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The characterization of MSWI bottom ash

Introduction

The incineration of municipal solid waste has great benefits as it can reduce the volume and the mass of the waste by about 90% and 70%, respectively (Chimenos et al. (1999)). Municipal solid waste is collected and burned in an incinerator; the by-products of the combustion process are collected. Bottom ash typically accounts for 80% of the whole amount of by-products (Wiles (1996)) in the MSWI plants.

MSWI bottom ash is a solid material which contains unburned matter, glass, ceramics, metals, minerals (Chimenos et al. (1999)). A series of studies have been done on MSWI bottom ash: Cioffi et al. (2011), Li et al. (2012), Müller and Rübner (2006), Quenee et al. (2000), and Siddique (2010) studied the application of MSWI bottom ash in concrete. The characteristics and treatments for solving the leaching of contaminants in MSWI bottom ash were also studied, such as washing (Cossu et al. (2012); Lin et al. (2011); Steketee et al. (1997)), weathering (Meima and Comans (1999)), carbonation (Arickx et al. (2006); Meima et al. (2002)), and solidification/stabilization, as well as their efficiency. The results show that MSWI bottom ash has the potential to be used as road base or as aggregates in concrete; however leaching problem is the main drawback in its application.

In this paper, the basic physical properties of bottom ash were measured by laboratory tests and leaching contaminants in bottom ash produced by two Netherlands MSWI plants in recent years were analyzed. This is the first stage of the research on the bottom ash from the two MSWI plants.

Bottom ash from MSWI plants

The MSWI bottom ash investigated in this paper comes from two waste-to-energy plants in Wijster and Moerdijk in the Netherlands which are in operation since 1996 and 1997, respectively. The incineration capacity of the plants in Wijster and Moerdijk is 625.000 tons and 1.000.000 tons, respectively. The plant in Wijster has separation treatment lines to remove paper and plastics from the waste before combustion, while in the plant in Moerdijk the waste is sent to the incinerator without pre-treatment. The waste is burned in the incinerator between 800 and 1000 °C and then transported into a water bunker to be quenched. After 3 to 6 weeks storage the quenched bottom ash is sent to the separation line to remove the unburned part, ferrous and non-ferrous parts using magnets and eddy current separators. The upgraded bottom ash is then stored for further use.

Test methods

The MSWI bottom ash was dried at 105 °C for at least three days. The sieving test was performed on the dried bottom ash and the PSDs of bottom ash were obtained. The densities of particles in each fraction were also measured using a Micromeritics AccuPyc Ⅱ 1340 helium pycnometer.

Every two or three weeks, bottom ash from the two plants is analyzed for leaching. Leaching data of bottom ash in Wijster (B.A.W.) since 1999 and bottom ash in Moerdijk (B.A.M.) since 2005 was analyzed; PSD data of the B.A.M. was studied and compared with the PSDs of fresh bottom ash, as well as the water content.

Results

Particle size distributions (PSD)

Figure 1 shows the PSDs of fresh bottom ash in both plants and the average PSD of bottom ash produced in 2011 in Moerdijk. It can be seen that the PSD curves are similar and bottom ash particles smaller than 11.2 mm in both plants accounts for approximately 80 % by mass. About 5 – 10 % bottom ash particles are between 0.1 µm and 100 µm. This means that the particle size distributions of bottom ash in both MSWI plants are quite stable.

