Municipal solid waste incineration (MSWI) provides significant benefits on waste treatment technologies. Nevertheless some by-products such as fly ash (FA) and bottom ash (BA) are produced in the incineration plant. Indeed, FA is considered a toxic waste due to the presence of leachable heavy metals (i.e. Zn, Cd, Pb, Hg) and metalloid (like As). This data article aims to investigate the reactivity of Ca(OH)$_2$ and Mg(OH)$_2$ as possible substitute of flue gas desulfurization (FGD) residues by mixing with FA, BA and silica fume through a low cost technology. To assess the immobilization process of heavy metals and metalloid, three different samples’ compositions were prepared for Ca(OH)$_2$ and Mg(OH)$_2$ series, respectively. Elemental chemical analysis of leaching solutions were carried out by Total reflection X-Ray Fluorescence spectroscopy (TXRF). Data revealed that mixing municipal solid waste ashes with Mg(OH)$_2$ decrease significantly Pb and Zn leachability after two months, and reduce their environmental impact in landfill.

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Data of leaching test performed on stabilized samples (with Ca(OH)\(_2\) and Mg(OH)\(_2\)) relative to one and two months after aging at 120 °C and room temperature are reported in Tables 1 and 2, respectively. The data contain the samples' compositions, treatment in terms of temperature conditions used, pH values and elemental concentration. Since lighter elements such as P, S and Cl may be underestimated by TXRF analysis, under the reported experimental conditions [4], relative sensitivities for P and S were calculated based on a calibration curve as recommended [5].

### 2. Experimental design, materials, and methods

CFA raw powder was provided from Brescia pulverized coal thermal power plant, and MSWI FA and MSWI BA from Brescia municipal solid waste incinerator plant. Tests were made in metals...
Table 1
Raw data of the TXRF analysis and pH values of stabilized samples at 120 °C (A) and room temperature (B) after the first and second month. Elemental concentrations are expressed as the average ± standard deviation of three measurements.

