Mineralogical Analysis of MSWI Bottom Ash

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Where innovation starts

Project

STW project: Environmental concretes based on treated MSWI bottom ashes

Stichting voor de Technische Wetenschappen
Foundation for Technical Sciences

- Applying MSWI bottom ash in concrete
- Application of fine bottom ash in Autoclaved Aerated Concrete
- Environmental impact of bottom ash-containing products

Incineration

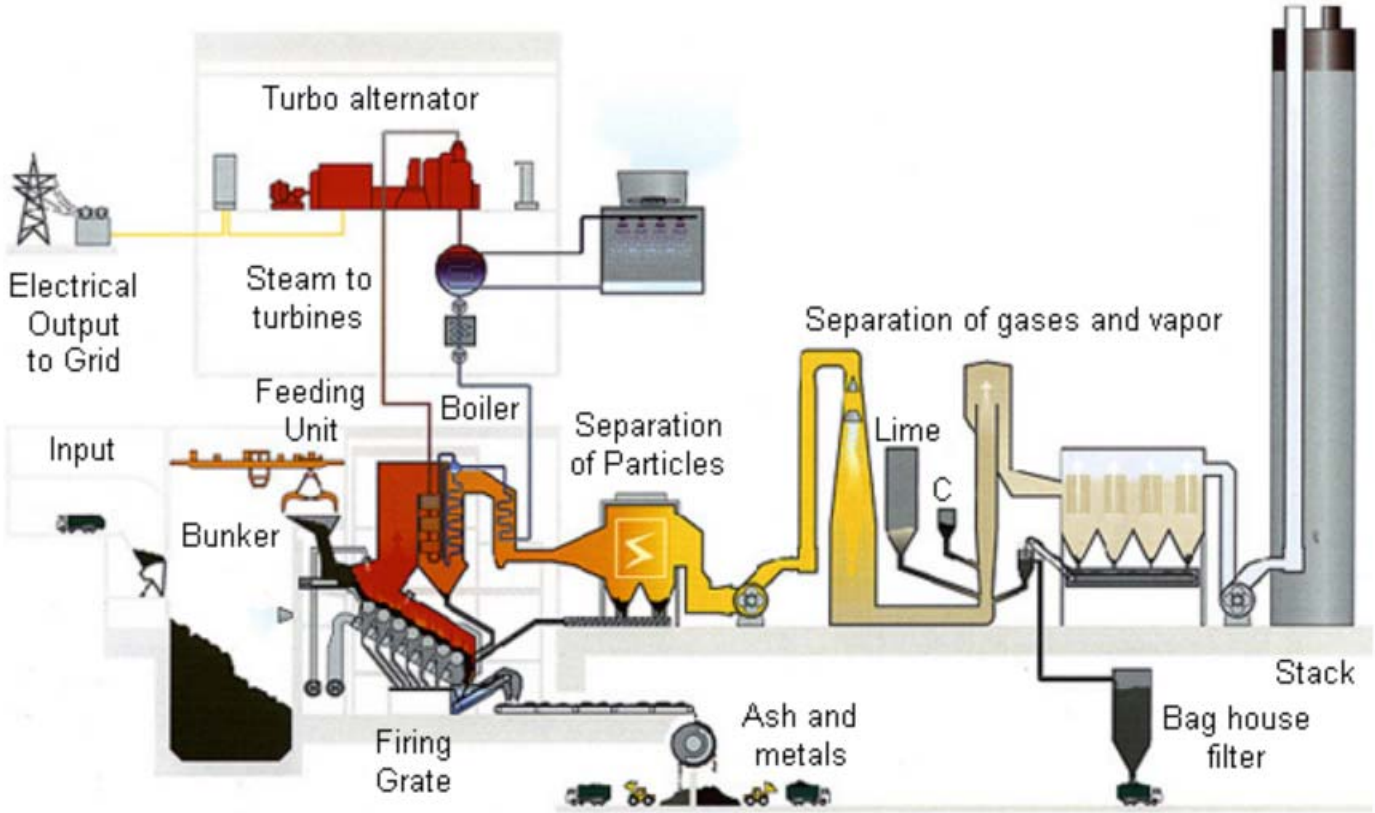
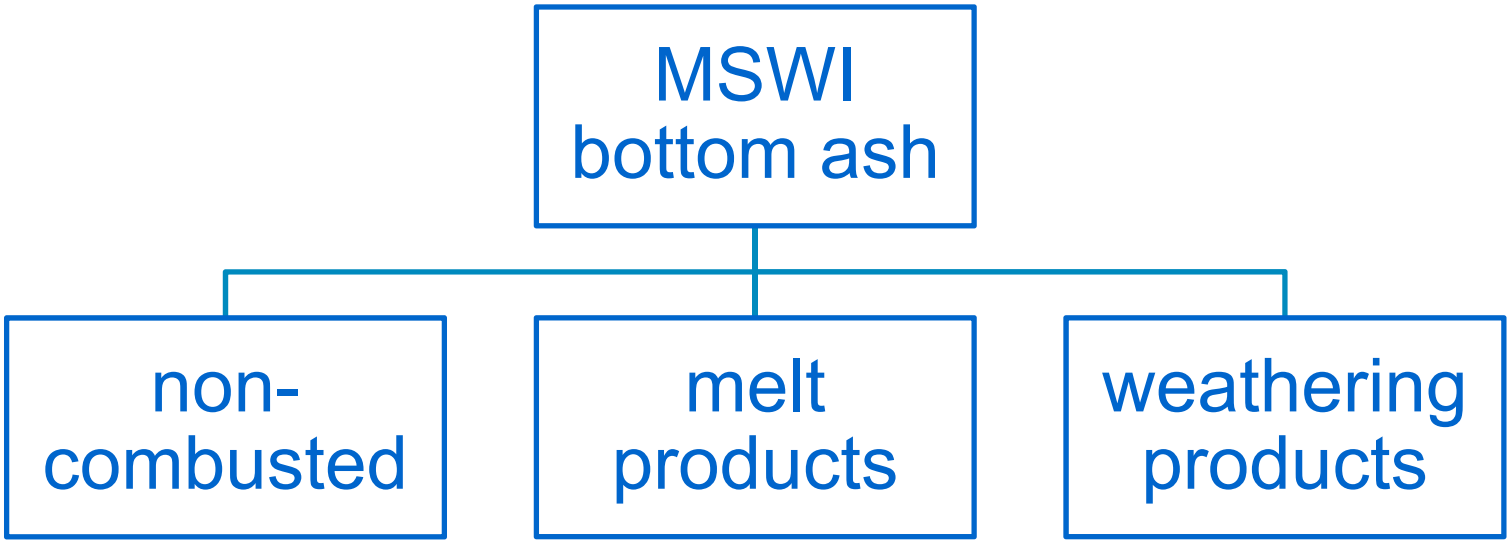


