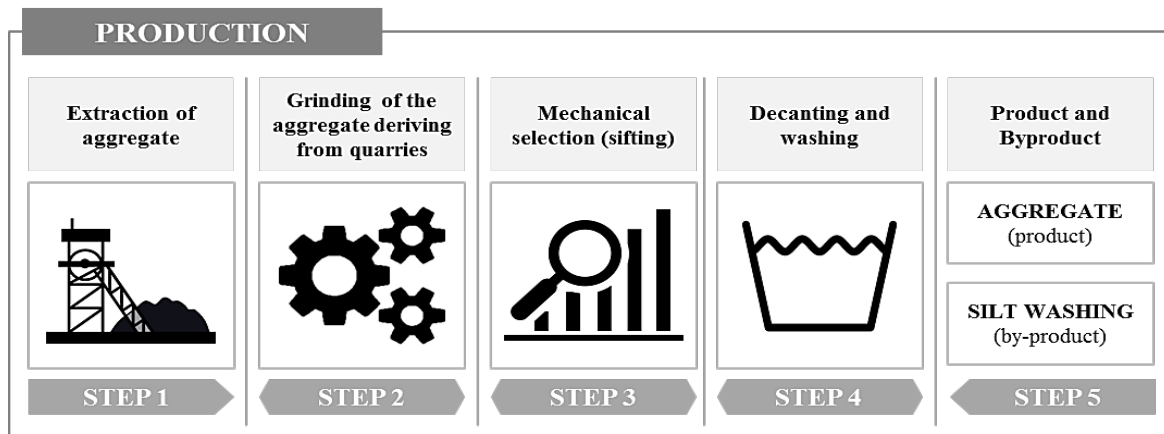


Fig. 1. Scheme of the process that generates silt washing

Therefore "the silts from washing of aggregates deriving from quarry (sludge from mining activities) fall outside the scope of application of the guidelines on waste only when they remain within the production cycle of mining and associated cleanup, while when it is activated a subsequent and different processing activities, they are subject to General rules about waste disposal, storage depots and dump". Discriminating factor, for the correct identification of the applicable legislation, is the classification of cleanup of aggregates extracted as internal activities of the production process considered.

From the point of view of technological features and capabilities, the "silts washing" can be considered an equivalent to the aggregates themselves resulting from the processing of materials extracted from the quarry (Migliore et al., 2015; Sansone, 2016). Several international studies (Chang et al., 2010; Lupo et al., 2007a) showed that the performance of the "silts washing" are within the parameters set by international technical standards for materials that can be used in construction. Therefore, the use of silts becomes possible even without any preliminary processing, because it is clear that their potential use qualifies them as by-product. Based on these premises, the purpose of the article is to highlight the potential derived from their recovery and their exploitation. So was chosen as a case study an Italian company that produces cement products, in which a systematic recovery of this by-product could be activated.

2. Case studies

2.1. Quarries issue in Italy, impacts and sustainability perspectives

The quarries report of Legambiente (2017) every year provides data on the state of the quarries in Italy and highlights the data about the number of active quarries, quantities of materials extracted, and predicts the perspectives on this sector (both in economic and in environmental point of view). The data published in the report of 2017 have highlighted that

the quarries of aggregates constitute the largest percentage among the active quarries; it is estimated that they represent approximately 61% of the total active quarries in Italy (Legambiente, 2017) for a total figure of about 2900 quarries. In quantitative terms (Table 1), for the aggregate quarries is registered a movement of 53 million cubic meters of material (sand and gravel), which currently are focused mainly on three regions in Italy (Lombardia, Puglia and Piemonte). These regions detain the 60% of national amount extracted (only aggregates), for a quantity of approximately 32 million cubic meters of material extracted.