| Samples | MSWI-FA + CFA + Ca(OH)₂ + SiO₂ | MSWI-FA + CFA + Ca(OH)₂ + BA | MSWI-FA + CFA + Ca(OH)₂ |
|---------|--------------------------------|-----------------------------|-------------------------|
|         | Treatment A M 1 | Treatment A M 2 | Treatment A LOD |
| pH      | 12 | 10.97 | 12.4 | 10.93 | 12.42 | 12.41 | 12.35 | 12.31 | 12.42 | 12.35 | 12.38 | 12.33 | 12.31 |
| Elements | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| P       | 81 ± 9 | 64 ± 27 | 58 ± 13 | 67 ± 7 | 58 ± 15 | 85 ± 39 | 68 ± 9 | 73 ± 18 | 90 ± 13 | 62 ± 20 | 88 ± 30 | 68 ± 27 | 0.23 |
| S       | 552 ± 16 | 490 ± 99 | 167 ± 27 | 186 ± 6 | 427 ± 97 | 524 ± 141 | 205 ± 51 | 194 ± 81 | 562 ± 92 | 528 ± 123 | 303 ± 200 | 210 ± 35 | 0.2 |
| Cl      | 6450 ± 457 | 5440 ± 1270 | 5760 ± 183 | 5893 ± 237 | 5891 ± 1358 | 7082 ± 2124 | 5850 ± 880 | 7941 ± 1745 | 8157 ± 226 | 6042 ± 493 | 7136 ± 3930 | 6882 ± 2487 | 0.08 |
| K       | 1288 ± 103 | 1050 ± 230 | 968 ± 190 | 1163 ± 37 | 990 ± 420 | 1380 ± 490 | 933 ± 175 | 1443 ± 268 | 1458 ± 339 | 1159 ± 274 | 1030 ± 772 | 1310 ± 314 | 0.04 |
| Ca      | 4241 ± 262 | 3500 ± 800 | 4118 ± 3356 | 3437 ± 112 | 4493 ± 1057 | 4493 ± 1557 | 4365 ± 752 | 4796 ± 1276 | 5756 ± 533 | 4302 ± 673 | 5370 ± 2550 | 4676 ± 1642 | 0.05 |
| Cr      | 0.16 ± 0.09 | 0.46 ± 0.04 | 0.56 ± 0.47 | 0.28 ± 0.02 | 0.07 ± 0.01 | 0.34 ± 0.04 | <LOD | 0.21 ± 0.02 | 0.20 ± 0.01 | 0.35 ± 0.08 | <LOD | <LOD | 0.007 |
| Mn      | 0.14 ± 0.04 | 0.52 ± 0.13 | 0.15 ± 0.01 | 0.17 ± 0.01 | 0.17 ± 0.03 | 0.18 ± 0.05 | 0.15 ± 0.07 | 0.14 ± 0.05 | 0.26 ± 0.04 | <LOD | <LOD | 0.18 ± 0.10 | 0.11 ± 0.04 | 0.006 |
| Fe      | <LOD | <LOD | 0.17 ± 0.04 | <LOD | 0.47 ± 0.26 | 0.52 ± 0.19 | <LOD | <LOD | <LOD | <LOD | <LOD | 0.004 |
| Zn      | 0.06 ± 0 | 0.089 ± 0.002 | 0.19 ± 0.04 | 0.12 ± 0.01 | 1.11 ± 0.21 | 0.91 ± 0.37 | 0.76 ± 0.36 | 0.31 ± 0.13 | 0.89 ± 0.20 | 0.60 ± 0.01 | 1.40 ± 0.40 | 0.97 ± 0.49 | 0.003 |
| Br      | 108 ± 8 | 105 ± 28 | 93 ± 3 | 115 ± 5 | 103 ± 12 | 120 ± 37 | 88 ± 16 | 129 ± 33 | 148 ± 25 | 106 ± 4 | 125 ± 55 | 102 ± 45 | 0.002 |
| Rb      | 3.4 ± 0.4 | 3.1 ± 0.7 | 3.7 ± 0.1 | 2.6 ± 0.7 | 3.73 ± 0.35 | 3 ± 1 | 2.9 ± 0.4 | 4.5 ± 1.4 | 6 ± 1 | 3.7 ± 0.4 | 4.3 ± 1.9 | 3.7 ± 1.9 | 0.002 |
| Sr      | 18 ± 1 | 15 ± 4 | 16 ± 1 | 20 ± 1 | 14 ± 2 | 18 ± 6 | 14 ± 3 | 21 ± 6 | 25 ± 4 | 20 ± 2 | 20 ± 9 | 16 ± 9 | 0.002 |
| Pb      | <LOD | <LOD | 3 ± 1 | <LOD | 7 ± 1 | 7 ± 3 | 6 ± 2 | 3 ± 1 | 5 ± 1 | 3 ± 1 | 10 ± 6 | 7 ± 3 | 0.002 |

* a Calculated values based on a calibration curve; LOD - Limit of Detection.
Table 2
Raw data of the TXRF analysis and pH values of stabilized samples at 120 °C (A) and room temperature (B) after the first and second month. Elemental concentrations are expressed as the average ± standard deviation of three measurements.