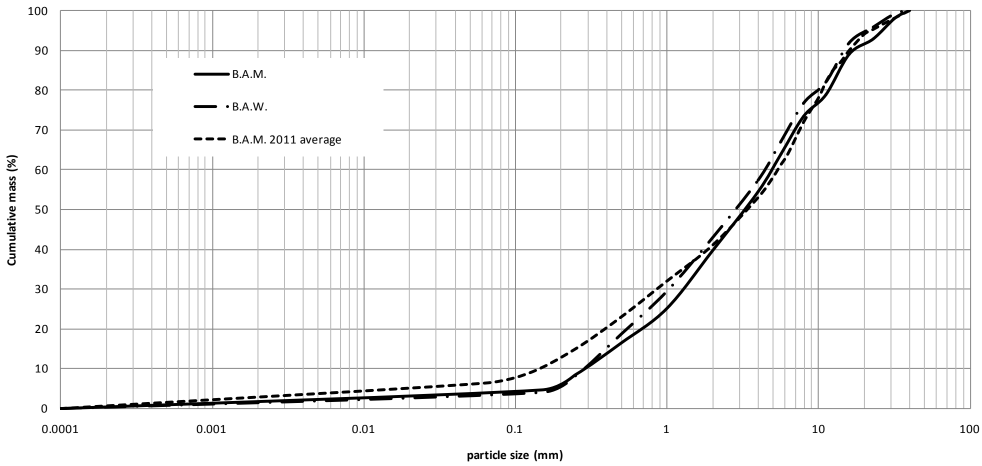

Figure 1. Particle size distribution of MSWI bottom ash

Densities each size fraction

The densities of each fraction sieved from both materials (B.A.M. and B.A.W.) were measured and the results are shown in Figure 2. It can be seen that the densities of bottom ash particles in each fraction in both B.A.M. and B.A.W. are very close and for each fraction the change of density is small. Bottom ash particles between 8 and 11.2 mm in both plants have the highest density.

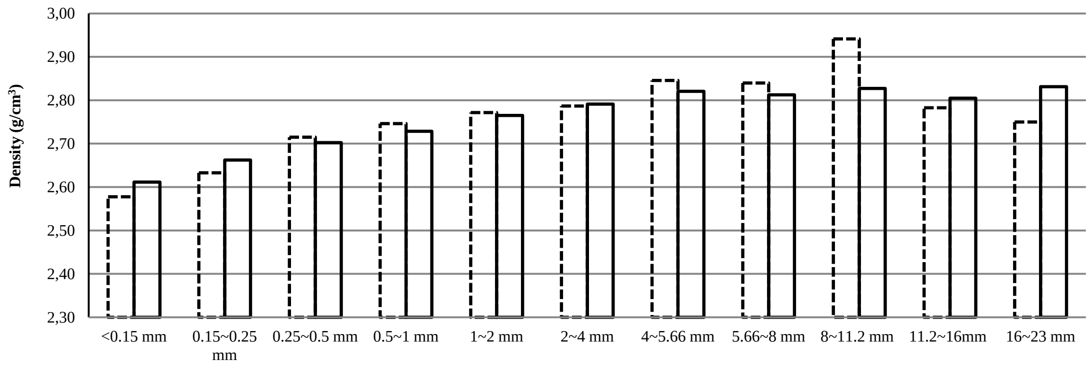

Figure 2. Densities of particles in each fraction of B.A.M. (left columns) and B.A.W.

Water content

Table 1 and Figure 3 show the water content of fresh bottom ash and bottom ash produced in recent three years in Moerdijk. It is shown that water content of bottom ash in both plants change randomly. This attributes to the quenching process after burning and the conditions of storage. The bottom ash in the two plants is stored under natural open air, so the weather conditions are a significant factor of the bottom ash water content.

Table 1. Water content of bottom ash

Water content value (%)	B.A.M. (%)			Fresh B.A.M.	Fresh B.A.W.
Year	2009	2010	2011		
Average value	17.91	18.04	15.14	17.35	14.16
Max value	20.82	25.03	16.84	18.02	14.94
Min value	16.44	12.78	12.80	16.16	12.83