Table 1. Annual amount extracted by Region [cm] (Legambiente, 2017)

Region	[cm]	%
Lombardia	19.585.433 cm	36,95%
Puglia	7.024.137 cm	13,25%
Piemont	4.804.258 cm	9,06%
Other regions	21.591.430 cm	40,74%
Italy	53.005.073 cm	100%

These quantities have been reduced in the years of the economic crisis that has hit Europe; indeed, the crisis in the construction industry has forced the closure of many quarries (20% of open quarries) and decreased the amount of material extracted (about 40% in reduction). However, the values of the material extracted, remain high and attention shall be given in order to reduce the use of resources, even in respect of what is asked by the Community Directives (EC Directive, 2011a; 2011b; 2014; 2015) on environmental sustainability. Some ways to contain these large consumptions of raw materials are represented on one side by the reduction of the use of resources and on the other side by the progressive recovery of scraps/waste resulting from the extraction and processing.

With reference to the sand and gravel quarries, the scraps (silt washing etc.) can be quantified in about 5/8% of the total extracted. Considering the entire national context, the overall quantity of about 4 million cubic meters of material unless otherwise used (restoration and enhancement as inert material in different purpose) would be destined to landfill.

2.2. Reuse of silt washing of aggregate

Reuse of silt washing of aggregates is an important opportunity to promote processes of circular economy, and several studies have shown that this by-product is adequate to replace virgin raw materials in different production cycles. A study Gonzalez-Corrochano et al. (2009a) has shown that the silt washing (along with used motor oil and fly ash) can be used to produce lightweight aggregates with high insulating capacity. This is an alternative use of this by-product that highlights so far unexploited features that can increase the business value, qualifying the reuse as a process of up-cycling.

A similar result has emerged from another research work (Lupo et al., 2007b) funded by DEFRA (Waste and Resources R&D Programme UK), which intended to produce a lightweight aggregate in the form of pellets using scraps of washing of aggregates. Always as lightweight aggregate (Gonzalez-Corrochano et al., 2009b) was studied its reuse as a product for agriculture and building industry, in this case, it is worked with other by-products and/or non-contaminated waste and compatible with the proposed uses. On the quality of scraps resulting from the extraction (Tutumluer et al., 2015) has also expressed a study conducted in Illinois Institute of Transportation, who sees in this by-product an excellent material to stabilize the subgrade.

2.3. Case study

Based on the assumptions made, it emerges clearly that the proposal of systematic strategies for the enhancement of silt washing, can result in significant environmental benefits. Benefits may arrive in terms of reduction in the use of natural resources (by turning scraps into secondary raw material for further processing and avoiding landfill disposal) and in terms of environmental benefits with reduced impacts of the supply chain.

Focusing the attention to the Italian context, and specifically to the Lombardy region, it is clear that strategies to obtain a systematic recovery of this by-product can lead to the activation of processes of circular economy with a considerable impact on territory. It can be estimated that only in the Lombardy region it is produced a quantity of silt washing of about 1/1.5 million cubic meters, not negligible compared to the data of national production.

The need to undertake a requalification of what is generated (in terms of scrap/waste) from industrial processes is an important objective and the same regional authority (Region Lombardia, 2016) support initiatives aimed at better environmental protection and respect for natural resources. These initiatives have resulted in significant improvements in waste management, aligning with the European averages. To highlight the potential in terms of valorization of the resources a case study is presented referred to an Italian

manufacturer that produces concrete elements. The company studied is Senini Spa that operates on the Lombard territory from many years; its main production consists in concrete elements such as masonry units, curbs, paving, block paving etc. However, over the years it has innovated by putting in new products such as hemp brick manufacture.

Actually, the production of Senini Spa regards approximately 90,000 tons of aggregates (derived from alluvial sand and gravel quarries located in Lombardy) that are treated for the manufacturing of finished products. The treatment of the raw aggregates can generate about 7,000 tons of silt washing that, if properly managed, could become an additional resource. The hypothesis under study is the transformation of the washing silt in substrate for the gardening, hypothesis already pursued in other contexts (Gonzalez-Corrochano et al., 2009b) and that if further investigated could turn the current type of process into a zero waste production.

