



ELSEVIER

Contents lists available at ScienceDirect

Data in brief

journal homepage: www.elsevier.com/locate/dib

Data Article

Dataset on the use of metal hydroxides, instead of flue gas desulfurization residues, to stabilize fly ash by using bottom ash



Fabjola Bilo, Ahmad Assi, Alessandra Zanoletti, Elza Bontempi*

INSTM and Chemistry for Technologies Laboratory, Department of Mechanical and Industrial, Engineering, University of Brescia, Via Branze, 38, 25123, Brescia, Italy

ARTICLE INFO

Article history:

Received 11 November 2019

Received in revised form 22 November 2019

Accepted 2 December 2019

Available online 14 December 2019

Keywords:

Municipal solid waste

Ca(OH)₂Mg(OH)₂

Bottom ash

Fly ash

Heavy metals

ABSTRACT

Municipal solid waste incineration (MSWI) provides significant benefits on waste treatment technologies. Nevertheless some by-products such as fly ash (FA) and bottom ash (Ash) 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.

© 2019 Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

* Corresponding author.

E-mail address: elza.bontempi@unibs.it (E. Bontempi).

Specifications Table

Subject	Environmental Science
Specific subject area	Waste Management and Disposal
Type of data	Tables
How data were acquired	Leachate solutions of stabilized samples were analysed using S2 Picofox system from Bruker (Bruker AXS Microanalysis GmbH, Berlin, Germany) equipped with Mo tube operating at 50 kV and 750 μ A and a Silicon Drift Detector (SDD).
Data format	Analysed data
Parameters for data collection	Toxicity of MSWI FA raw powder is related to heavy metals (Pb and Zn) leachability [1]. Several technologies are proposed for FA stabilization, and some of them have shortcomings [2]. Reactivity of $\text{Ca}(\text{OH})_2$ and $\text{Mg}(\text{OH})_2$ were investigated as substitute to Flue Gas Desulfurization (FGD) residues for heavy metals immobilization. Stabilization process and pH of leaching solutions were monitor with aging (one and two months).
Description of data collection	Elemental chemical analysis of leaching samples was performed (Tables 1 and 2). TXRF data were compared with those obtained from utilization of FGD residue in the stabilization process. Pb and Zn concentrations are compared with the legislation limit of D.M. August 3, 2005 (50 $\mu\text{g/L}$ and 3 mg/L , respectively) [3].
Data source location	Coal Fly Ash (CFA) was collected from Brescia pulverized coal thermal power plant, while MSWI BA and FA were provided by the Brescia municipal solid waste incinerator plant (Italy). Calcium hydroxide [$\text{Ca}(\text{OH})_2$, CAS number: 1305-62-0] and Magnesium hydroxide [$\text{Mg}(\text{OH})_2$, CAS number: 1309-42-8] were purchased from Carlo Erba Reagents. Silica fume was provided by Metalleghe SPA, Brescia, Italy, as an industrial by-product derived from ferrosilicon and silicon metal alloy processing.
Data accessibility	Data are available in this article
Related research article	Ahmad Assi, Fabjola Bilo, Alessandra Zanoletti, Jessica Ponti, Andrea Valsesia, Rita La Spina, Annalisa Zacco, and Elza Bontempi, "Zero-waste approach in municipal solid waste incineration: reuse of bottom ash to stabilize fly ash" Journal of Cleaner Production, Available online October 7, 2019, 118779, Doi: 10.1016/j.jclepro.2019.118779

Value of the Data

- This dataset provides chemical characterization of three stabilized samples obtained by mixing FA, considered a toxic residue, with other ashes (i.e: BA, Silica fume and FGD), or two metal hydroxide [$\text{Ca}(\text{OH})_2$ or $\text{Mg}(\text{OH})_2$] as possible substitute of FDG.
- These outcomes can be useful for municipal solid waste incineration plant to open new possibilities of by-products, that after a stabilization process, the inert material can be reused as filler in new sustainable composites.
- Data in this article increase the possibility to use metal hydroxide [$\text{Ca}(\text{OH})_2$ or $\text{Mg}(\text{OH})_2$] as heavy metals stabilizer.
- The data suggest that all samples are stabilized if silica fume is used, while $\text{Mg}(\text{OH})_2$ reduces heavy metals leachability after two months, giving better outcomes instead of $\text{Ca}(\text{OH})_2$.
- Stabilization process using $\text{Mg}(\text{OH})_2$ in place of FGD residues requires a longer time.
- Dataset figured out that stabilization process does not depend on the treatment temperature.