Figure 1: Waste incineration plant schematic, to know more of each of the units please click on the image (Image: LondonWaste)

Composition



- Glass
- Ceramics
- Metal
- Soil minerals
- Organics

- Amorphous
- Spinel-Group ($A^{2+}B^{3+}_2O^{2-}_4$)
- Melilite-Group $(Ca,Na)_2(Al,Mg,Fe^{2+})[(Al,Si)SiO_7]$
- Feldspar

- $CaCO_3$
- Clays

Challenges

- **BA normally used as road base or landfilled**
- **Strict legal limits for amounts of contaminants**

Contaminant	Shaped building materials (mg/m^2)	Non-shaped building materials (mg/kg)	IBC materials (mg/kg)
Sb	8.7	0.32	0.7
As	260	0.9	2
Ba	1500	22	100
Cd	3.8	0.04	0.06
Cr	120	0.63	7
Co	60	0.54	2.4
Cu	98	0.9	10
Hg	1.5	0.02	0.08
Ni	81	2.3	2.1
Mo	144	1	15
Pb	400	0.44	8.3
Se	4.8	0.15	3
Sn	50	0.4	2.3
V	320	1.8	20
Zn	800	4.5	14
Cl^-	110000	616	8800
F^-	2500	55	1500
SO_4^{2-}	165000	1.730	20000

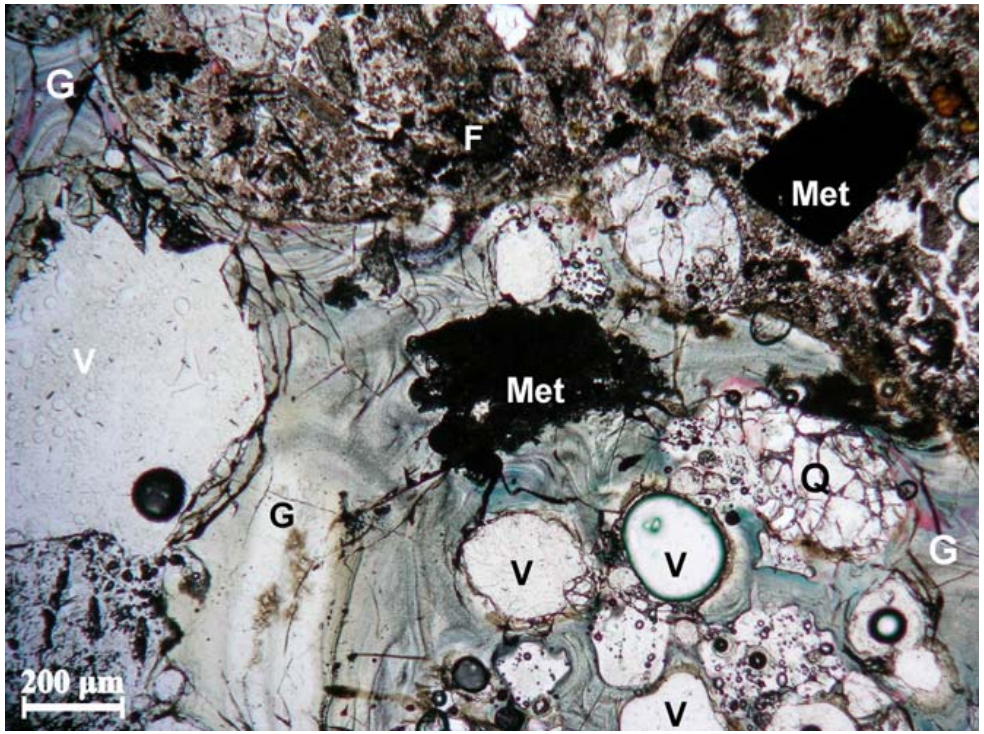
Soil Quality Decree/ Landfill Ban Degree

Composition

Composition

BA after sorting, magnetic separation and sieving

Composition



V – Void; Met – Metal; G – Glass; Q – Quartz

Wei et.al. Journal of Hazardous Materials 187 (2011) 534–543

- Particles can be complex mixtures of glass and minerals
- 85% melt products, 25% voids
- Dykstra Eusden et.al (1999) estimate T based on CaO-FeO-SiO_2 and CaO-Al_2O_3-SiO_2

Opaque glas: 1100-1400°C
Non opaque: 1500-1700°C

Impurities?

