Evaluations of the reuse of municipal solid waste incinerator bottom ashes as aggregated materials in civil applications

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Il tempo del pianeta Terra e il tempo dell'uomo: le geoscienze tra passato e futuro
SIMP Società Italiana di Mineralogia e Petrologia
SGI Società Geologica Italiana
SOGEI Società Geochimica Italiana

Università degli Studi di Torino
Dipartimento di Scienze della Terra

Evaluations of the reuse of municipal solid waste incinerator bottom ashes as aggregated materials in civil applications

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INTRODUCTION

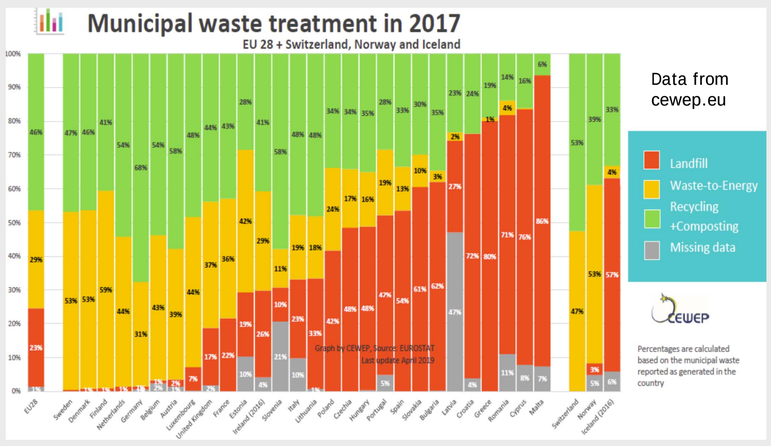
Nowadays, the availability of the natural mineral resources is not always able to meet the demands and it requires higher and higher energetic and environmental costs. As a consequence of the growth of the population that involves the construction of an increasing number of infrastructures, the sustainable supply of raw materials used for the production of aggregates has become a topic of fundamental importance.

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.

Bottom ashes reuse is a common practice in many countries of Europe, and even in Italy, most of the bottom ashes from MSWI (Municipal Solid Waste Incinerators) is used, depending on the legislation, for the production of aggregates for civil infrastructures.

The aim of the present study is to characterize the bottom ashes taken by a plant located in the Northern part of Italy, applying a multidisciplinary approach. Some inertization techniques, as the natural and the accelerated carbonation, are also tested to reduce the release of polluting substances in the environment. The carbonation process involves the absorption of carbon dioxide by an alkaline material, as bottom ash, decreasing pH and making calcite precipitate (Van Gerven et al., 2005; Nam et al., 2012). The interaction of carbon dioxide with municipal solid waste incinerator (MSWI) bottom ash has been studied to investigate 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 laboratories 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 threshold limits.

MSW TREATMENTS: PROBLEMS AND OPPORTUNITIES



In Italy, around 82 wt% of BA produced by incinerators was treated in 2016 for reuse and only 18% was landfilled. The differences which depend on the geographical areas: northern Italy recovers some 75,6 wt% of the BA, while central Italy only 8,4 wt%, and southern Italy about 15,9 wt% (ISPRA, 2014, 2017).

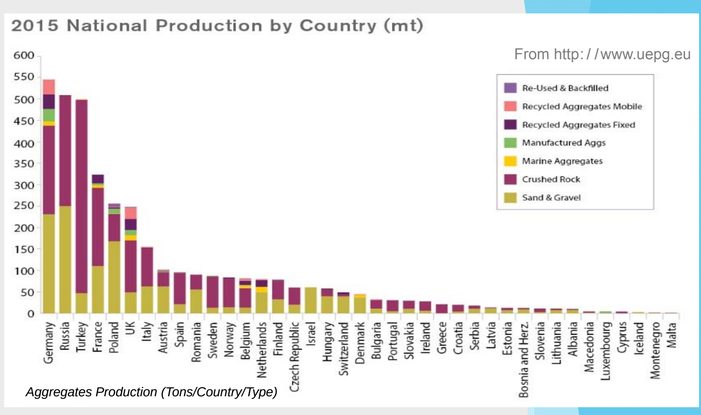
Municipal Solid Waste after thermal treatment

