6th CEWEP Congress 2012
Waste-to-Energy
Energy & Resource Efficiency
6-7 September 2012, in Würzburg

Metal Recycling from bottom ash

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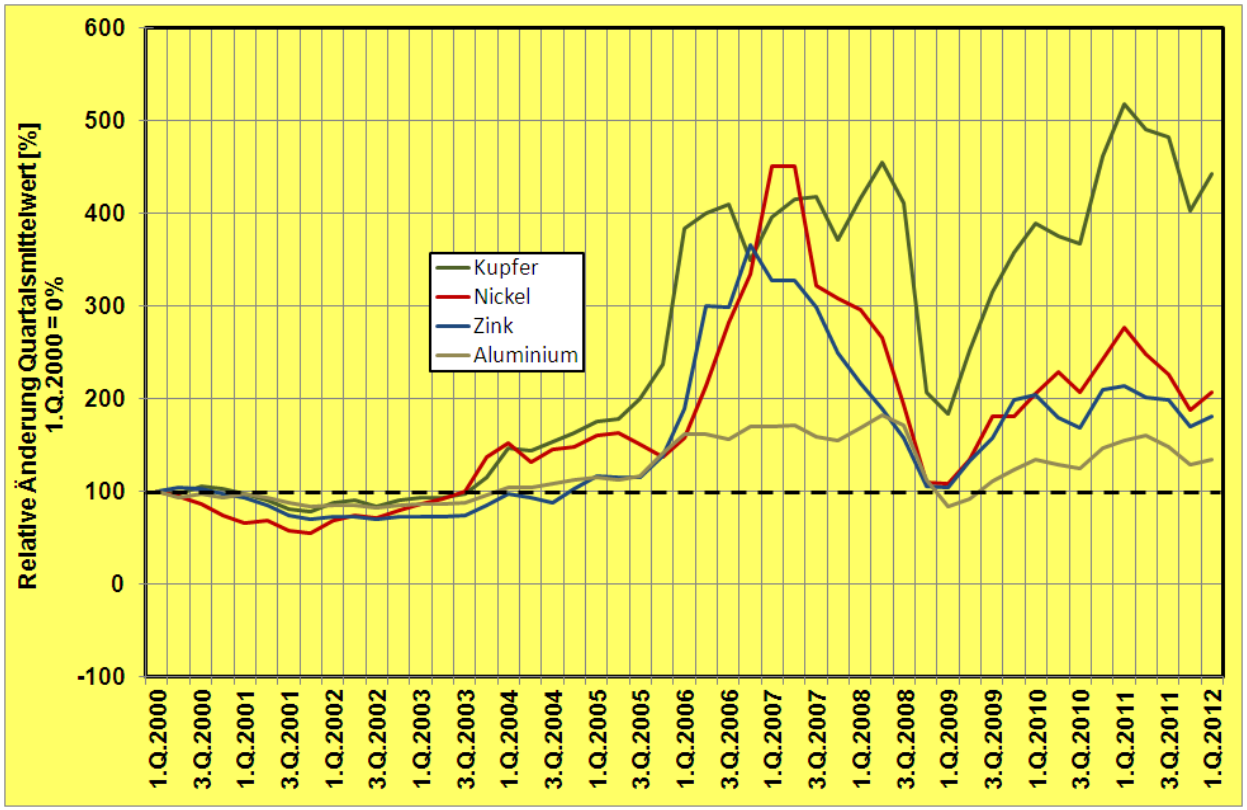
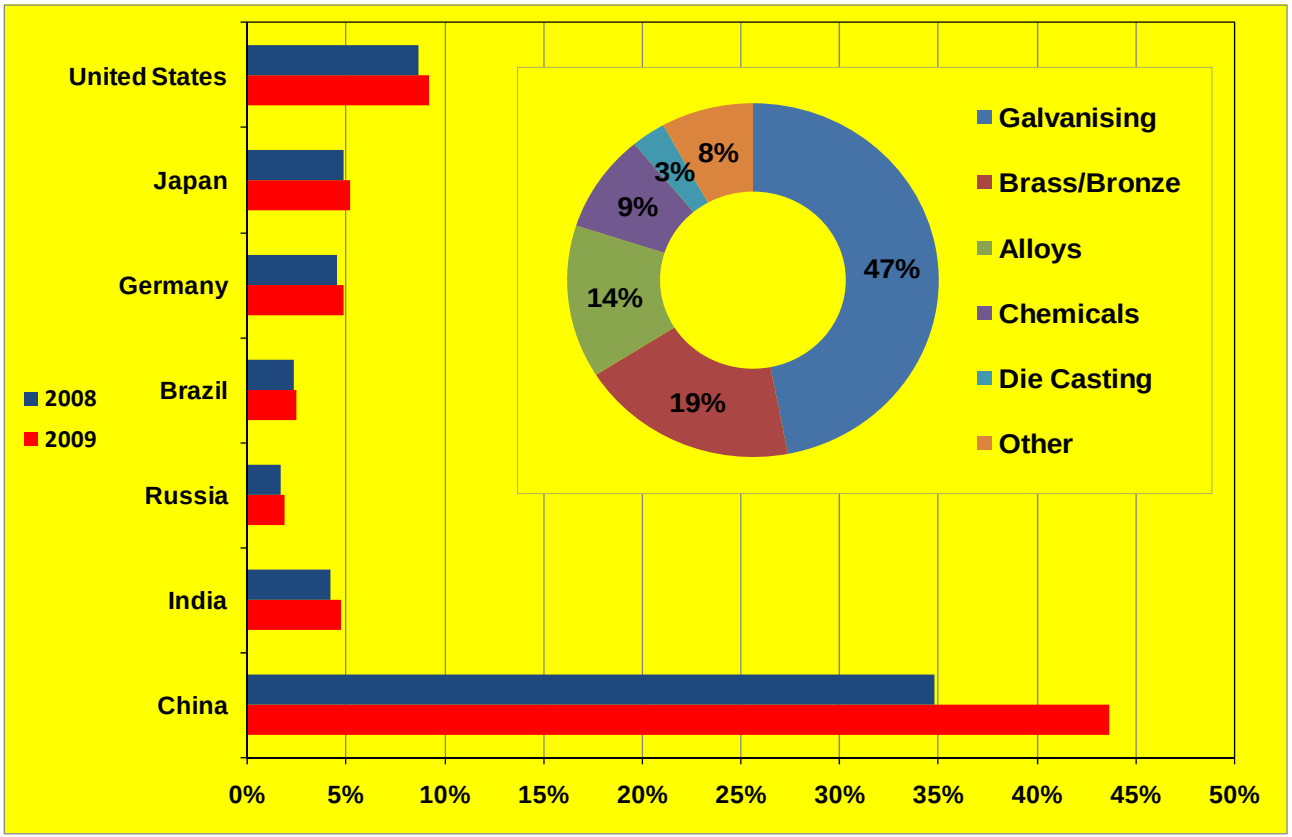
Development of various metals prices quarterly averages (1. Q. 2000 = 100%)