Goal

- **Creation of environmental concretes by replacing cement with MSWI BA**

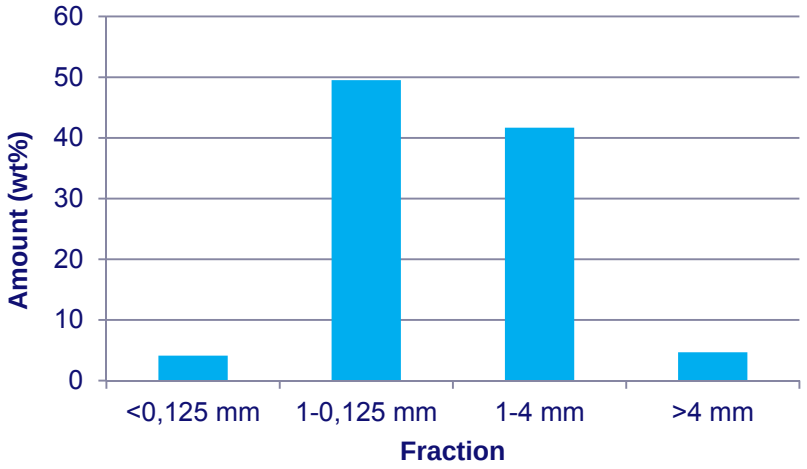
  - **Economical and ecological advantages**
  - **Immobilisation of contaminants**
  - **Treatment of BA**

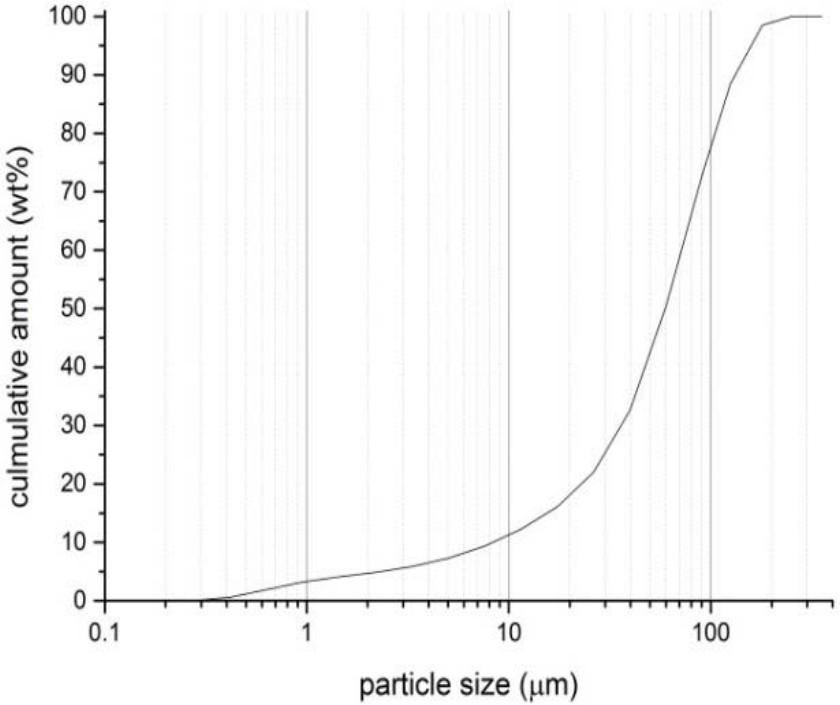
Mineralogical,
Physical,
Chemical properties

(0-4 mm)

Properties

Bottom ash fraction	Moisture Content (%)	Density (g/cm^3)
Small (< 0.125 mm)	15.80	2.64
Medium (0.125 - 1 mm)	14.29	2.63
Large (1 - 4 mm)	13.02	2.73