| Samples       | MSWI-FA + CFA + Mg(OH)₂ + SiO₂ | MSWI-FA + CFA + Mg(OH)₂ + BA | MSWI-FA + CFA + Mg(OH)₂ |
|---------------|--------------------------------|------------------------------|-------------------------|
|               | Treatment A                     | Treatment B                  | Treatment B             |
| Time          | 1M                             | 2M                           | 1M                      | 2M                      | 1M                       | 2M                        |
| pH            | 10.12                          | 9.13                         | 12.1                    | 10.21                   | 10.71                     | 9.26                       | 12.35                    | 10.53                   | 10.62                     | 9.4                        | 12.18                     | 10.54                     |
| Elements      | (mg/L)                         | (mg/L)                       | (mg/L)                  | (mg/L)                  | (mg/L)                   | (mg/L)                    | (mg/L)                  | (mg/L)                  | (mg/L)                   | (mg/L)                   | (mg/L)                    | (mg/L)                   |
| P             | 4 ± 2                           | 5.9 ± 0.2                    | 47 ± 11                 | 7 ± 4                   | 8 ± 3                    | 12 ± 6                    | 29 ± 2                   | 17 ± 2                   | 92 ± 49                   | 13 ± 3                    | 53 ± 14                   | 10 ± 6                    |
| S             | 42 ± 8                          | 41 ± 25                      | 5 ± 2                   | 49 ± 23                 | 14 ± 8                   | 43 ± 12                   | 1.18 ± 0.11              | 13 ± 4                   | 0.8 ± 0.4                 | 76 ± 14                   | 1.42 ± 0.30               | 25 ± 9                    |
| Cl            | 8967 ± 3214                     | 9220 ± 976                   | 12995 ± 3979            | 8059 ± 1098             | 8165 ± 1761              | 8049 ± 352                | 9081 ± 461               | 8109 ± 588               | 1054 ± 99                 | 797 ± 68                  | 16854 ± 5666              | 8411 ± 2094               |
| K             | 699 ± 287                       | 960 ± 222                    | 1349 ± 734              | 971 ± 256               | 700 ± 362                | 810 ± 53                  | 1054 ± 99                | 797 ± 68                 | 3271 ± 122                | 2715 ± 409                | 1936 ± 684                | 792 ± 304                 |
| Ca            | 2959 ± 1032                     | 2230 ± 301                   | 3010 ± 1406             | 2545 ± 429              | 2541 ± 516               | 2424 ± 230                | 6142 ± 2071              | 2468 ± 835               | 4189 ± 1379               | 2303 ± 92                 | 1223 ± 503                | 687 ± 125                 |
| Cr            | 0.83 ± 0.04                     | 0.57 ± 0.20                  | 0.24 ± 0.15             | 0.45 ± 0.07             | 0.46 ± 0.10              | 0.49 ± 0.16               | 0.21 ± 0.08              | 0.41 ± 0.20              | 0.42 ± 0.18               | 0.65 ± 0.18               | 0.22 ± 0.06               | 0.41 ± 0.06               |
| Mn            | 0.13 ± 0.01                     | 0.21 ± 0.08                  | 0.20 ± 0.05             | 0.14 ± 0.03             | 0.09 ± 0.03              | 0.16 ± 0.04               | 0.15 ± 0.03              | 0.11 ± 0.04              | 0.25 ± 0.13               | 0.15 ± 0.00               | 0.52 ± 0.45               | 0.07 ± 0.01               |
| Fe            | 0.19 ± 0.06                     | 0.27 ± 0.09                  | <LOD                    | 0.59 ± 0.23             | 0.18 ± 0.08              | 0.72 ± 0.35               | 0.57 ± 0.13              | 0.06 ± 0.03              | 0.42 ± 0.11               | 0.19 ± 0.10               | <LOD                     | 0.13 ± 0.01               |
| Zn            | 0.07 ± 0.04                     | 0.15 ± 0.05                  | 0.64 ± 0.19             | 0.11 ± 0.06             | 0.10 ± 0.03              | 0.12 ± 0.05               | 1.11 ± 0.15             | 0.07 ± 0.04              | 1.73 ± 0.18               | 0.18 ± 0.08               | 1.64 ± 0.82               | 0.03 ± 0.01               |
| Br            | 103 ± 11                        | 97 ± 6                       | 94 ± 48                 | 82 ± 5                  | 102 ± 8                  | 87 ± 7                    | 73 ± 5                   | 86 ± 12                  | 134 ± 39                  | 99 ± 9                    | 91 ± 33                   | 85 ± 3                    |
| Rb            | 3.5 ± 0.3                       | 3.5 ± 0.6                    | 2.5 ± 1.3               | 3.1 ± 0.3               | 3.3 ± 0.3                | 2.9 ± 0.3                 | 2.0 ± 0.2                | 2.9 ± 1.4                | 4.3 ± 1.6                 | 3.5 ± 0.6                 | 2.7 ± 1.1                 | 2.9 ± 0.1                 |
| Sr            | 16 ± 4                          | 12 ± 1                       | 19 ± 9                  | 15 ± 1                  | 16 ± 1                   | 13 ± 1                    | 10 ± 1                   | 14 ± 1                   | 18 ± 6                    | 15 ± 2                    | 13 ± 4                    | 15 ± 1                    |
| Pb            | <LOD                           | <LOD                         | <LOD                    | <LOD                    | <LOD                     | <LOD                      | <LOD                     | <LOD                     | <LOD                     | <LOD                     | <LOD                      | <LOD                     |