1. Data

Data of leaching test performed on stabilized samples (with $\text{Ca}(\text{OH})_2$ and $\text{Mg}(\text{OH})_2$), 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 term 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 \pm standard deviation of three measurements.

Samples	MSWI-FA + CFA + Ca(OH) ₂ + SiO ₂				MSWI-FA + CFA + Ca(OH) ₂ + BA				MSWI-FA + CFA + Ca(OH) ₂				LODI
Treatment	A		B		A		B		A		B		
Time	1 M	2 M	1 M	2 M	1 M	2 M	1 M	2 M	1 M	2 M	1 M	2 M	
pH	12	10.97	12.4	10.93	12.42	12.35	12.41	12.31	12.42	12.35	12.38	12.33	
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 ^a	81 \pm 9	64 \pm 27	58 \pm 13	67 \pm 7	58 \pm 15	85 \pm 39	68 \pm 9	73 \pm 18	90 \pm 13	62 \pm 20	88 \pm 30	68 \pm 27	0.23
S ^a	552 \pm 16	490 \pm 99	167 \pm 27	186 \pm 6	427 \pm 97	524 \pm 141	205 \pm 51	194 \pm 81	562 \pm 92	528 \pm 123	303 \pm 200	210 \pm 35	0.2
Cl	6450 \pm 457	5440 \pm 1270	5760 \pm 183	5893 \pm 237	5891 \pm 1358	7082 \pm 2124	5850 \pm 880	7941 \pm 1745	8157 \pm 226	6042 \pm 493	7136 \pm 3930	6882 \pm 2487	0.08
K	1288 \pm 103	1050 \pm 230	968 \pm 190	1163 \pm 37	990 \pm 420	1380 \pm 490	933 \pm 175	1443 \pm 268	1458 \pm 339	1159 \pm 274	1030 \pm 772	1310 \pm 314	0.04
Ca	4241 \pm 262	3500 \pm 800	4118 \pm 3356	3437 \pm 112	4493 \pm 1057	4493 \pm 1557	4365 \pm 752	4796 \pm 1276	5756 \pm 533	4302 \pm 673	5370 \pm 2550	4676 \pm 1642	0.05
Cr	0.16 \pm 0.09	0.46 \pm 0.04	0.56 \pm 0.47	0.28 \pm 0.02	0.07 \pm 0.01	0.34 \pm 0.04	<LOD	0.21 \pm 0.02	0.20 \pm 0.01	0.35 \pm 0.08	<LOD	<LOD	0.007
Mn	0.14 \pm 0.04	0.52 \pm 0.13	0.15 \pm 0.01	0.17 \pm 0.01	0.17 \pm 0.03	0.18 \pm 0.05	0.15 \pm 0.07	0.14 \pm 0.05	0.26 \pm 0.04	<LOD	0.18 \pm 0.10	0.11 \pm 0.04	0.006
Fe	<LOD	0.17 \pm 0.04	<LOD	<LOD	0.47 \pm 0.26	0.52 \pm 0.19	<LOD	<LOD	<LOD	0.22 \pm 0	<LOD	<LOD	0.004
Zn	0.06 \pm 0	0.089 \pm 0.002	0.19 \pm 0.04	0.12 \pm 0.01	1.11 \pm 0.21	0.91 \pm 0.37	0.76 \pm 0.36	0.31 \pm 0.13	0.89 \pm 0.20	0.60 \pm 0.01	1.40 \pm 0.40	0.97 \pm 0.49	0.003
Br	108 \pm 8	105 \pm 28	93 \pm 3	115 \pm 5	103 \pm 12	120 \pm 37	88 \pm 16	129 \pm 33	148 \pm 25	106 \pm 4	125 \pm 55	102 \pm 45	0.002
Rb	3.4 \pm 0.4	3.1 \pm 0.7	3.7 \pm 0.1	2.6 \pm 0.7	3.73 \pm 0.35	3 \pm 1	2.9 \pm 0.4	4.5 \pm 1.4	6 \pm 1	3.7 \pm 0.4	4.3 \pm 1.9	3.7 \pm 1.9	0.002
Sr	18 \pm 1	15 \pm 4	16 \pm 1	20 \pm 1	14 \pm 2	18 \pm 6	14 \pm 3	21 \pm 6	25 \pm 4	20 \pm 2	20 \pm 9	16 \pm 9	0.002
Pb	<LOD	<LOD	3 \pm 1	<LOD	7 \pm 1	7 \pm 3	6 \pm 2	3 \pm 1	5 \pm 1	3 \pm 1	10 \pm 6	7 \pm 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 \pm standard deviation of three measurements.