Deike, R, Ebert, D., Warnecke, R.; Vogell, M.: 11. VDI Fachkonfererenz Feuerung und Kessel, Bremen, 13.06.2012

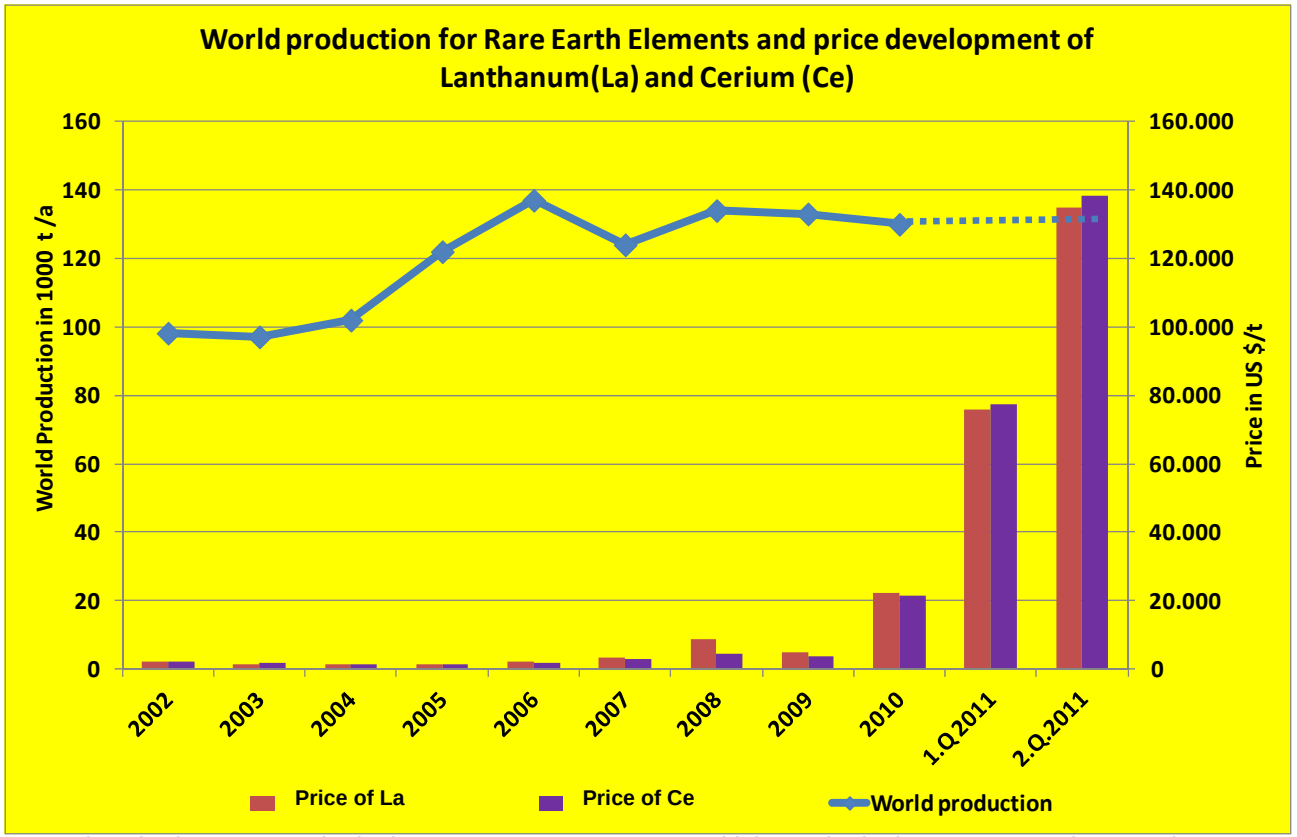
World zinc consumption in 2008/2009 (11.5 / 10.8 million tons) divided by regions and major consumers