The idea of being able to follow this direction stems from the fact that the aggregates processed by Senini are free from contamination (Table 2) (several laboratory tests have been performed) and therefore the washing silt can be considered as virgin raw material. Its use does not need to take action to treat it or to decontaminate it; on the contrary it is a fertile material (enriched by years of sedimentation) that could establish itself as a product with many powerful features for target sector. Also, if the silts are properly added and blended with other materials (fertilizers etc.) they may be enriched for more specific purposes (Fig. 2).

Table 2. Chemical tests conducted on samples of material used (data from Senini Spa)

<i>Level of contaminant mg/kg s.s.</i>	<i>Results</i>	<i>Limit value max</i>
Arsenic [As]	4.6	20
Cadmium [Cd]	0.4	2
Cobalt [Co]	4.4	20
Chrome total [Cr]	11.2	150
Chrome VI [Cr]	<1	2
Mercury [Hg]	<0.1	1
Nickel [Ni]	12.6	120
Lead [Pb]	8.7	100
Copper [Cu]	16.0	120
Zinc [Zn]	56.8	150

The proposal represents a perfect example of circular economy, which provides the possibility to establish systemic cycles between different sectors. In this case the transfer is from the construction sector to agricultural sector. These cross-sectorial transfers are the basis of the circular economy: providing some form of systematic reuse within consolidated production contexts (like industrial districts) they make the reuse of the scraps/by-product/waste easier and promote forms of industrial innovation both incremental and disruptive.

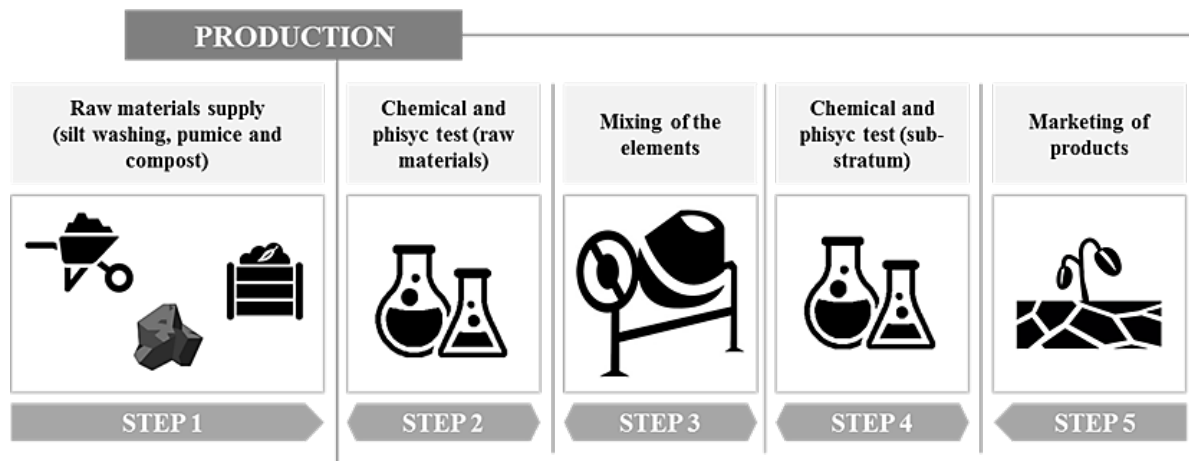


Fig. 2. Scheme of the hypothetical production process of the soil

3. Conclusions

The paper is intended to highlight the negative effects associated with unsuccessful recovery and valorization of the outputs of the processes related to the extraction and processing of aggregates for the construction sector. Quantitative data reported have revealed that this is a problem not marginal and therefore deserving of thorough investigations. The context of region Lombardia appears as a perfect case study for the implementation of initiatives aimed at recovering these scraps; the huge amount of material gives the possibility to operate with continuity over time (continuous supply of resources).

The proposal made by referring to the context of Senini spa represents an incentive to proceed in different directions to encourage the reuse and recovery of silt washing; therefore, are underlined the peculiarities emerged about the investigation conducted on silt washing and the prospects for feasible recovery.

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