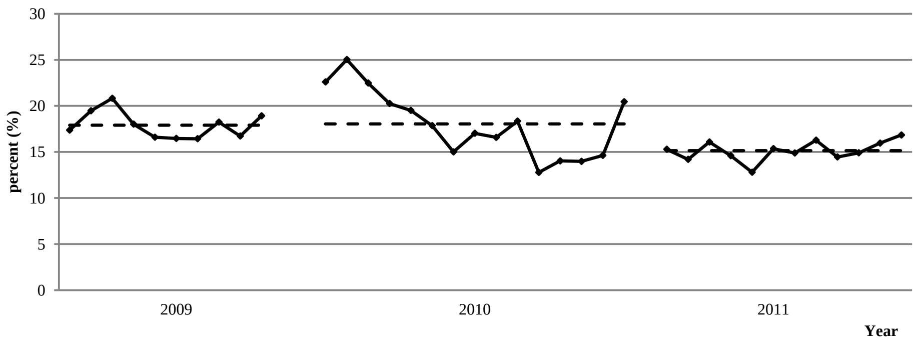

Figure 3.Water content of B.A.M. from 2009 to 2011

Leaching data analysis

In the Netherlands, there are two legislative documents that regulate the use of materials: the Building Materials Decree (BMD) and the Landfill Ban Decree. Both decrees specify acceptable emission levels of both inorganic and organic compounds in the leaching test. According to the Building Materials Decree (Table 2), the bottom ash from the two plants can be used as IBC material in road construction which is the current way of the use of bottom ash from the two MSWI plants. The IBC category refers to materials that can only be used with certain isolation precautions. For using as non shape-retaining materials, the leaching contaminants in bottom ash which exceed the limits of BMD are chloride, sulphate, copper and antimony in B.A.W. and chloride, sulphate, copper in B.A.M. (Figures 4 to 7).

Table 2. Maximum leaching of inorganic compounds for building materials from the Building Material Decree and the range of average leaching values per year of B.A.M. and B.A.W., in mg contaminant/ kg dry solids (d.s.)

Contaminant	Non shape-retaining (mg/kg d.s.)	IBC materials (mg/kg d.s.)	B.A.M. min-max average value (mg/kg d.s.)	B.A.W. min-max average value (mg/kg d.s.)
Sb	0.16	0.7	0.08-0.2	0.11-0.63
As	0.9	2	0.05-0.19	0.005-0.25
Ba	22	100	0.35-7.4	0.47-23.01
Cd	0.04	0.06	<0.01	0-0.01
Cr	0.63	7	<0.05	0.05-0.24
Co	0.54	2.4	<0.03	0.03-0.05
Cu	0.9	10	2.23-3.86	0.67-11.11
Hg	0.02	0.08	<0.0004	0
Pb	2.3	8.3	<0.1	0.01-3.25
Mo	1	15	0.69-1.86	0.46-0.91
Ni	0.44	2.1	<0.05	0.05-0.22
Se	0.15	3	0.007-0.014	0.01-0.02
Sn	0.4	2.3	<0.2	0.02-0.1
V	1.8	20	<0.29	0.1-0.12
Zn	4.5	14	<0.43	0.2-1.06
Br^-	20	34	6.82-24.5	3.5-16.3
Cl^-	616	8800	1200-4407.15	1143.75-3566.67
F^-	55	1500	<3	1.91-8.8
SO_4^{2-}	1730	20000	740-6766.67	80.43-13333.33

It can be seen from Figure 4 that the concentration of chloride from B.A.W. and B.A.M. in the leachate mostly exceeds the limit value of BMD for non shape-retaining materials. From 1999 to 2001 the average values are almost constant, while starting from 2007, there is a descending trend. The leached chloride has decreased to just two times the allowed limit in 2010. However, in 2011 the average chloride leachate reached the highest value in the past 12 years and over six times the limit provided by the BMD for non-shaped building materials. The average leaching value of B.A.M. has an ascending trend from 2007 to 2010 and peaks at 4407 mg Cl^-/kg d.s. in 2010, which is also the highest value during these years. In 2011, the average value is 6.5 times the limit value of BMD.