PSD fines

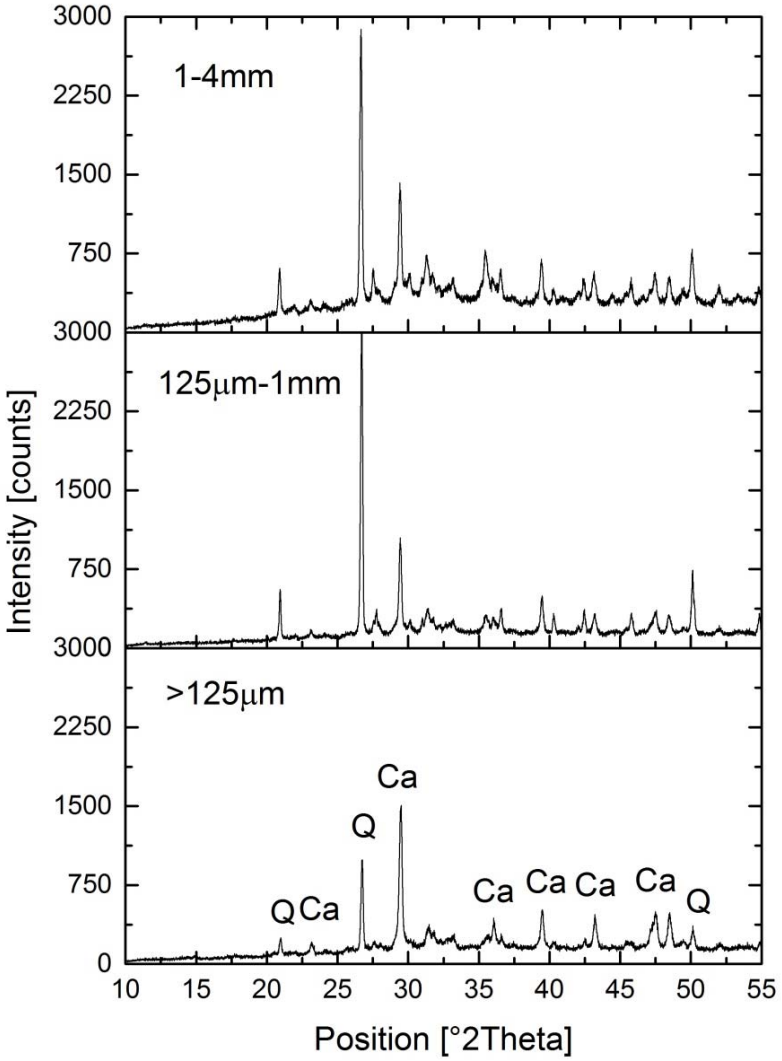
Properties

Oxide	Small	Medium	Large
Na_2O	1.74	1.80	2.2
MgO	1.97	1.95	2.53
Al_2O_3	14.78	12.30	10.93
SiO_2	16.59	25.79	28.14
P_2O_5	2.13	2.25	2.22
SO_3	6.31	5.29	4.1
K_2O	1.37	1.40	1.46
CaO	39.67	30.63	27.58
TiO_2	1.99	1.74	1.53
Cr_2O_3	0.13	0.11	0.14
MnO	0.24	0.20	0.21
Fe_2O_3	8.87	13.03	16.02
NiO	0.03	0.02	0.03
CuO	0.51	0.42	0.41
ZnO	1.28	1.07	0.71
SrO	0.12	0.09	0.08
ZrO_2	0.06	0.10	0.06
BaO	0.16	0.14	0.14
PbO	0.18	0.15	0.22
Cl	1.87	1.49	1.27

Low SiO_2/CaO ratio due to Quartz/Calcite

Calcite accumulates in finer fraction

Properties



Q – Quartz
Ca - $CaCO_3$

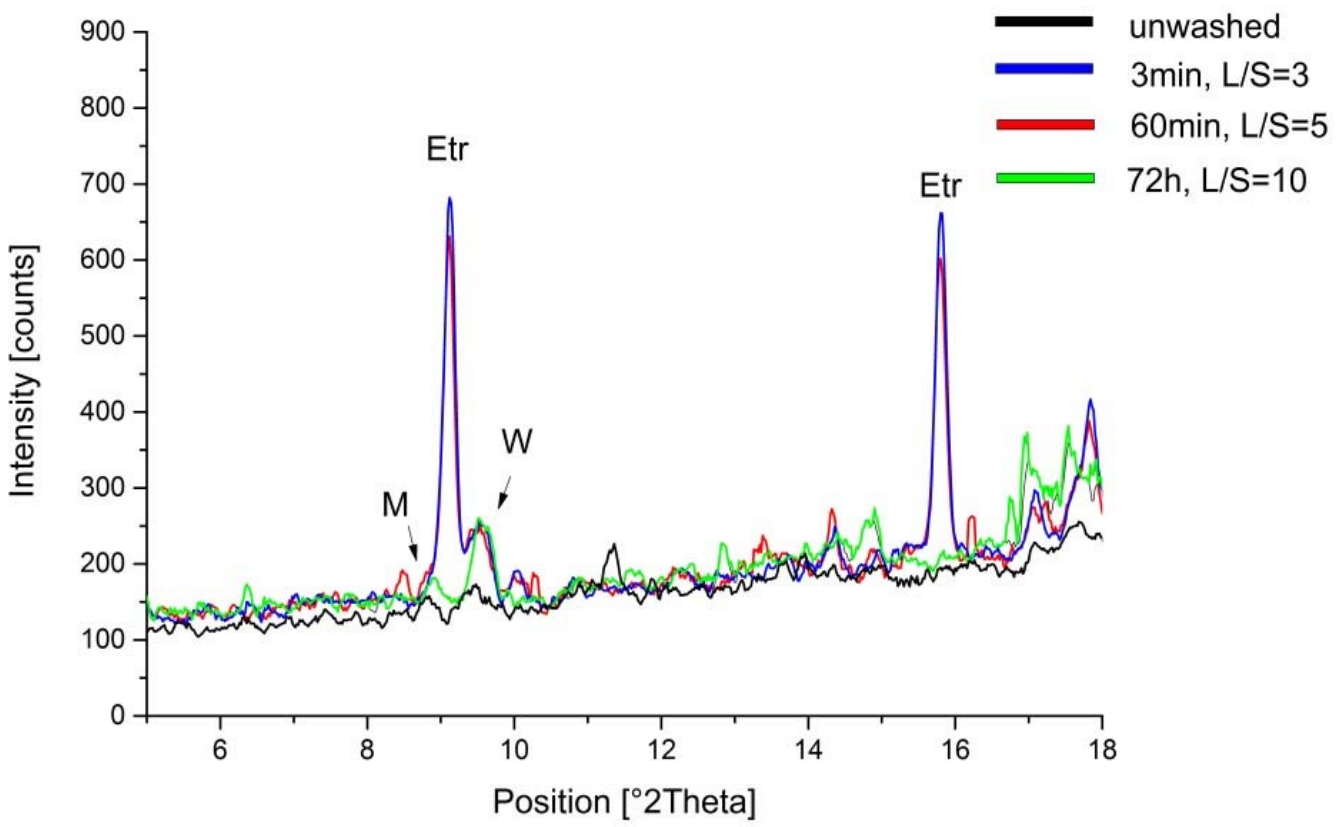
Other minerals according to literature:

Halite	NaCl
Spinel	$MgFe_2O_4$
Magnetite	
Hematite	
Melilite	

???