Data of LME and Bundesanstalt für Geowissenschaften und Rohstoffe

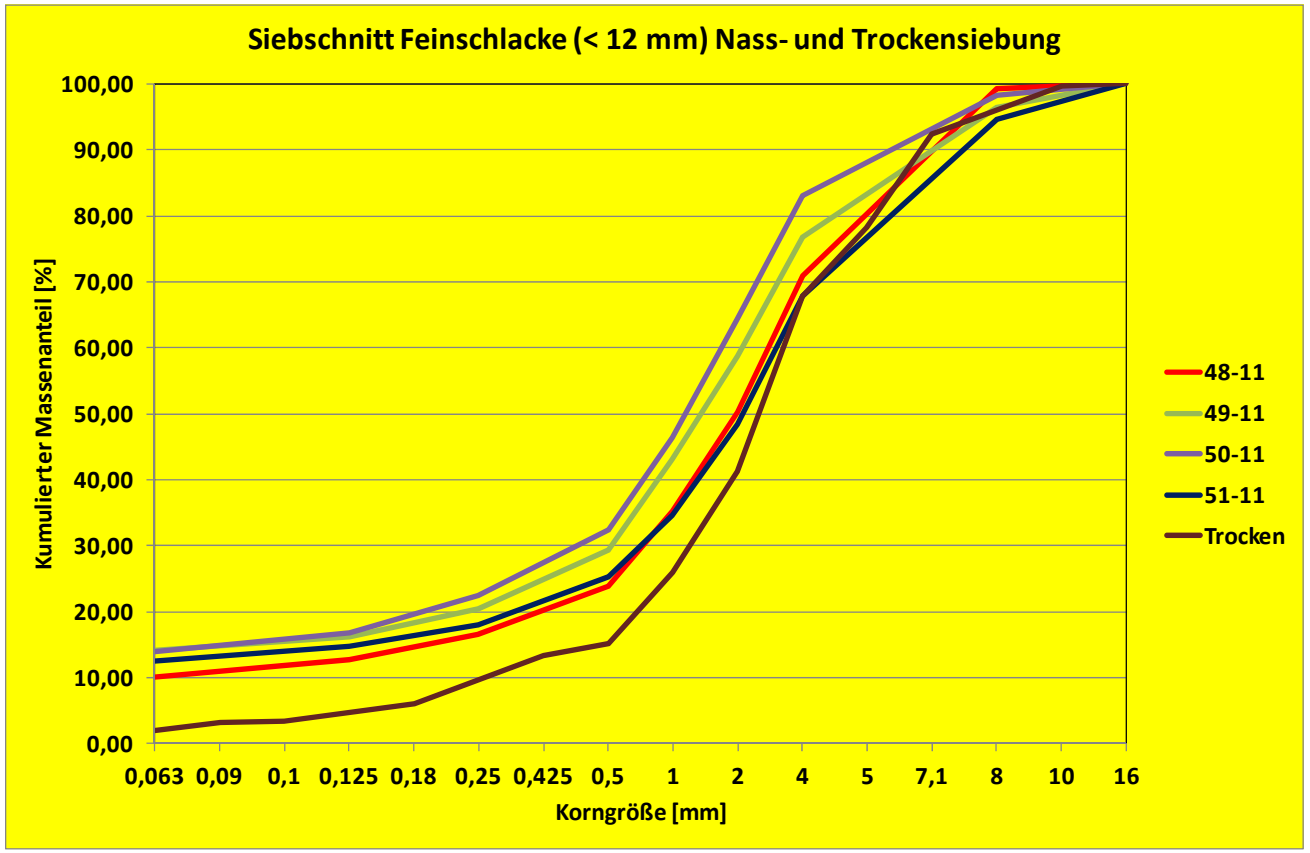
Deike, R. : 51st International Foundry conference, Portorož, 15.09.2011

World production of rare earths and the development of prices for lanthanum and cerium in 2011