20% BOTTOM ASHES (**BA**)

2% FLY ASHES (**FA**)

Most of the recovered material is represented by additive for cement (97 wt%). According to the Italian Legislation about reuse of waste (Decree n. 186 of the 5th April 2006) BA can be reused without any treatment or acceptance test for the production of cement, bricks and expanded clay. In the case of road material, bottom ashes can be used if leaching tests comply with the thresholds provided for heavy metals (Lombardi and Carnevale, 2016).

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 energetic and environmental costs. This may not only concern fossil fuels but also raw materials used for the production of aggregates.

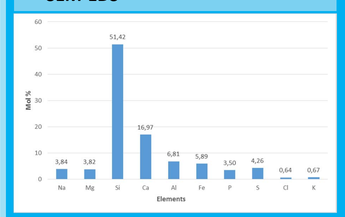


MATERIAL AND METHODS

A BA sample from an MSW treatment facility was characterized to evaluate the possibilities of its reuse as a second raw material. It was therefore characterized dimensionally, chemically and subjected to release tests and subsequently to treatments to make it more inert and suitable for reintegration into a production chain (*end of waste* status).

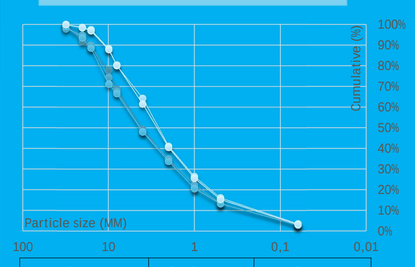
BA CHARACTERIZATION

CHEMICAL COMPOSITION
- XRF
- ICP/OES+MW DISSOLUTION
- SEM-EDS



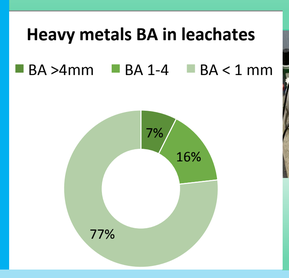
BA average composition without grain size separation.

DIMENSIONAL CHARACTERIZATION



>4 mm	4 -1 mm	<1 mm
% wt	% wt	%wt
36	38	26

RELEASE IN WATER TESTS
- LEACHING TESTS WITH EC LOGS
- ICP-OES AND CHROMATOGRAPHY ANALYSIS OF LEACHATES



Leaching test were performed for each grain size in deionized water (L/S=10:1)

The average *mol*-composition of the BA is represented by 52% Si, 17% Ca, 7% Al, 6% Fe, 4% Na and Mg.

The highest concentrations of heavy metals (mol %) are represented by Ti (1,3%), Zn (0,3%), Cu (0,2%) and Cr (0,2%); concentrated in the finer grain sizes.

BOTTOM ASHES → SIZE DISCRIMINATION

- < 1 mm: Needs **relevant** treatments: **CARBONATION**
- > 1 mm: Needs **moderate** treatments *For ex. Washing and metal separation*

Heavy metals (Cu, Zn, Pb, Ni, Cr) after leaching concentrate in the finer grain size (<1mm), especially Cu (<3 mg/l).

The sum of the heavy metals concentrations in the leachates of BA <1 mm is more than three times larger than the one in the case of grain size ≥ 1 mm.