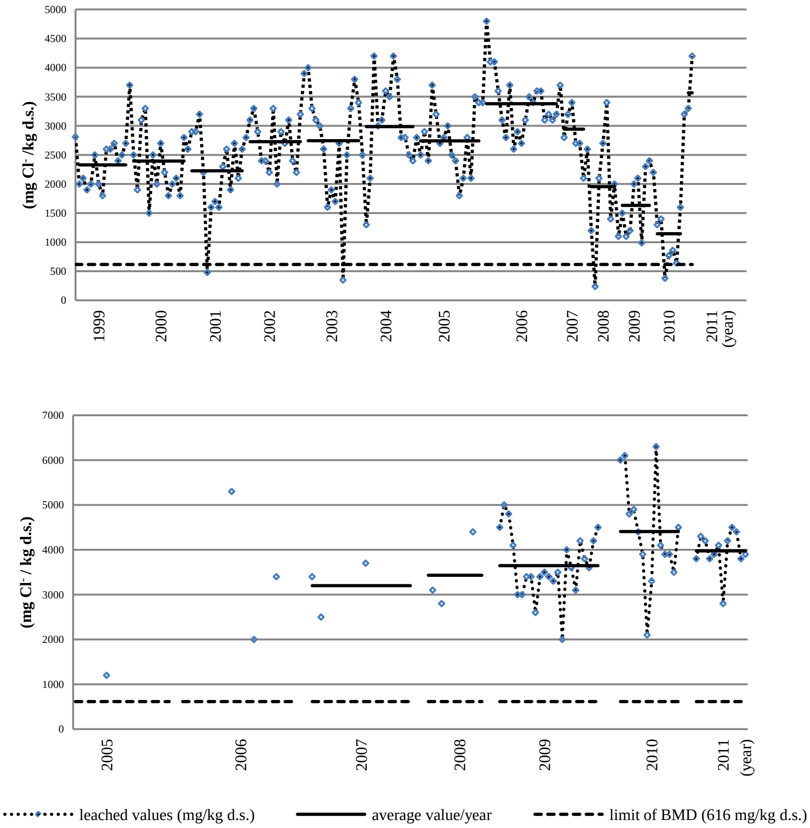

Figure 4. Chloride leaching data of B.A.W. (top) and B.A.M. (bottom)

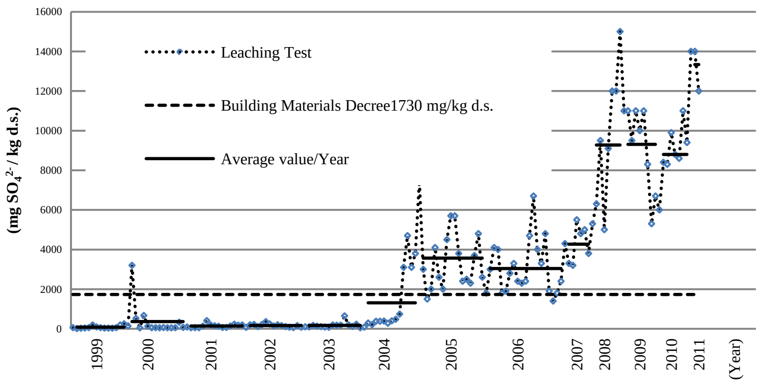

Figure 5. Sulphate leaching data of B.A.W.

As can be seen from Figure 5, the average values of leached sulphate of B.A.W. are far under the limit of BMD from 1999 to 2003. However, the values exceed the maximum value given by BMD from 2005. The average value peaked to 13333 mg SO_4^{2-}/kg in 2011 (7.7 times BMD), the highest in the past 12 years. The average value of sulphate leaching of B.A.M. has an increasing trend during the seven years. In 2011, the average value is over 3.5 times the limit of BMD.

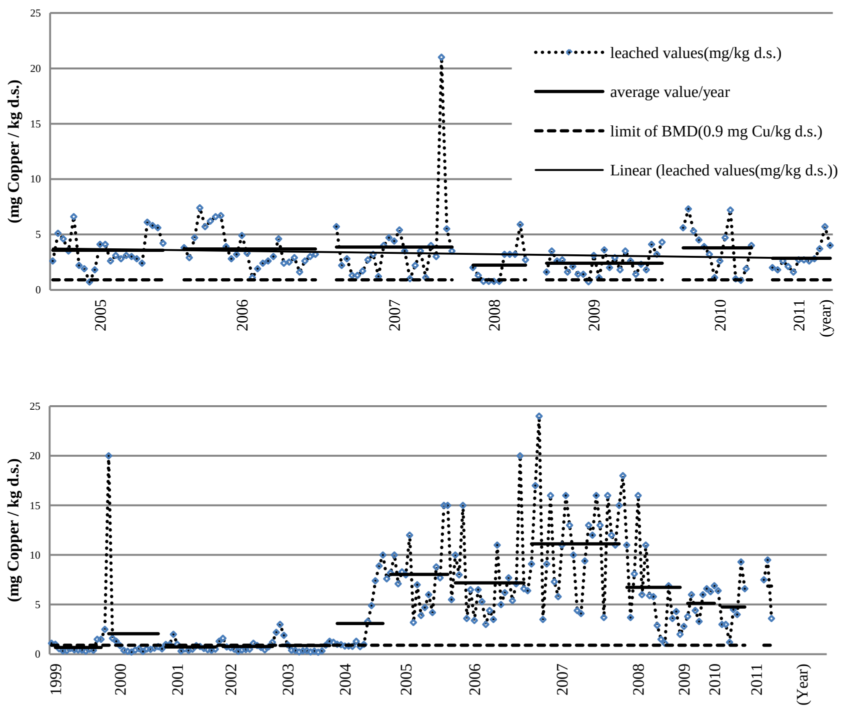

Figure 6. Copper leaching data (mg/ kg d.s.) of B.A.W. (top) and B.A.M. (bottom)