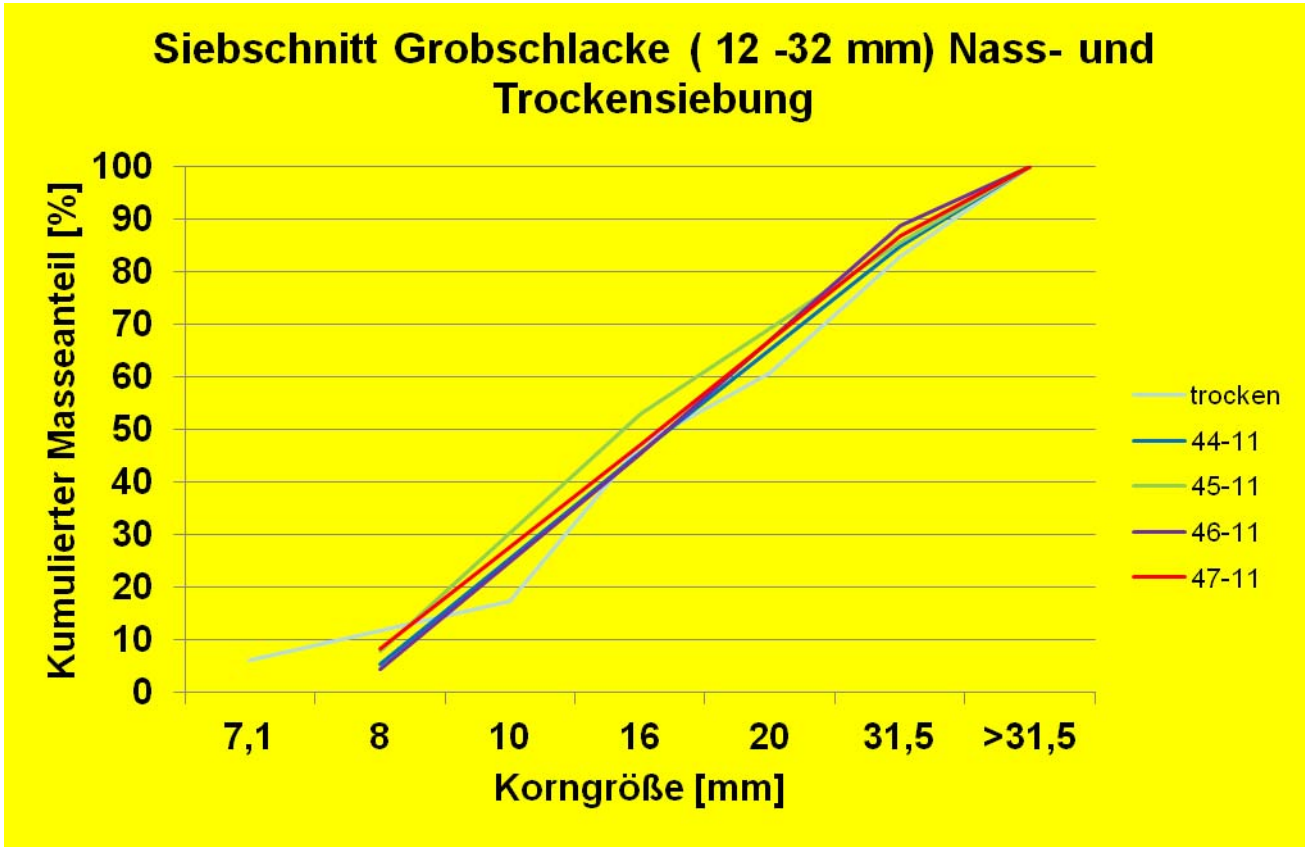
Data of United States Geological Survey, www.usgs.gov; British Geological Survey, www.bgs.ac.uk

Grain size distribution curves of prepared fine bottom ash (< 12mm) under wet and dry sieving conditions



Deike, R., Ebert, D.: VGB Workshop Produkte aus der thermischen Abfallverwertung, Bleicherode, 18.04.2012

Grain size distribution curves of prepared coarse bottom ash (12-32 mm) under wet and dry sieving conditions



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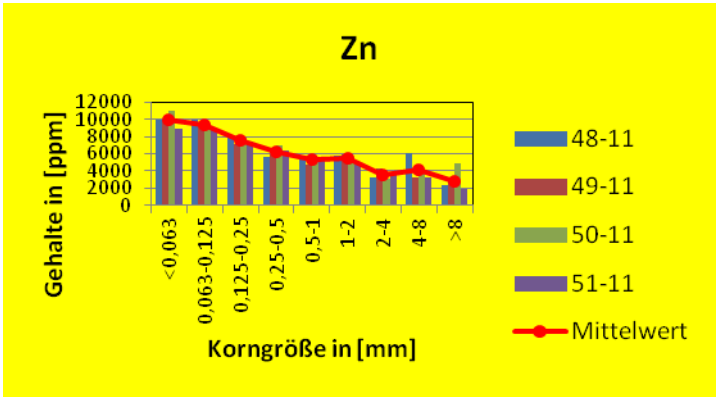
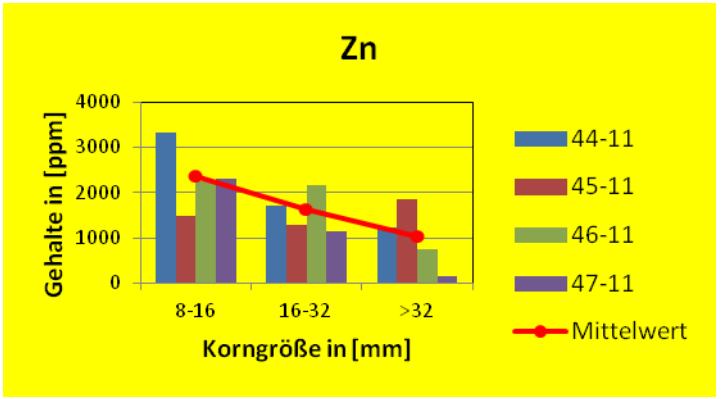
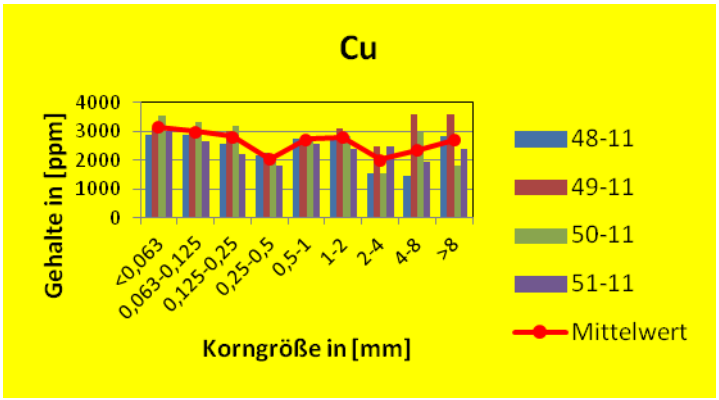
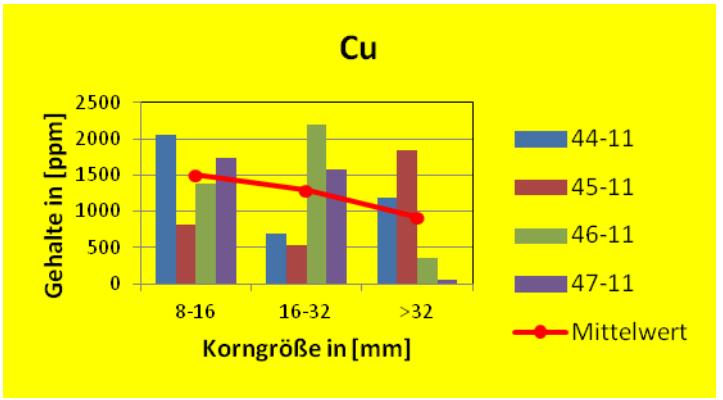
Zn and Cu contents in dependence on the grain size









