**Article Title**

Dataset on ten-years monitoring of MSWI bottom ashes in six MSWI plants in the Canton of Zürich, Switzerland

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**Abstract**

The dataset presented in this article is the supplementary data for the research article “Ten-years monitoring of MSWI bottom ashes with focus on TOC development and leaching behaviour” by Glauser et al. (2020) [1]. From 2008 – 2018 bottom ashes have been monitored in six MSWI plants in the Canton of Zürich with regular sampling campaigns and analysis of important species defined in the Swiss Waste Legislation [2]. Both the size of the dataset and the long period of consistent and representative monitoring are unique for Switzerland. Relevant aspects of the monitoring data are discussed and interpreted in the above mentioned research article and complemented by simple emission forecast modelling. While only selected species were discussed in the research article, this data article covers all the monitoring data. The focus of the monitoring was laid on carbon-species with the analysis of total carbon (TC), total organic carbon (TOC), total inorganic carbon (TIC), degradable organic carbon (OC) and elemental carbon (EC). Total contents of nitrogen (N), sulphur (S), phosphorus (P), selected heavy metals (As, Cd, Cr, Cu, Ni, Pb, Sb and Zn) and loss on ignition (LOI) complete the solid chemical analysis. In addition, particulate ferrous (Fe) and non-ferrous (NF) metals and unburnt material were determined manually. Batch eluate tests according to Swiss Waste Legislation [3] were performed and analysed for dissolved organic carbon (DOC), ammonium (NH4+), nitrite (NO2-), fluoride (F-), sulphite (SO32-), sulphide (S2-), chromate Cr(IV) and the heavy metals Cu (aq) and Zn (aq) and Cr(IV). In addition, data on the biochemical oxygen demand (BOD) and the physical parameters pH and electrical conductivity complete the eluate analysis.

**Keywords**

Municipal solid waste incineration, bottom ash, monitoring, chemical analysis, batch leaching test

**Specifications Table**

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| **Subject** | Waste Management and Disposal |
| **Specific subject area** | MSWI bottom ash, representative sampling, chemical analysis, batch eluate tests |
| **Type of data** | Table |
| **How data were acquired** | Solid chemical analysis:   * Cr, Cu, Ni, P, Pb and Zn with ICP-OES (ISO 11885, 2007) [4] * As, Cd and Sb with ICP-MS (EN ISO 17294-2, 2016) [5] * TC, TOC, TIC, N and S with CHNS-analysis (EN 15936, 2012) [6] * OC and EC with temperature-dependent combustion of carbon (DIN 19539, 2016) [7] * Loss on ignition (LOI) at 550°C for 2 h in muffle furnace * Fe- and NE-metal content and unburnt material by manual magnetic and optical separation   Analysis of eluate behaviour:   * Cr(IV), Cu (aq) and Zn (aq) with ICP-MS (EN ISO 17294-2, 2016) [5] * DOC with thermal oxidation (EN 1484, 1997) [8] * NH4+ and NO2- with photometry (DIN 38406-5, 1983) [9] * SO32- and S2- with polarography (Metrohm Appl. 99/1) * F- with ion-sensitive electrode in water samples and digestions (DIN 38405-1, 1985 and ISO 10304-1, 2007) [10, 11] * BOD 5 days respirometric measurement (Oxitop-system) * Electrical conductivity (El. Cond) with a 5-ring conductivity measuring cell (c = 1.0 cm-1) * pH with an Aquatorde plus |
| **Data format** | Raw |
| **Parameters for data collection** | Bottom ash was sampled regularly for monthly periods in six MSWI plants. Subsequently the monthly composite samples were homogenised, and crushed in order to reduce the amount of material and to acquire the grain size needed for analysis. |
| **Description of data collection** | For solid chemical analysis, bottom ash was dried at 105°C, crushed to <1 mm and milled to <0.1 mm. Total digestion was performed for analysis with ICP-OES and MS. For CHNS-analysis, the material <0.1 mm was combusted.  Batch elute tests were performed on bottom ash in its original condition, crushed to <5 mm. The test consists of two parts, each with a liquid to solid (L/S) ratio of 10 and a duration of 24 h. One part (Test 1) is performed with CO2-saturated water for the analysis of heavy metals. The other part (Test 2) is performed with deionised water, for the analysis of all other constituents (incl. CrIV). |
| **Data source location** | MSWI Plants A-F, Canton of Zürich, Switzerland |
| **Data accessibility** | Data are accessible with the article |
| **Related research article** | Glauser et al. (2020), Ten-years monitoring of MSWI bottom ashes with focus on TOC development and leaching behaviour, Waste Management [1] |