XRD limitations: low quantities, low crystallinity especially in complex mixes

Properties

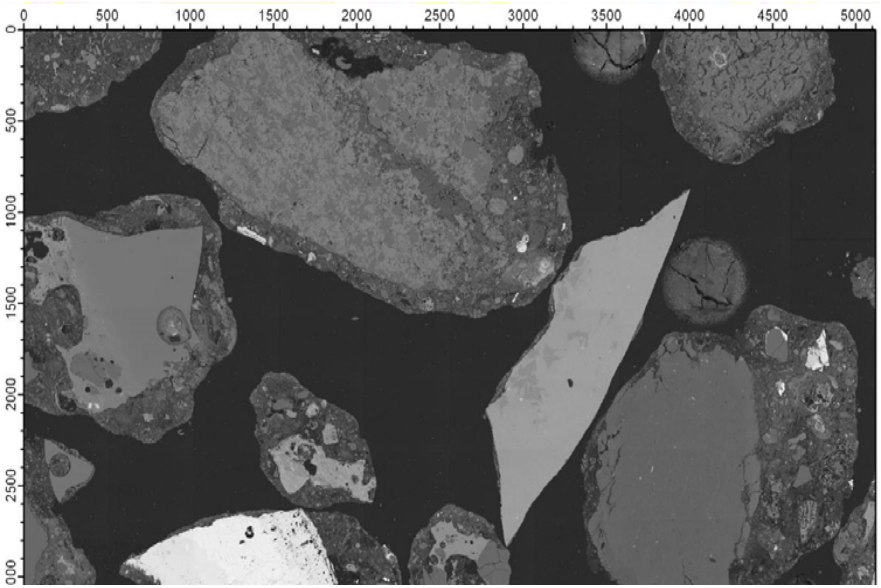


M – Muscovite, W – Wollastonite, Etr – Ettringite

Properties

Mineral	Formula	Type
Quartz	SiO_2	inert residue
Calcite	$CaCO_3$	weathering
Magnetite (Spinel)	$Fe^{2+}Fe^{3+}{}_2O_4/Fe_3O_4$	incineration
Hematite	Fe_2O_3	incineration
Gehlenite (Melilite)	$Ca_2Al(AlSiO_7)$	incineration
Bassanite	$CaSO_4 \cdot 0.5(H_2O)$	weathering
Muscovite	$KAl_2(OH,F)_2(AlSi_3O_{10})$	inert residue
Wilhendersonite (Zeolite)	$K_2Ca_2\ (H_2O)_{10}\ (Al_6Si_6O_{24})$	weathering
Wollastonite	$CaSiO_3$	incineration/inert residue