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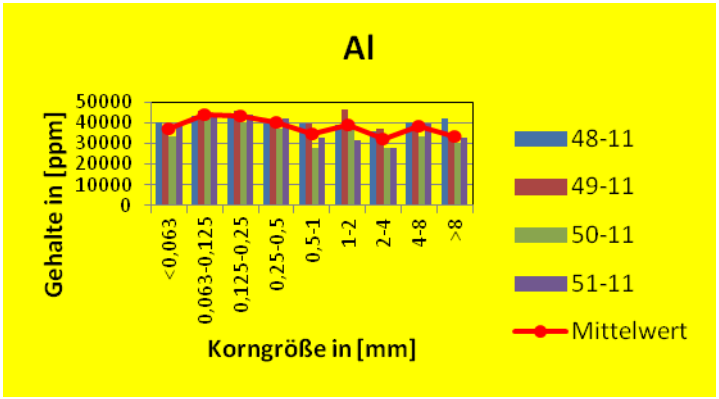
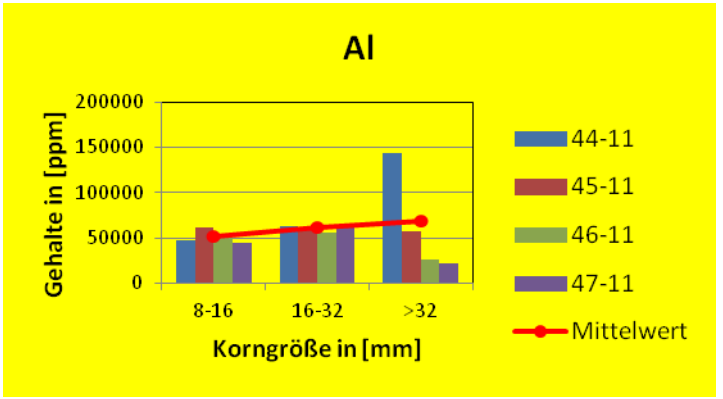
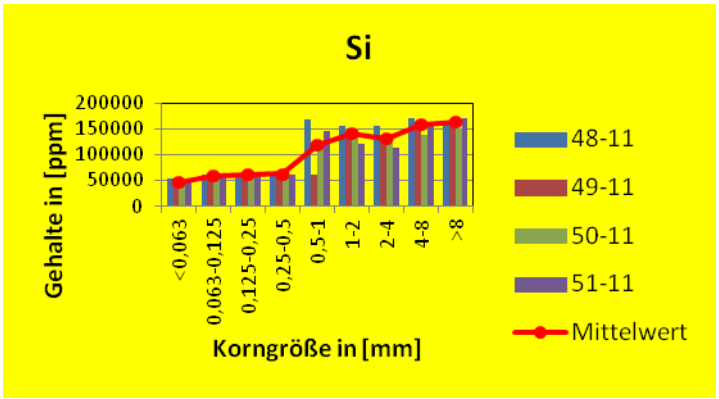
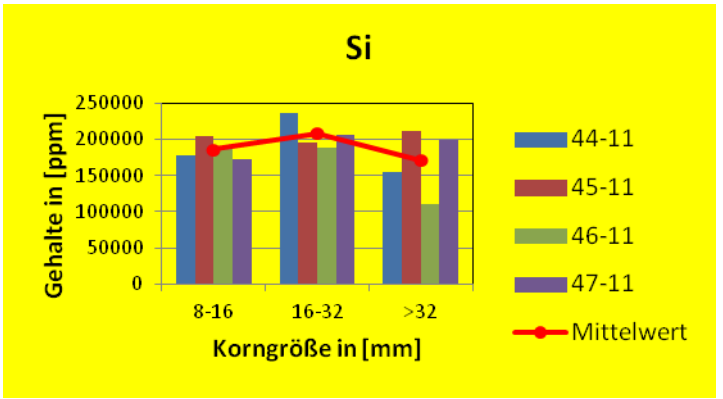
Al and Si contents in dependence on the grain size









