Characterization of Combustion Residues from a MSW Incinerator

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Introduction

In combustion processes, incomplete conversions and side-reactions may take place and cause the production of unwanted by-products, for examples, CO, CO2, NO_x, SO_2, HC and vapours and particulates. Emissions from biomass and waste combustion also contain incomplete combustion products and other toxic micropollutants including

- heavy metals such as Hg, Cd and Pb,
- Persistent organic species such as PCDD/Fs and
- ultra-fine particulates.

The objectives of this study were

- To characterize the combustion residues collected from a MSW incineration plant
- To investigate the behaviours of metals released.

Five samples consisted of i) bottom ash, ii) superheater deposit, iii) heat exchanger ash, iv) economiser ash and v) fabric filter ash were analysed for particle size distribution, carbon content, chemical components, chemical concentration and morphology.

Description of Plant and Samples

Plant Description

- A large-scale mass burn MSW incineration plant : waste throughput 11.7 ton/hr
- Reverse reciprocating grate.
- Heat recovery : superheaters, heat exchanger and economiser.
- Gas cleaning : Fabric filters with injection of hydrated lime and activated carbon.

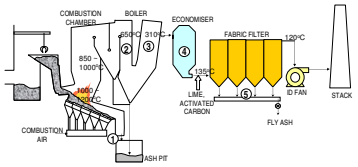


Figure 1 Plant A : a large-scale mass burn MSW incineration plant

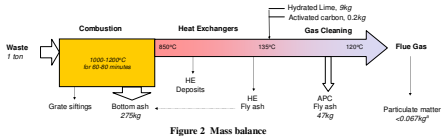


Figure 2 Mass balance

Visual Characteristics of Samples

- S1 Bottom ash : dark grey, heterogeneous matrix
- S2 Superheater deposit : yellow to brown
- S3 Heat exchanger ash : dark grey
- S4 Economiser ash : white, dark brown, grey and black
- S5 Fabric filter ash : light grey powder.

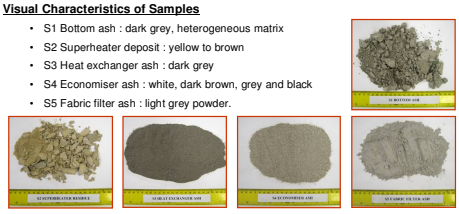


Figure 3 Five samples of combustion residues collected

Analytical Methods

- Particle size distribution: Sieving analysis and Malvern mastersizer S.
- Unburnt carbon: British Standard 1016 Part 6.
- SEM analysis: Camscan Mark II – Link Analytical EXL energy dispersive spectrometer. .
- SEM-EDS analysis: Link Analytical EXL" energy dispersive spectrometer.
- Elemental analysis: ICP (Inductively Coupled Plasma) Emission Spectrophotometer.

Results and Discussion

Particle Size Distribution by Sieve Test

- Bottom ash contained mainly large particles.
- Results of superheater deposit was not representative since it was in plate form.
- More finer fraction : heat exchanger ash, economiser ash, and fabric filter ash

Table 1 Results of Sieve test

Particle Size	S1: Bottom ash	S2: SH Deposit	S3: HE ash	S4: EC ash	S5: FF ash
> 4750 µm	57.0%	(31.1%)	0	0	0
> 850 µm	85.7%	(54.2%)	2.1%	7.4%	0
> 212 µm	98.2%	(63.3%)	66.0%	74.7%	9.2%

Particle Size Distribution by Malvern Instrument

- Superheater deposit composed of particles with various sizes.
- Size distributions of heat exchanger and economizer ash were almost identical.
- Small size of fabric filter ash : injection of lime and activated carbon, and the contribution of small particles trapped by fabric filter.

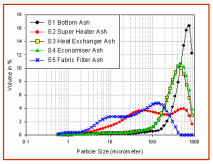


Figure 4 Particle Size Distribution

Table 2 Mean diameter from Malvern instrument

Samples	Mean Diameter (µm)
S1: Bottom ash	503
S2: SH Deposit	181
S3: HE ash	344
S4: EC ash	366
S5: FF ash	75

Carbon Content

- Carbon 3 – 5 % : the combustion was efficient
- High content in the fabric filter ash:
  - entrained carbon containing particles,
  - activated carbon injection