SEM

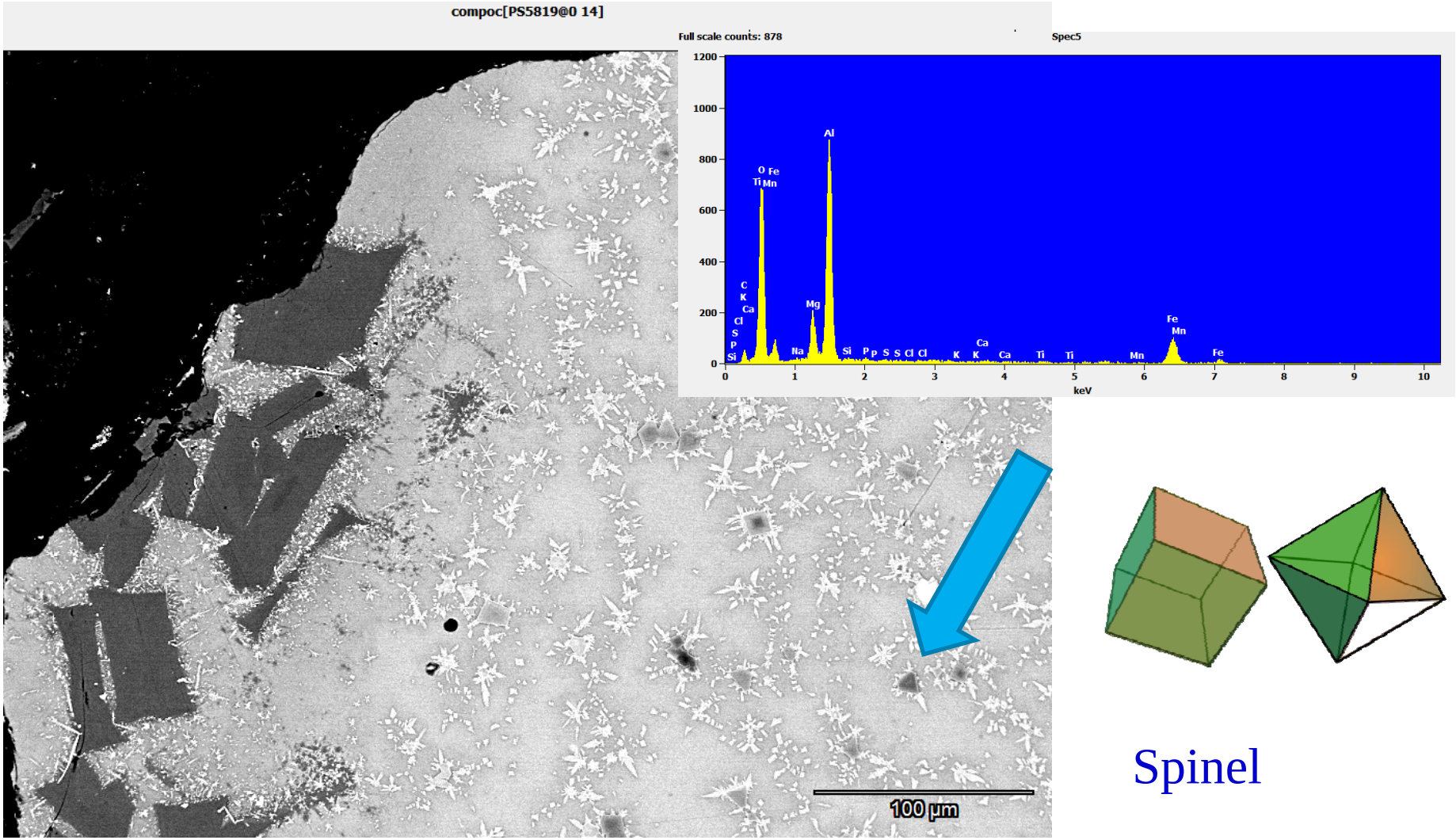


-more information about the phases via SEM/EDX

-sample cast in resin and polished without water

- JEOL JSM-7001 and a Noran System 7 EDS system

SEM


compoc[PS5819@0 14]
Full scale counts: 878
Spec5
1200
1000
800
600
400
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0
O
Fe
Ti
Mn
Al
C
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Ca
Cl
S
P
Si
Mg
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Si
P
S
Cl
K
Ca
Ti
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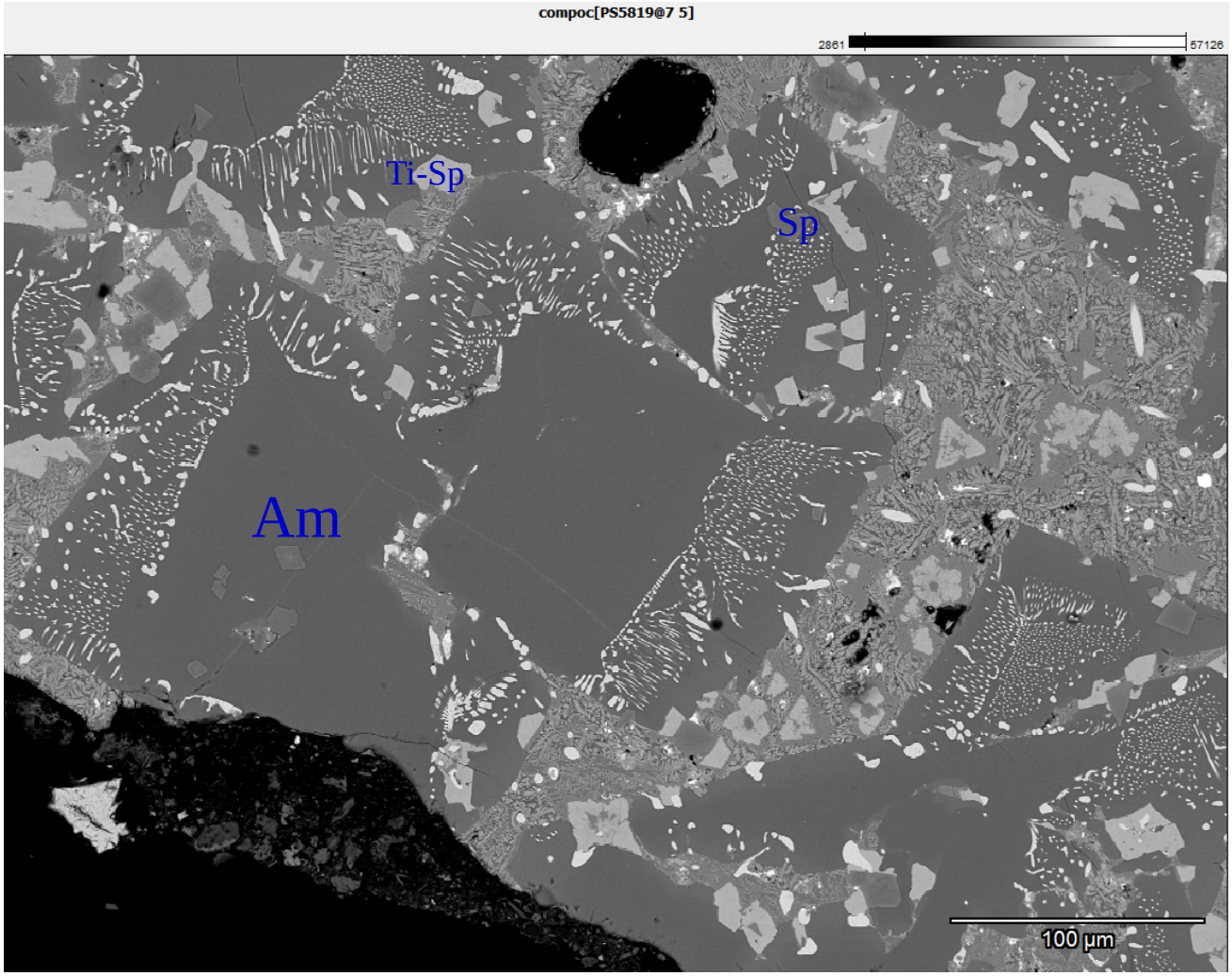
Fe
0
1
2
3
4
5
6
7
8
9
10
keV
100 µm

