A second life of waste products for a responsible and ethical use of natural resources: evaluations of the use of ashes produced by waste-to-energy plants as aggregated materials

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INTRODUCTION
In many geographical contexts, the availability of natural mineral resources is not always able to meet the demands and often the supply is carried out at high environmental and economic costs. This may not only concern fossil fuels but also raw materials used for the production of aggregates and availability of metals for each type of application. It is one of the consequences of the growth of the living standard that involves the continuous expansion of consumerism and the construction of infrastructures. For this reason the figures called to solve the problems of supplying raw materials and their use, as geologists and engineers, are necessarily faced with problems different from the normal market conditions, increasingly new and insufficient to cover the demand or available with very high energy costs and in contrast with the environmental protection issues that we try to apply in many countries.

The research therefore moves from the traditional reviewing of geological and mineral prospecting to the conventional and re-use of materials considered waste or waste deriving from an industrial process. With regard to sustainability, the use of residues from waste-to-energy plants for urban waste is included; after moderate treatments, they can find a role of raw materials in the construction of works, reducing the need to find additional natural resources and related problems for their disposal or storage. From the plants Waste to Energy, in 2016 only in Europe about 19 million of bottom ashes have been produced, thus offering a good opportunity for material to be processed to produce the desired end product.

The aim of the present study is to characterize the bottom ashes of municipal solid wastes incineration processes, which are used in many construction works. This study will be performed on the basis of the results we have defined the quality of material available for its entry into the “portfolio” of raw materials. We have also tested some incineration techniques to reduce polluting substances in the environment as natural and accelerated carbonation. The carbonation process involves the adsorption of carbon dioxide by an alkaline material, as bottom ash, decreasing pH and making calcite precipitate. The interaction of carbon dioxide with municipal solid waste incineration PM10 bottom ash has been studied to evaluate the resulting changes in pH and bottom ash mineralogy and the impact that these changes have on the mobility of dangerous substances, especially heavy metals. This process can be natural, in an open environment, or accelerated, using laboratory reactors to study the variation of time, temperature and humidity to maximize the carbonation process. We have compared these two methods to evaluate the possibility of a reuse of bottom ashes, respecting the European legislation thresholds.

MATERIALS AND METHODS
Some bottom ash samples were taken from the accumulation deposits of a waste-to-energy plant located in northern Italy. The material leaves the incineration process as it is and is rather heterogeneous and contains a significant fraction of metal elements. The samples divided in a fraction over and under 3 mm to perform the best treatments for each grain size.

Three BET samples were selected: one untreated (BA), one washed (WASH), and one accelerated carbonated (AC). The BET sample is not treated (BA), WASH treatment is washing, AC treatment is accelerated carbonation. Accelerated carbonation was performed using 20g of BA, applying different conditions of temperature, water content, presence of CO₂ and time. The fraction > 4 mm was excluded from carbonation since it doesn’t contain high concentrations of dangerous substances, as already recognized in many works (Quintana et al., 2015), and it is not usually used in the best treatments as washing. Accelerated carbonation tests were applied to the grain size fraction between 4 mm and 3 mm, and on the fraction < 4 mm.

The following results are relative to the fraction < 4 mm because most of the heavy metals and polluting substances concentrate in it. In fact heavy metals detected in the < 4 mm fraction of BA are three times higher than in the coarser fraction < 1 mm. Different sets of parameters were applied in the accelerated carbonation tests, as indicated by previous work on BA carbonation (Bertotti et al., 2004; Van Gerven et al., 2005; Barsicchi et al., 2010; Nag et al., 2012; Pen et al., 2012): the water to solid ratio (L/S) in the samples was maintained in the range 0.2-0.4 and L/S temperature variation has been set from 20 °C to 60 °C, time from 60 to 120 minutes and PH from 1 to 3 bar.

RESULTS
• Weight loss for BA: 6.5%, Weight loss for BA treated: 11.5%
• The difference of 5% is compatible with the weight increase (measured in laboratory) after carbonation of 4.5%