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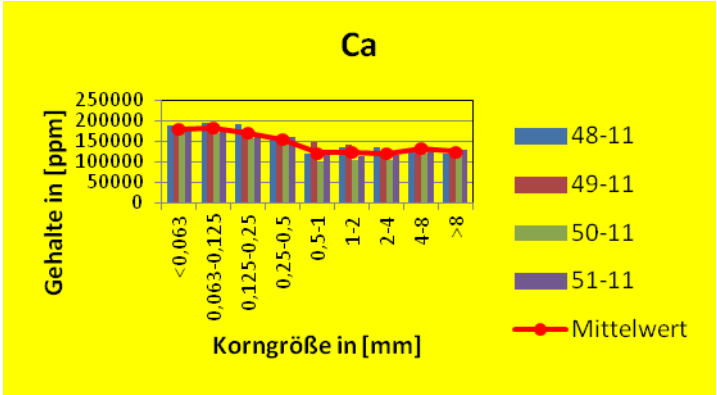
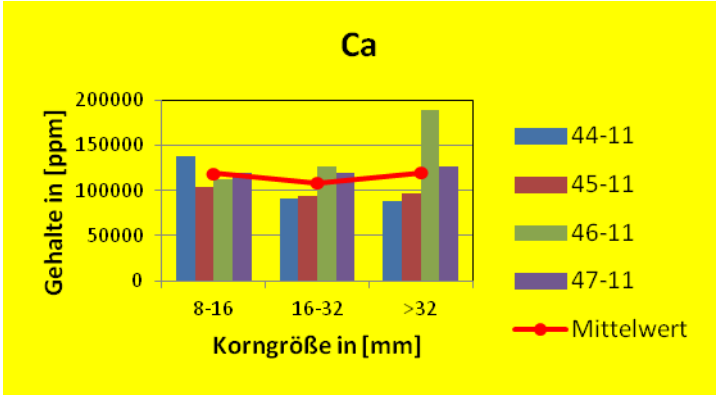
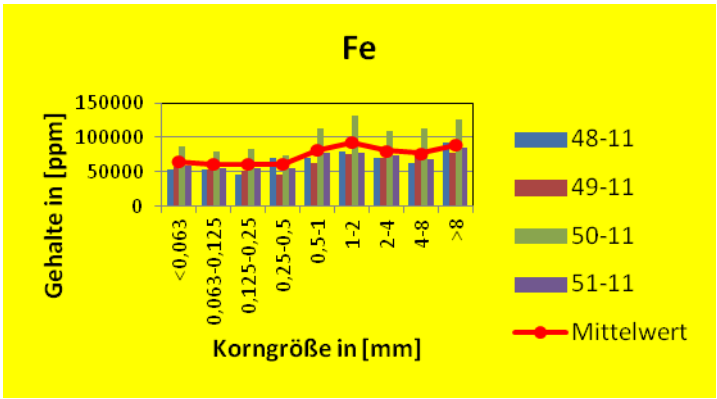
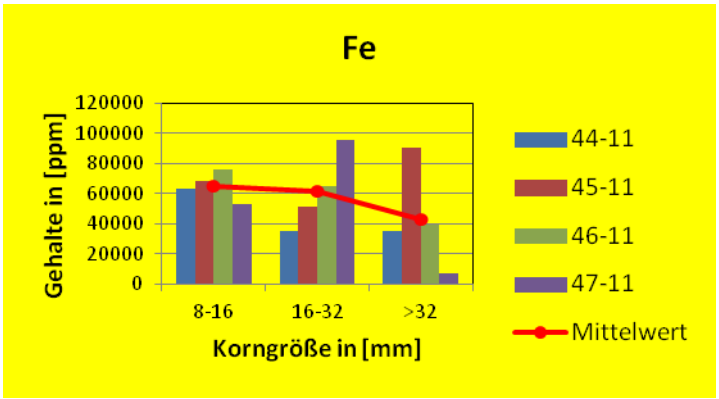
Ca and Fe contents in dependence on the grain size