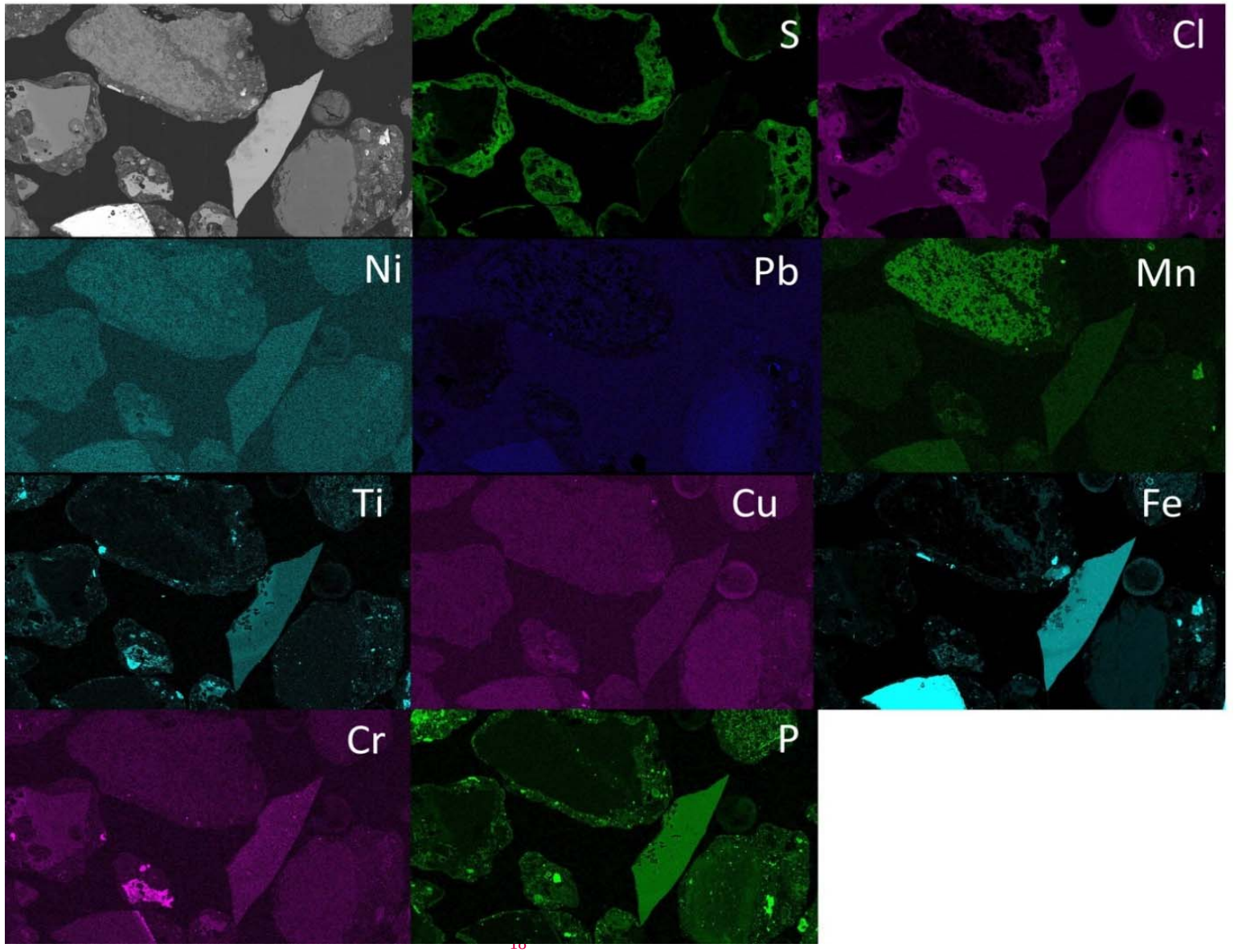
Spinel

SEM

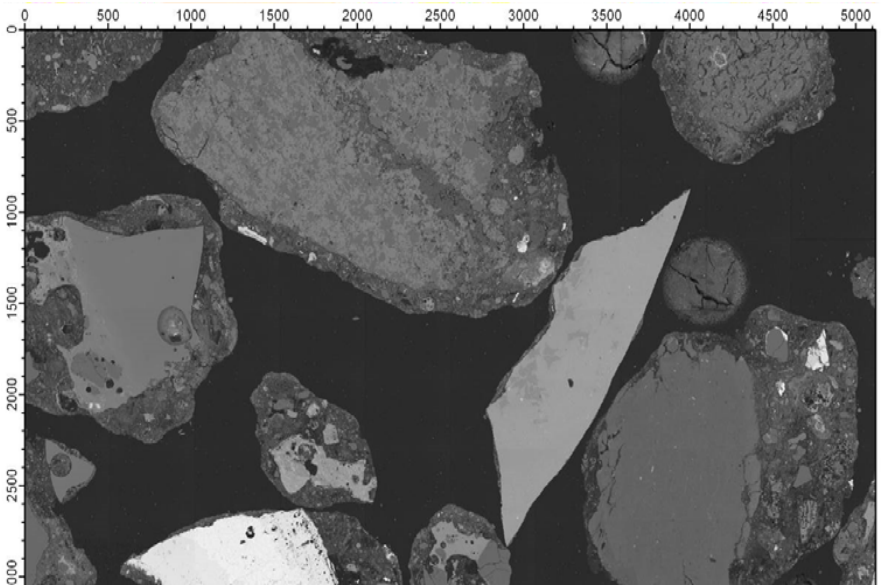


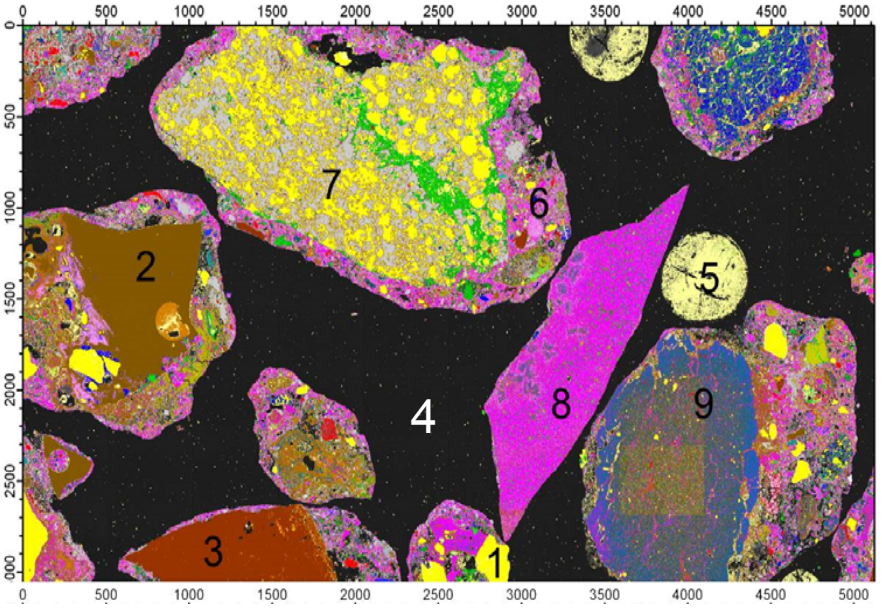
Am – Amphibol
Sp – Spinell
$FeAl_2O_4$

SEM/EDX



PARC - Phase Recognition and Characterisation





1) quartz grain
2) bottle glas
3) iron oxide
4) resin used to embed BA particles
5) rubber incineration residue
6) “melilite” rim
7) mix of calcite and quartz (natural sandstone with lime matrix)
8) melilite rich grain
9) feldspar

PARC

Oxide	FeOx	Calcite	Melilite 1	Ca-Melilite 1	Si Oxide residue	Quartz
Na_2O	0	1.1	2.6	2.4	2.4	0.1
MgO	0.1	0.7	2.9	1.6	1.8	0.3
Al_2O_3	0.2	3.7	15.1	20.8	5.9	0.5
SiO_2	0.5	4.6	32	10.5	65.2	97.2
P_2O_5	0	1.1	1.6	1.5	1.4	0
SO_3	0.1	3.8	2.5	10.9	1.6	1.4
Cl	0	1	1.1	2.9	1.6	0.1
K_2O	0	0.2	1	0.7	1	0
CaO	0.3	74.6	25.3	39.8	11.1	0.2
TiO_2	0	0.8	1.2	1.1	0.6	0
MnO	0.1	1.8	0.1	0.1	0.1	0
Fe_2O_3	98.5	1.3	11.6	2.1	5.6	0.1