Samples	MSWI-FA + CFA + Mg(OH) ₂ + SiO ₂				MSWI-FA + CFA + Mg(OH) ₂ + BA				MSWI-FA + CFA + Mg(OH) ₂			
	A		B		A		B		A		B	
Treatment												
Time	1M	2M	1M	2M	1M	2M	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 ^a	4 \pm 2	5.9 \pm 0.2	47 \pm 11	7 \pm 4	8 \pm 3	12 \pm 6	29 \pm 2	17 \pm 2	92 \pm 49	13 \pm 3	53 \pm 14	10 \pm 6
S ^a	42 \pm 8	41 \pm 25	5 \pm 2	49 \pm 23	14 \pm 8	43 \pm 12	1.18 \pm 0.18	13 \pm 4	0.8 \pm 0.4	76 \pm 14	1.42 \pm 0.30	25 \pm 9
Cl	8967 \pm 3214	9220 \pm 976	12995 \pm 3979	8059 \pm 1098	8165 \pm 1761	8049 \pm 352	9081 \pm 461	8109 \pm 588	16854 \pm 5666	8411 \pm 2094	11168 \pm 503	7306 \pm 537
K	699 \pm 287	960 \pm 222	1349 \pm 734	971 \pm 256	700 \pm 362	810 \pm 53	1054 \pm 99	797 \pm 68	1936 \pm 684	792 \pm 304	1223 \pm 503	687 \pm 125
Ca	2959 \pm 1032	2230 \pm 301	3010 \pm 1406	2545 \pm 429	2541 \pm 516	2424 \pm 230	3271 \pm 122	2715 \pm 409	6142 \pm 2071	2468 \pm 835	4189 \pm 1379	2303 \pm 92
Cr	0.83 \pm 0.04	0.57 \pm 0.20	0.24 \pm 0.15	0.45 \pm 0.07	0.46 \pm 0.10	0.49 \pm 0.16	0.21 \pm 0.08	0.41 \pm 0.20	0.42 \pm 0.18	0.65 \pm 0.18	0.22 \pm 0.06	0.41 \pm 0.06
Mn	0.13 \pm 0.01	0.21 \pm 0.08	0.20 \pm 0.05	0.14 \pm 0.03	0.09 \pm 0.03	0.16 \pm 0.04	0.15 \pm 0.03	0.11 \pm 0.04	0.25 \pm 0.13	0.15 \pm 0.00	0.52 \pm 0.45	0.07 \pm 0.01
Fe	0.19 \pm 0.06	0.27 \pm 0.09	<LOD	0.59 \pm 0.23	0.18 \pm 0.08	0.72 \pm 0.35	0.57 \pm 0.13	0.06 \pm 0.03	0.42 \pm 0.11	0.19 \pm 0.10	<LOD	0.13 \pm 0.01
Zn	0.07 \pm 0.04	0.15 \pm 0.05	0.64 \pm 0.19	0.11 \pm 0.06	0.10 \pm 0.03	0.12 \pm 0.05	1.11 \pm 0.15	0.07 \pm 0.04	1.73 \pm 0.18	0.18 \pm 0.08	1.64 \pm 0.82	0.03 \pm 0.01
Br	103 \pm 11	97 \pm 6	94 \pm 48	82 \pm 5	102 \pm 8	87 \pm 7	73 \pm 5	86 \pm 12	134 \pm 39	99 \pm 9	91 \pm 33	85 \pm 3
Rb	3.5 \pm 0.3	3.5 \pm 0.6	2.5 \pm 1.3	3.1 \pm 0.3	3.3 \pm 0.3	2.9 \pm 0.3	2.0 \pm 0.2	2.9 \pm 1.4	4.3 \pm 1.6	3.5 \pm 0.6	2.7 \pm 1.1	2.9 \pm 0.1
Sr	16 \pm 4	12 \pm 1	19 \pm 9	15 \pm 1	16 \pm 1	13 \pm 1	10 \pm 1	14 \pm 1	18 \pm 6	15 \pm 2	13 \pm 4	15 \pm 1
Pb	<LOD	<LOD	0.42 \pm 0.04	<LOD	<LOD	<LOD	10 \pm 2	<LOD	17 \pm 6	<LOD	11 \pm 5	<LOD