**Value of the Data**

* The data derive from a systematic and representative monitoring over ten years of bottom ashes identically applied in six Swiss MSWI plants. The extent of the dataset and the systematic of sampling are unique for bottom ash.
* Beneficiaries of these data include researchers, authorities, MSWI plant operators and others involved in waste management.
* The data is of value for the ongoing political discussion in Switzerland regarding legislation of bottom ash quality requirements. The dataset further serves as a basis for comparison with other bottom ashes worldwide and helps to estimate potential for bottom ash quality improvements.
* Thanks to the long sampling period at six different MSWI plants temporal trends and correlations between parameters can be derived from these data. In addition, the data serve as a basis for further studies such as the investigation of long-term behaviour using geochemical modelling.

**Data Description**

In Switzerland, bottom ash has to be deposited on landfills due to elevated total contents of pollutants, such as heavy metals and TOC. With the periodic measurements presented in this dataset, the Canton of Zürich monitors the development of bottom ash quality of all six MSWI plants. For technical details of the concerning MSWI plants in the Canton of Zürich refer to [1].

The results of the monitoring of each plant are presented inTable 1-6 as well as in a supplementary excel file and are structured as follows:

* Results of the solid chemical analysis
* Results of the batch eluate tests

The results are listed in Table 1-6, in the following order: Table 1: Plant A, Table 2: Plant B, Table 3: Plant C, Table 4: Plant D, Table 5: Plant E, Table 6: Plant F. Parameters that have not been analysed in one of the measurement campaigns are indicated with “not sampled” (n.s.).

**Table 1:** Dataset on ten-years monitoring of MSWI bottom ashes in MSWI Plant A in the Canton of Zürich, Switzerland.



**Table 2:** Dataset on ten-years monitoring of MSWI bottom ashes in MSWI Plant B in the Canton of Zürich, Switzerland.



**Table 3:** Dataset on ten-years monitoring of MSWI bottom ashes in MSWI Plant C in the Canton of Zürich, Switzerland.



**Table 4:** Dataset on ten-years monitoring of MSWI bottom ashes in MSWI Plant D in the Canton of Zürich, Switzerland.



**Table 5:** Dataset on ten-years monitoring of MSWI bottom ashes in MSWI Plant E in the Canton of Zürich, Switzerland.



**Table 6:** Dataset on ten-years monitoring of MSWI bottom ashes in MSWI Plant F in the Canton of Zürich, Switzerland.



**Experimental Design, Materials, and Methods**

Sampling campaigns were performed from 2008–2018 generally on a four month interval at all six MSWI plants with identical sampling procedure. During selected months, at least 20 sub-samples of ~12 kg of untreated bottom ash have been sampled on working days over all furnace lines. Samples were collected on the conveyor belt directly after wet or dry discharge and stored in an air-tight container. At the end of the month, this composite sample has been homogenised and split into two representative samples of ~12 kg. One composite-sample was retained, while the other was split in two parts, which were used for (1) solid chemical analysis and (2) batch eluate tests. The preparation of the material for these two purposes was performed differently: (1) the material was dried at 105°C and subsequently crushed to a grain size <1 mm, while metals and unburnt material were manually separated. In an additional step the material was milled to <0.1 mm using a planetary ball mills. (2) The material was sieved at 5 mm in its original condition, while particles >5 mm were crushed and metals and unburnt material were manually separated. Subsequently the crushed bottom ash was mixed with the material portion <5mm.