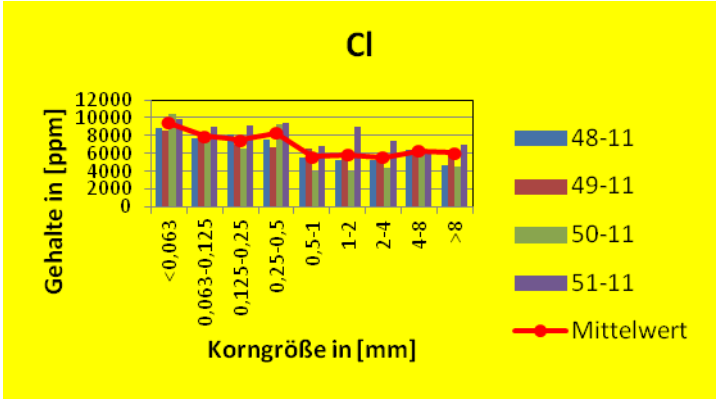


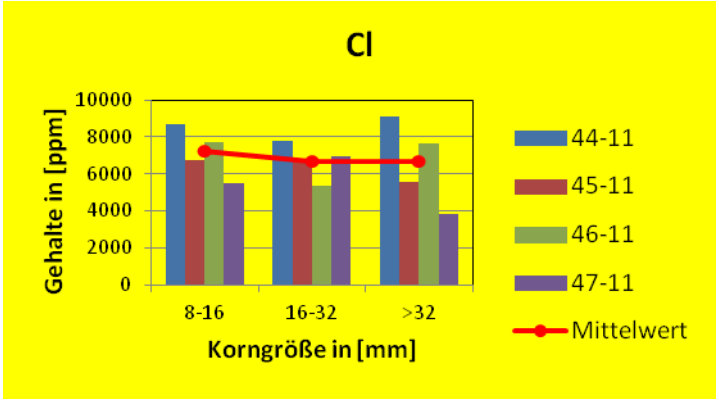


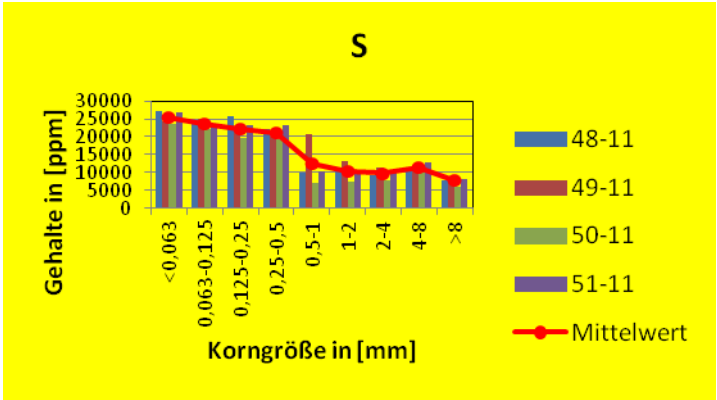


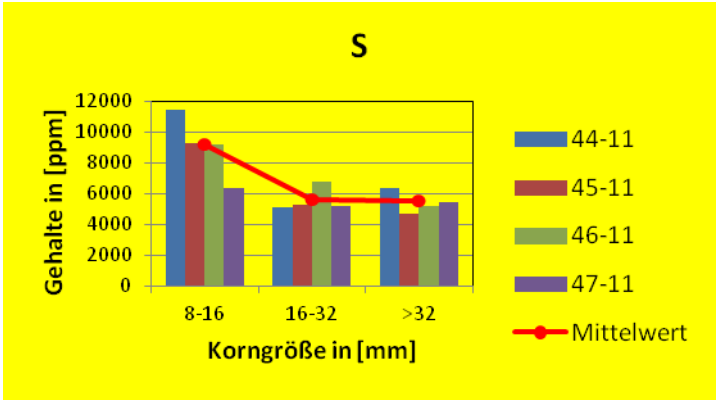
Deike, R., Ebert, D.: VGB Workshop Produkte aus der thermischen Abfallverwertung, Bleicherode, 18.04.2012

Cl and S contents in dependence on the grain size









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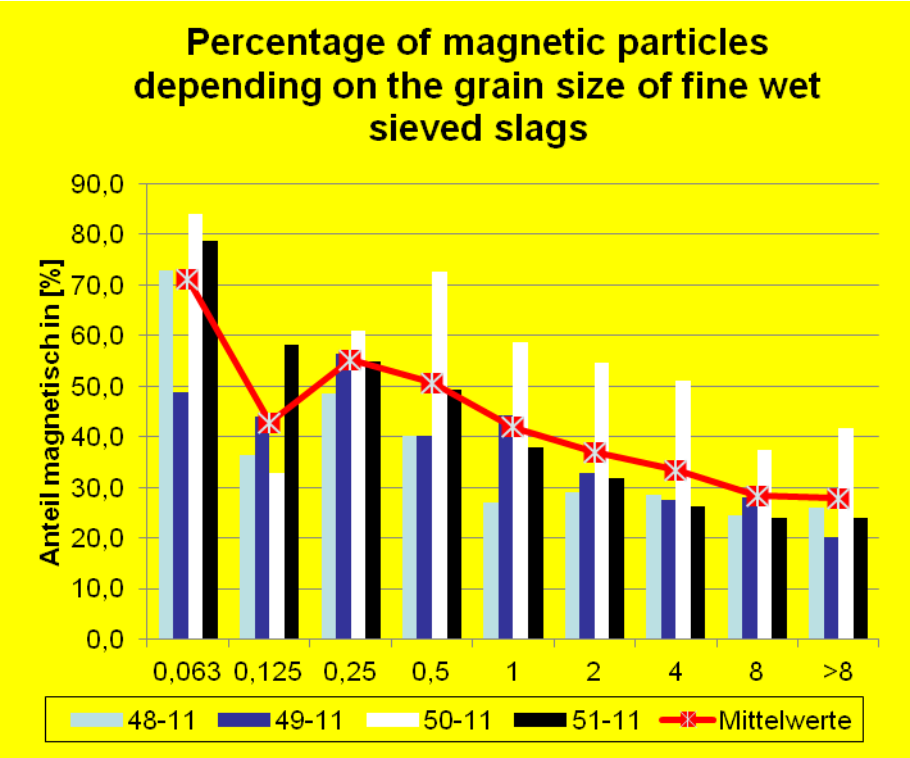
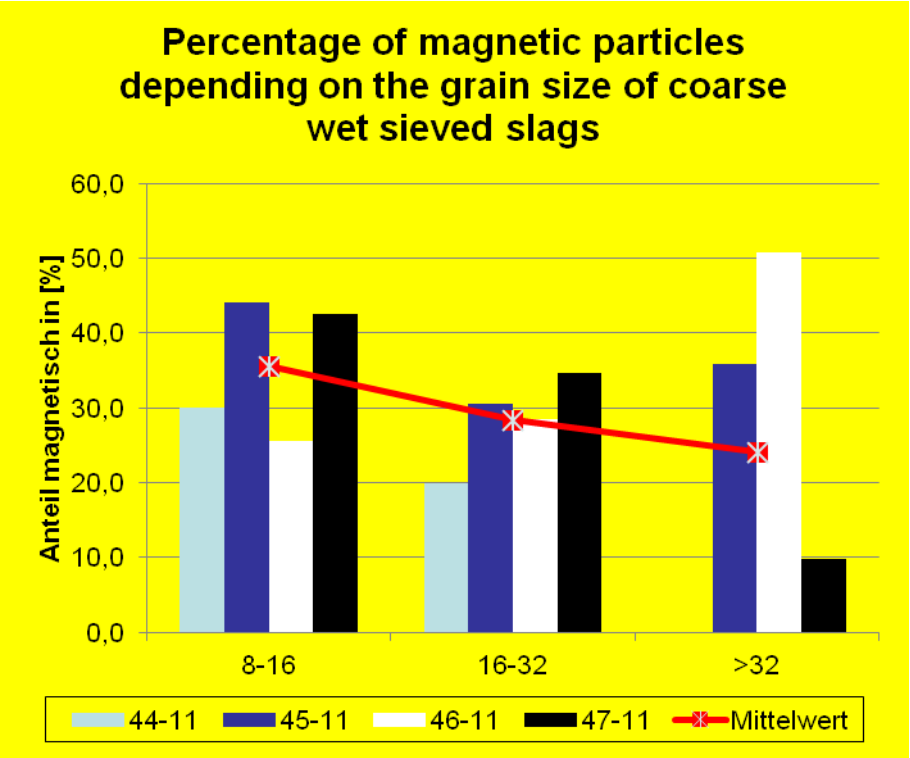
Percentage of magnetic compounds in the various grain fractions of prepared bottom ash