^a Calculated values based on a calibration curve; LOD - Limit of Detection.

immobilization from MSWI FA by adding CFA [6], $\text{Ca}(\text{OH})_2$, $\text{Mg}(\text{OH})_2$, MSWI BA, and silica fume have been used in combination. The stabilization process was conducted following the procedure of [7] with some modifications, using $\text{Ca}(\text{OH})_2$ and $\text{Mg}(\text{OH})_2$ 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, $\text{Ca}(\text{OH})_2$ (or $\text{Mg}(\text{OH})_2$) and CFA. The following relative weight percentage was present in the stabilized samples: 65% FA, 20% $\text{Ca}(\text{OH})_2$ [or $\text{Mg}(\text{OH})_2$] and 15% CFA [9]. Latter, approximately 200 mL of ultrapure deionized 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.

References

- [1] A. Bosio, A. Zacco, L. Borgese, N. Rodella, P. Colombi, L. Benassi, L.E. Depero, E. Bontempi, A sustainable technology for Pb and Zn stabilization based on the use of only waste materials: a green chemistry approach to avoid chemicals and promote CO₂ sequestration, *Chem. Eng. J.* 253 (2014) 377–384.
- [2] F. Zhu, Y. Xiong, Y. Wang, X. Wei, X. Zhu, F. Yan, Heavy metal behavior in “Washing–Calcination–Changing with Bottom Ash” system for recycling of four types of fly ashes, *Waste Manag.* 75 (2018) 215–225, <https://doi.org/10.1016/j.wasman.2018.01.032>.
- [3] <https://www.arpa.veneto.it/servizi-online/normativa/normativa-ambientale/decreto-del-ministero-dellambiente-e-della-tutela-del-territorio-5-aprile-2006-n.186>.
- [4] R. Klockenkämper, A. von Bohlen, *Total-reflection X-Ray Fluorescence Analysis and Related Methods*, second ed., Wiley, New York, 2015.
- [5] L. Borgese, R. Dalipi, A. Riboldi, F. Bilo, A. Zacco, S. Federici, M. Bettinelli, E. Bontempi, L.E. Depero, Comprehensive approach to the validation of the standard method for total reflection X-ray fluorescence analysis of water, *Talanta* 181 (2018) 165–171, <https://doi.org/10.1016/j.talanta.2017.12.087>.

- [6] E. Bontempi, A. Zacco, L. Borgese, A. Gianoncelli, R. Ardesi, L.E. Depero, A new method for municipal solid waste incinerator (MSWI) fly ash inertization, based on colloidal silica, *J. Environ. Monit.* 12 (2010) 2093–2099, <https://doi.org/10.1039/c0em00168f>.
- [7] A. Assi, F. Bilo, A. Zanoletti, J. Ponti, A. Valsesia, R. La Spina, A. Zacco, E. Bontempi, Zero-waste approach in municipal solid waste incineration: reuse of bottom ash to stabilize fly ash, *J. Clean. Prod.* (2019) 118779, <https://doi.org/10.1016/j.jclepro.2019.118779>.
- [8] N. Rodella, A. Bosio, R. Dalipi, A. Zacco, L. Borgese, L.E. Depero, E. Bontempi, Waste silica sources as heavy metal stabilizers for municipal solid waste incineration fly ash, *Arab. J. Chem.* 10 (2017) S3676–S3681, <https://doi.org/10.1016/j.arabj.2014.04.006>.
- [9] A. Assi, S. Federici, F. Bilo, A. Zacco, L.E. Depero, E. Bontempi, Increased Sustainability of Carbon dioxide mineral sequestration by a technology involving fly ash stabilization, *Materials (Basel)* 12 (2019) 2714, <https://doi.org/10.3390/ma12172714>.
- [10] T.Y. Cherkashina, S.V. Panteeva, G. Pashkova, Applicability of direct total reflection X-ray fluorescence spectrometry for multielement analysis of geological and environmental objects, *Spectrochim. Acta Part B* 99 (2014) 59–66, <https://doi.org/10.1016/j.sab.2014.05.013>.
- [11] S2 PICOFOX™ User Manual, Bruker AXS Microanalysis GmbH, Berlin, 2007.