Analysis of the bottom ash was based on the criteria of the Swiss Waste Ordinance according to certified procedures [12]. Only TOC, being the parameter of main interest, was monitored during the entire period from 2008-2018. The other C-constituents, N, S, P, heavy metals (As, Cd, Cr, Cu, Ni, Pb, Sb and Zn) and the eluate composition were only measured in the period 2008–2015, OC and EC only from 2011–2013.

For solid chemical analysis test portions of 0.5 g bottom ash <0.1 mm were digested with a mixture of 3 ml hydrochloric acid, 8 ml nitric acid and 3 ml hydrofluoric acid. Free hydrofluoric acid was bound with boric acid and the mixture subsequently heated in three steps to 175°C using a high-pressure microwave system. In this total digest Cr, Cu, Ni, P, Pb and Zn were determined by inductively coupled plasma optical emission spectroscopy (ICP-OES) (ISO 11885, 2007) [4] using a Thermo Fisher Scientific iCap 7400 Duo Full MFC (Dual View). The heavy metals As, Cd and Sb were determined by inductively coupled plasma mass spectroscopy (ICP-MS) (EN ISO 17294-2, 2016) [5] using a Agilent Technologies 7900. Total contents of C, N and S were determined using a EuroEA3000 CHNS-analyser by Hekatech with the software Callidus according to EN 15936, 2012 [6]. The composition of C was additionally characterised by TOC and TIC with the same method as used for TC. Further, applying another method based on temperature-dependent combustion of carbon (DIN 19539, 2016) [7] using a Primacs SCN-100 analyser, the differentiation of TOC into degradable organic carbon (TOC400 or OC) and residual oxidisable carbon or elemental carbon (ROC or EC) was achieved. The TIC900, which is released from 400 to 900°C is the third fraction produced with this method and corresponds to the TIC. Finally, the loss on ignition (LOI) was determined by heating a few grams of bottom ash <0.1 mm for 2 h at 550°C in a muffle furnace.

For the analysis of the eluate behaviour, batch tests have been performed with a liquid to solid (L/S) ratio of 10 during 24 h according to the Swiss Waste Legislation [3]. To meet the legal requirements, batch test have to be performed in two parts: Test 1 - Mixing of bottom ash <5 mm in its original condition with CO2-saturated water for the determination of Cu (aq + CO2) and Zn (aq + CO2) in order to simulate acid rain conditions. Test 2 - Mixing of bottom ash <5 mm in its original condition with deionised water for the determination of DOC, NH4+, NO2-, F-, SO32-, S2-, Cr(IV) and Cu(aq). Saturation with CO2 is achieved by continuous injection of ~50 mL CO2/min through a glass tube into the elution vessel. The analyses of Cr(IV), Cu (aq), Cu (aq + CO2) and Zn (aq + CO2) was performed by liquid chromatography (LC) coupled with ICP-MS using a Agilent Technologies 7900 (EN ISO 17294-2, 2016) [5]. DOC was determined by thermal oxidation using a Shimadzu 5000 (EN 1484, 1997) [8], NH4+ and NO2- photometric with an Aquakem 250 (DIN 38406-5, 1983) [9]. Sulphite and sulphide were measured by polarography using a Metrohm 884 Professional VA according to Methrom Appl. 99/1 and F- with an ion-sensitive electrode in water samples and digestions (DIN 38405-1, 1985; ISO 10304-1, 2007) [10, 11]. Finally, the biochemical oxygen demand (BOD) of five days has been measured respirometric using an Oxitop-system.

The physical parameters pH and electrical conductivity were measured with a pH electrode (Aquatrode plus, Metrohm 6.0257.600) and a 5-ring conductivity measuring cell with cell constant c = 1.0 cm-1 (Metrohm 6.0915.130), both with integrated Pt1000 temperature sensor.

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**Competing Interests**

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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