

PHYSICAL AND CHEMICAL PERFORMANCE OF TREATED MSWI BOTTOM ASH (FINE FRACTION) AS SAND REPLACEMENT IN CONCRETE

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Introduction

The strategy of the European Union (EU) is to build a circular economy that increasingly focuses on the reuse and recycling of mineral waste- and/ or by-products such as municipal solid waste incineration bottom ash. Previous research shows¹, by using specific dry and wet treatment steps, the large size bottom ash fraction > 2/3-16 mm, is upgraded to a high potential aggregate. This aggregate can be used as gravel replacement in concrete, and is in accordance with EU regulatory standards. However, for the fine bottom ash (BA) 0-2/3 mm, which initially contains a significant amount of contaminants, re-use in concrete as sand replacement hampers due to:

- Too high element leaching², that can influence the cement hydration mechanisms.
- The abundance of metallic non-ferro particles and unburned organic material, that can negatively influence the use of alkali binder systems. Mainly aluminium and zinc particle are quickly oxidised in alkaline environments. This forms hydrogen gas, which results in expansion and crack formation within concrete during hardening^{3,4}. Organic material can retard or disturb the cement hydration processes, affecting the concrete setting time and related strength development.
- High content of >10 wt% of very fine particles $\leq 63 \mu\text{m}$, which does not match with appropriate particle size distributions for concrete mixtures.

Therefore, optimisation of the produced BA fraction, by lowering and extracting all unwanted contaminants, is needed. This study focusses on the optimisation of BA 0-2/3 mm by implementing specially designed dry and wet treatment steps (more detailed described in our previous research ^[1], and involves:

- Step 1: Weathering of fresh MSWI bottom ash.
- Step 2: Crushing and dry separation MSWI bottom ash (specially designed plant).
- Step 3: Wet separation and washing treatment (specially designed plant).

The leaching of contaminants and the effects of the treatment processes on the final fine BA aggregate materials properties were studied. Additionally, the treated fraction is applied in concrete mixtures, replacing the initial natural sand fraction. The hardened concrete is tested on leaching in accordance to the standards.

Results and Discussion

Leaching as a function of particle size after dry treatment

Figure 1. shows the leaching of the most critical elements as a function of particle sizes after the material is only dry treated (Steps 1-2). Dissolved organic carbon (DOC) leaching is added, because it controls copper leaching. Further, significant exponential trends are observed between a higher element release and a smaller particle size. Especially the fine particles from $\leq 63\text{ }\mu\text{m}$ to 1 mm , result in high leachable concentrations. In more detail, research showed that mainly Cl and SO_4 are weakly bound at the particle outer surface⁵, making them easily soluble.

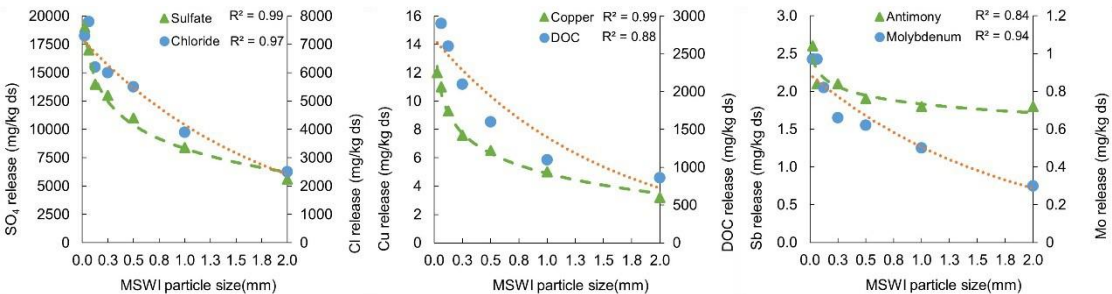


Figure 1: Element release as a function of BA particle size, of a dry treated BA, measured in accordance with NEN-EN 12457-3 (L/S 10)

Figure 2 shows that the Cu leaching is mainly controlled by DOC, as adsorbed as ligand by humic and fulvic acids, which make up a part of the DOC fractions. Ligands are highly soluble and therefore increase the Cu leaching [6]. The release of SO_4 is mainly related to calcium and therefore it is controlled by the presence of gypsum (CaSO_4). Additionally, XRD results, showed that CaSO_4 is highly abundant in the fine BA fractions.

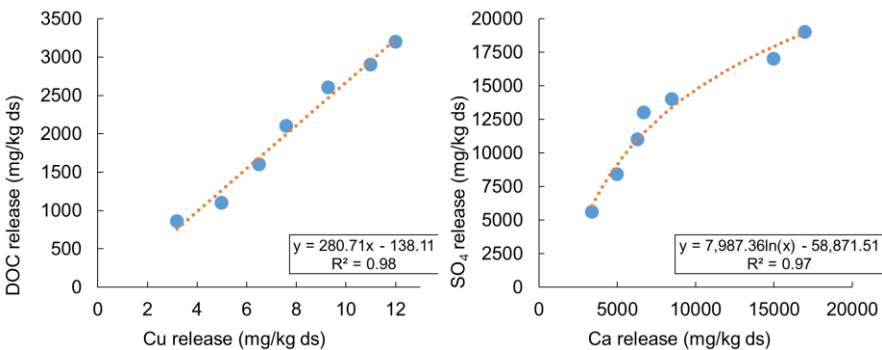


Figure 2: Relation between the leaching of Cu with DOC and Ca with SO_4 of a dry treated BA, release measured in accordance with NEN-EN 12457-3 (L/S 10)