* Calculated values based on a calibration curve; LOD - Limit of Detection.
immobilization from MSWI FA by adding CFA [6], Ca(OH)\textsubscript{2}, Mg(OH)\textsubscript{2}, MSWI BA, and silica fume have been used in combination. The stabilization process was conducted following the procedure of [7] with some modifications, using Ca(OH)\textsubscript{2} and Mg(OH)\textsubscript{2} as substitute of FGD. Approx. 20 g of MSWI BA (or silica fume [8]) was added to a mixture of 200 g of three powders including MSWI FA, Ca(OH)\textsubscript{2} (or Mg(OH)\textsubscript{2}) and CFA. The following relative weight percentage was present in the stabilized samples: 65\% FA, 20\% Ca(OH)\textsubscript{2} [or Mg (OH)\textsubscript{2}] and 15\% CFA [9]. Latter, approximately 200 mL of ultrapure de-ionized water, obtained from a Milli-Q purifier system (Millipore DirectQ-5 TM, Millipore S.A. S., 67120, Molsheim, France), was added and the mixture mixed for 20 min. Then, each prepared sample was divided, one half was placed in the oven for 4 h at 120 °C (sample A), while the other half was dried at room temperature (sample B). The CEN normative (CEN EN 12457-2) was applied to conduct the leaching tests of stabilized samples and the procedure optimized and reported in Ref. [6]. 20 g of each sample was ground using an agate mortar and mixed with 200 mL MQ water in a 600 mL becher, with a ratio of 1:10 for the leaching test and then mixed for 2 h using an agitator at room temperature and filtered via 0.45 μm pore membranes. The pH of the filtrates was measured using an 827 pH Lab Metrohm. The process efficacy was verified one and two months (1 M) and two months (2 M) after the stabilization process. During aging, samples were stored in blow glassware laboratory at room temperature. Elemental chemical analysis of leaching solutions was performed using Total reflection X-Ray Fluorescence (TXRF) spectroscopy [10], employing a S2 Picofox system from Bruker (Bruker AXS Microanalysis GmbH, Berlin, Germany) equipped with Mo tube operating at 50 kV and 750 μA and a Silicon Drift Detector (SDD) [11]. A stock solution of 1 g/L Ga in nitric acid (Ga-ICP Standard Solution, Fluka, Sigma Aldrich, Saint Louis, MO, USA) was used as an internal standard in order to calculate the concentration of interested analytes. Samples were prepared by weight. Approximately 0.010 g of 100 mg/L of Ga solution was added to the prepared solutions to obtain a final concentration of 1 mg/L Ga. Solutions were homogenized using a vortex shaker for 1 min at 2500 rpm. A 10 μL drop of the prepared sample was deposited in the centre of an acrylic reflector. Afterwards, the reflectors were dried on a hot plate at 50 °C under a laminar hood and the residues were measured. Three reflectors were prepared for each sample specimen and irradiated for 600 s of live time. TXRF spectra were analysed with the instrumental software using routine deconvolution based on mono-element profiles in order to evaluate the peak areas and Ga was used as internal standard.

Acknowledgments

This work was performed under the framework of the following project: Energy recovery of waste sludge and their re-use as an alternative to some natural resources, for the production of “Green” composites, RENDERING, financed by Ministero dell’Ambiente e della Tutela del Territorio e del Mare, and supported by the University of Brescia, CSMT, INSTM and Regione Lombardia.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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