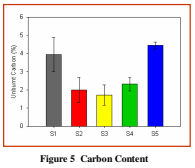


Figure 5 Carbon Content

Full Elemental Analysis

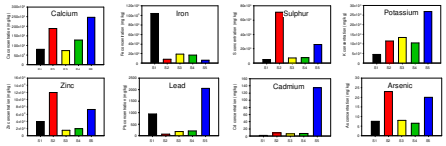


Figure 6 Selected Results of Full Elemental Analysis

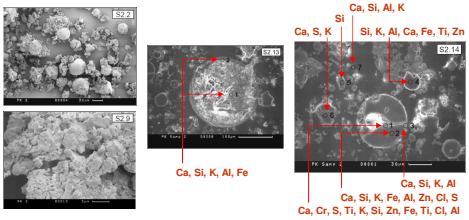
- Ash/deposits were mainly composed of Ca, Al, S, K, Na, Fe, Mg, P, Zn, and Ti.
- SH deposit : enriched in alkali and earth alkali sulphate.
- HE and EC ash : identical chemical composition/concentration
- FF ash : High concentration of Ca, S, K, Na, Zn, Pb, Cd, As and Cl.
- High volatile elements enriched in fabric filter ash : As, Cd, Hg, Pb, S, Sb, and Zn
- Non volatile elements enriched in bottom ash : Al, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Si, and Ti

Table 3 Elemental Partitioning

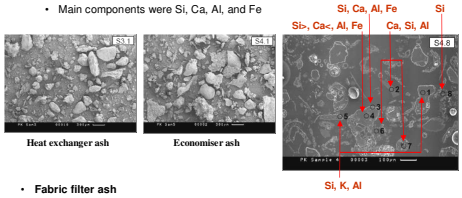
Combustion residues	Bottom ash	HE deposits	HE Fly ash	APC residues	Particulate in Flue gas
Weight fraction in the total ash	85.3%			14.7%	
Typical particle size	>1000µm	Agglomerates	50-1000 µm	1-300 µm	<1 µm
Enriched elements	Fe	S, K, Na, Zn, Sb	K, Na	All volatile metals, dioxins	
Fe	28.6 kg (99%)			0.3 kg (1%)	
Al	8.5 kg (88%)			1.1 kg (12%)	
Cu	0.4 kg (95%)			0.02 kg (5%)	< 0.067 g
S	1.39 kg (53%)			1.22 kg (47%)	< 33.3 g (SO_3)
K	1.3 kg (55%)			1.1 kg (45%)	
Cd	1 g (15%)			6 g (85%)	0.041 g
Pb	275 g (74%)			97 g (26%)	0.869 g
Zn	761 g (72%)			299 g (28%)	
As	1 g (44%)			1 g (56%)	0.095 g
Sb	6 g (37%)			11 g (63%)	
Sn	44 g (65%)			24 g (35%)	
Cr	20 g (83%)			4 g (17%)	<0.067 g
PCDD/Fs (I-TEQ)	16500 ng			76100 ng	0.13 ng

Morphology and Mineralogy

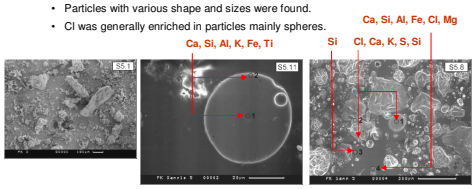
- **Superheater deposit**
  - Spherical particles (10 to 60 µm) + cubicle, elongated, needled, and platy particles.
  - Main components were Ca, Si, Al, Fe, Zn, S, Ti, K, Cl and Cr.



- **Heat exchanger ash and Economiser ash**
  - Entrained coarse fly ash – microporous particles
  - Economiser ash consisted of larger but lighter particles than heat exchanger ash
  - Main components were Si, Ca, Al, and Fe



- **Fabric filter ash**
  - Particles with various shape and sizes were found.
  - Cl was generally enriched in particles mainly spheres.



Conclusions

- Combustion residues collected at different sites in the incinerator were different in term of size, composition, and morphology. This was due to ash formation processes (chemical reaction, coagulation, chain agglomeration, condensation) as well as the transportation of entrained fly ash with gas stream.
- Superheater deposits consisted mainly of spherical particles that have diameters ranging from 10 µm - 60 µm. Common constituents were Ca, Si, Al, Fe and Zn.
- Particles in the heat exchanger ash and economiser ash were mostly entrained coarse fly ash. Larger and lighter particles were found more in economiser ash.
- Fabric filter ash contained high concentrations of Ca, C, Cl, S and volatile metals due to increase of entrained coarse fly ash, condensation of volatile compounds on the surface of finer fly ash, activated carbon and lime injection, and finally presence of aerosols trapped by fabric filter.
- Metals showed different partitioning behaviours depending on their physical and chemical properties. Less volatile elements (Al, Cu and Fe) were mostly found in the bottom ash while volatile elements (Cd, Pb and As) were enriched in fabric filter ash.

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