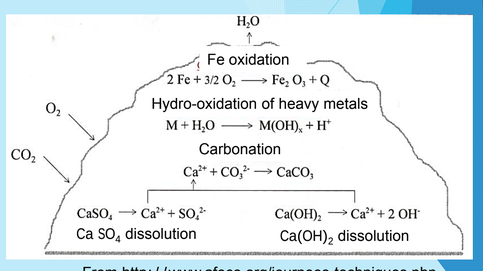
BA TREATMENT: CARBONATION

Carbonation with atmospheric CO_2, with stabilization of heavy metals, pH and porosity reduction, humidity loss and oxidation of ferrous metals. Maturation treatment is applicable especially on BA > 1 mm

$$CaO_{(s)} + H_2O \rightarrow Ca(OH)_2 \qquad Ca^{2+} + 2OH^- + CO_{2\,aq} \rightarrow CaCO_3 + H_2O$$

NATURAL CARBONATION

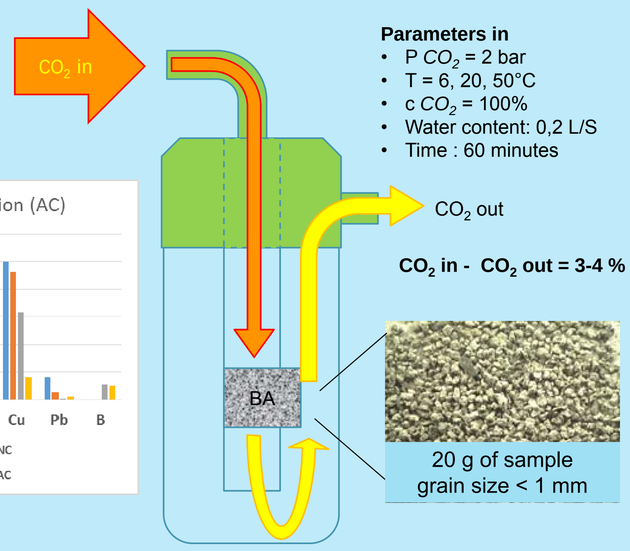
Natural carbonation requires large spaces for BA storage during the maturation period and long periods. It works better on the >1 mm fractions.

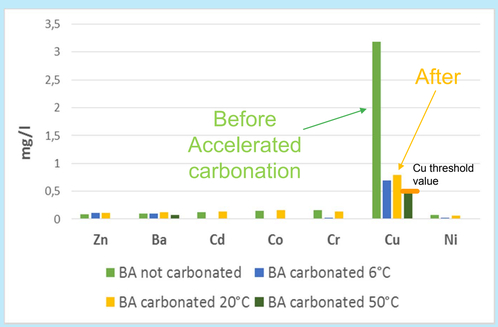


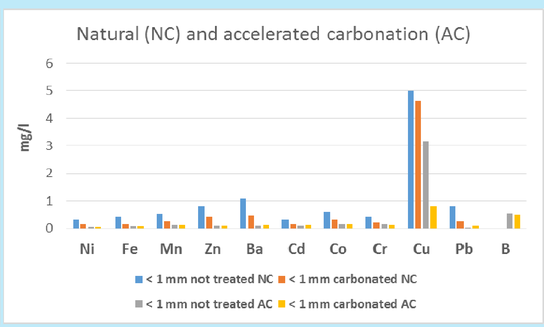
From http://www.afoco.org/journees-techniques.php

ACCELERATED CARBONATION

Accelerated carbonation is more effective than natural carbonation on the finer fractions (<1 mm), especially on the reduction of heavy metals. It requires a more complex technology but shorter times than the natural carbonation.







Accelerated carbonation at 50 °C
pH reduction from 11.4 to 8
Cu is reduced up to 84%
Cr is reduced up to 97%

CONCLUSIONS

Natural and accelerated carbonation are effective for inertization and reuse of BA (End of Waste), especially for the reduction of heavy metals:
- Cu can be reduced up to 70% but often is over the threshold values provided by the legislation for reuse.
- Chlorides and sulfates are also reduced remaining often high.

The production of BA in Italy was 1.035.352 tonnes in 2017 (ISPRA, 2018): if 30% could be recovered by carbonation 310.600 tonnes could be available for aggregates applications. Adding the % of waste landfillled (23% of total MSW) the amount of bottom ashes recovered could be around 360.000 tonnes for a total of 670.000 tonnes.

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