Leaching behaviour as function of pH after dry and wet treatment

Measurement with dry-treated material indicated that the leaching of the fine fraction of the bottom ash is still significant and it is dependent on the particle size. The implementation of a water washing treatment (Step 2), is needed to extract the fine particle fraction < 63 µm and reduce the leaching. Figure 3 shows the pH dependent leaching behaviour of Mo, Sb and Cu from a dry material in comparison with a dry- wet treated fine bottom ash. Leaching of Cl and SO₄ are not analysed, as their leaching behaviour is not pH depended, with an alkaline system between pH 7-14. Both are solubility-controlled and water washing is therefore highly effective to extract these contaminants from the BA. The water treatment demonstrated a reduced element release of the BA fraction. Which corresponds with our previous research¹, obtained with the treated coarse size BA aggregate fraction, as well as the explanation of element leaching behaviour as a function of pH.

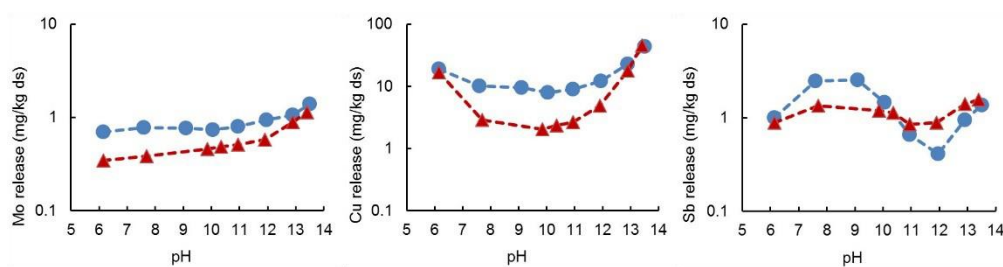


Figure 3: pH dependent element leaching, from 0-2/3 mm BA, in accordance with EN 14997 (blue dots: fine BA only dry-treated /Red triangle: fine BA dry- and wet-treated

Concrete production and its element leaching

Table 1 shows that the produced BA fraction material properties, meet the limit values of the Dutch product guideline BRL 2507⁷ and NEN-EN 12620 (aggregates for concrete use). In comparison to sand, BA its higher porosity, lower density and higher water absorption is mainly caused by the porous slag particles. Further, the very fine particle fraction content (< 63 µm) was reduced from initially > 10 to < 3.3 wt%, by the wet treatment. Which has an important influence on the reduction of the BA leaching after washing, as demonstrated in Figure 3.

Earth-moist concrete mixtures where composed, on a factory production pilot scale, for the production of pavement tiles. The natural sand fraction was replaced with 20 wt% treated BA fraction, based on an optimal PSD calculation. The concrete flexural strength results in Figure 4, indicate no significant differences between the bottom ash and reference concrete strength development.

The leaching of monolithic samples with the diffusion test (NEN 7375) was not performed. As our previous study¹ showed that the use of up to 100 wt% of treated BA, was feasible as gravel replacement in comparable concrete mixture. However, leaching of 28d old size reduced concrete material, is tested with the percolation test (NEN 7383) as a granular state/aggregate. No significant differences were found between the emission of the concrete mixtures with treated BA and the reference.

Elements leaching is far below the limits for granular (open) application⁸, as in line with the results from our previous study on the use of treated coarse fractions in concrete mixtures¹.

Table 1: Material properties of dry-wet treated of fine BA fraction

Parameter	BA 0-2/3 mm	Sand 0-4 mm	Limit*
LOI 500 (% mass)	4.60	< 1.0	≤ 5.0
Alkali equivalent (% mass)	0.15	-	≤ 0.2
Metallic Al+Zn (% mass)	0.70	-	≤ 1.0
SO ₃ (% mass)	0.74	-	≤ 0.8
Chloride content (% mass)	0.05	-	non
Density ρ_{rd} (kg/m ³)	2280	2640	≥ 2000
Water absorption 24 h (% mass)	6.5	0.6	non

*: Limit values in accordance to NEN-EN 12620/ BRL 2507

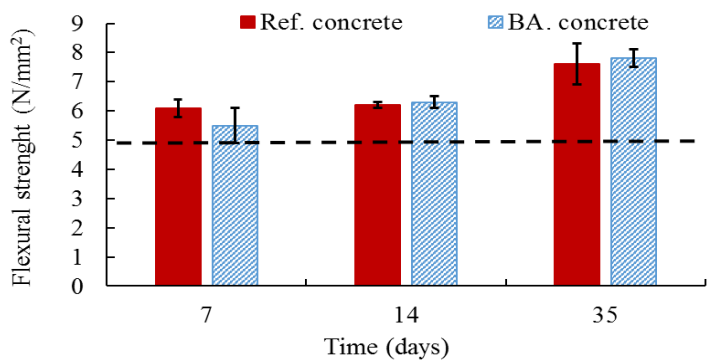


Figure 4: Flexural strength of pavement tiles (dashed line is the 35 strength limit value)

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