NiO	0	0.6	0	0.1	0.1	0
Cu_2O	0	0.2	0.2	0.2	0.5	0
ZnO	0	0.2	0.3	0.6	0.4	0
MoO_3	0	0.5	0.3	0.6	0.5	0
Sb_2O_3	0	3.7	2	4.2	0	0
Pixels	4.4	14.1	14.1	4.8	7.5	10

36 phases

12 phases = 84.3%

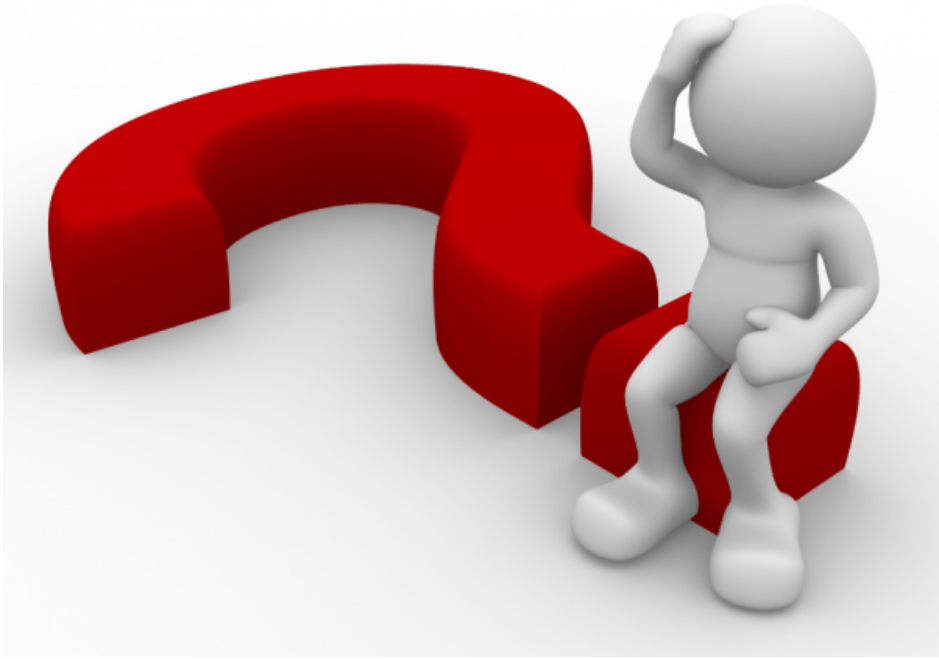
PARC

Melilite 1 $(Na_{0.23}Ca_{1.77})(Al_{0.47}Mg_{0.18}Fe_{0.16})Al_{0.63}Si_{1.37}O_7$
Melilite 2 $(Na_{0.74}Ca_{1.26})(Al_{1.3}Mg_{0.15}Fe_{0.14})Al_{0.04}Si_{1.96}O_7$

Magnetite
Hematite
Wollastonite $CaSiO_3$
Feldspar
Glass
Quartz
Calcite

Ca-Melilite 1 and 2 (glassy phase)

Outlook

- SEM/EDX and PARC can be used to identify phases in MSWI BA
- Based on that Rietveld quantification is planned including amorphous phase
- Sequential extraction will be applied in order to determine how certain contaminants are bound
- The results will be compared and used to explain and predict the leaching behavior of MSWI BA

Thank you
for your attention.