The average yearly values of B.A.W. are below the limit of BMD until 2004. After that, the average values always exceed the limits and peaked to 11 mg/kg in 2007 (12 times BMD). The value, however, decreased to 6.87 mg/kg in 2011 (7.6 times the limit of BMD). The leached copper in the B.A.M. (Figure 6) always exceeds the limit value of the BMD. From 2005 to 2007, the annual average values are similar and about 4 times the limit value. The average value in 2008 is 2.23 mg Cu/kg d.s., about 2.5 times the limit value, which is the lowest during these years. The leached copper value in 2011 is 2.86 mg Cu/kg d.s..

Figure 7 shows that before 2003 the average values of leached antimony of B.A.W. are well within the limit of BMD and have a gradual ascending trend. However, from 2003 to 2011, the average value always exceeds the maximum value in BMD. The value is over 3 times BMD and peaked to 0.63 mg/kg in 2011 (4 times BMD), the highest in the past 12 years.

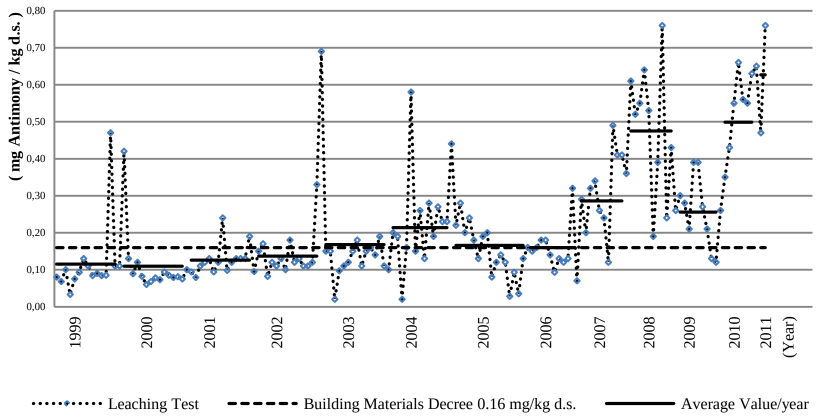

Figure 7. Antimony leaching data of B.A.W.

Conclusions

The basic physical properties of MSWI bottom ash from two plants in the Netherlands were determined by the laboratory tests.

1) The particle size distributions of MSWI bottom ash were quite stable for the two plants. Approximately 80% of particles were smaller than 11.2 mm and about 5 – 10 % particles are between 0.1 µm and 100 µm; the PSDs of the two bottom ashes were similar.
2) The densities of bottom ash from the two plants were similar; bottom ash particles between 8 and 11.2 mm for both plants have the highest density (2.83 – 2.94 g/cm^3).
3) The water content of bottom ash in the two plants can vary largely, and was affected significantly by the weather conditions and the water quenching process.
4) The leaching of the contaminants in bottom ash from the two plants are almost the same (chloride, sulphate, copper and antimony in B.A.W. and chloride, sulphate, copper in B.A.M.) according to the leaching limit from Building Materials Decree on non-shape retaining material; pre-treatments are needed to solve the problems.

These basic physical characteristics can be compared with other building materials (such as sand, aggregates in concrete) to find the potential use of these bottom ashes as a substitute of concrete aggregates. The other physical characteristics according to building materials legislations of MSWI bottom ash from the two plants, chemical properties, application potentials and treatments on solving the leaching problems or upgrading the quality of bottom ash for using as building materials will be studied in the future.

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“R” Recycling, GMB, Schenk Concrete Consultancy, Intron, Geochem Research, Icopal, BN International, APP All Remove, Consensor, Eltomation, Knauf Gips, Hess ACC Systems and Kronos (chronological order of joining).

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