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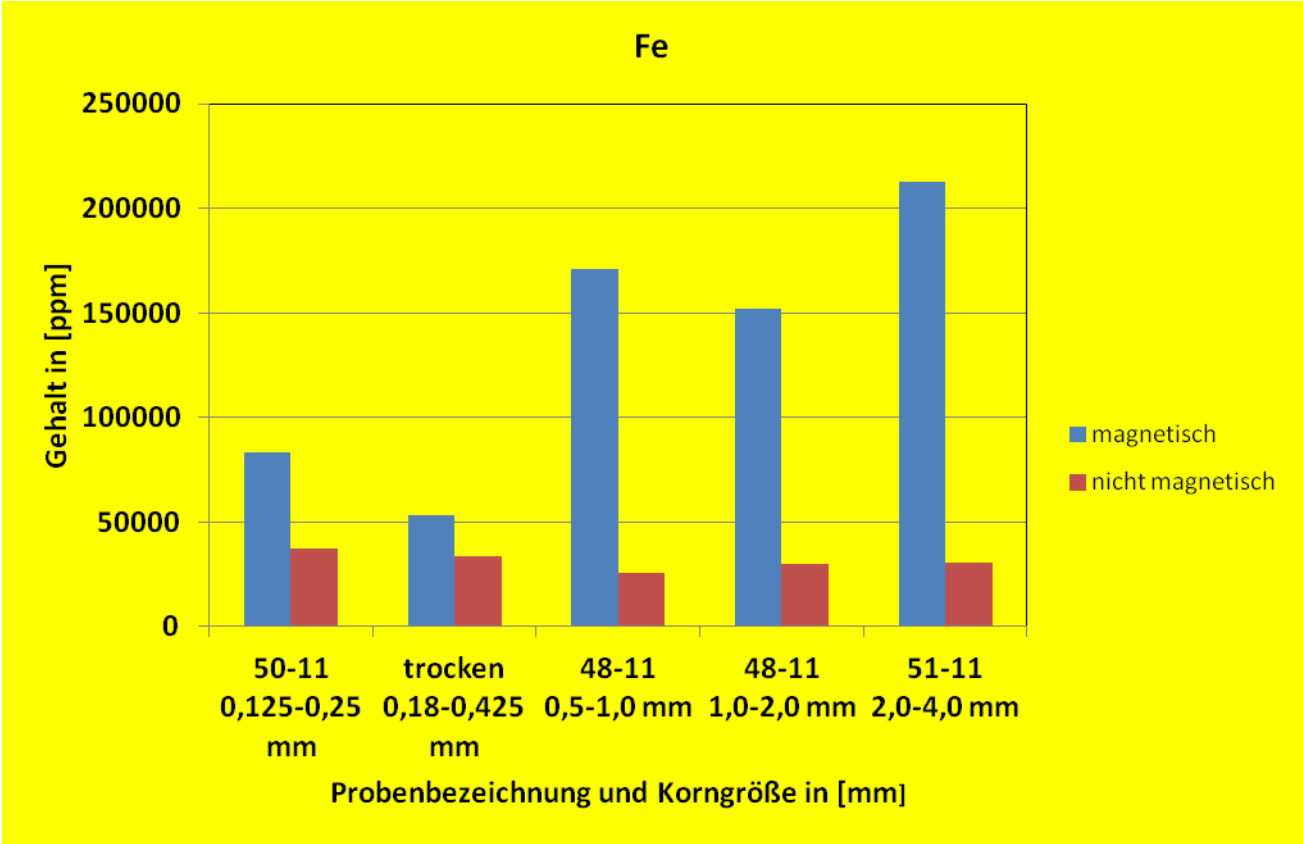
The iron content in the separated magnetic and nonmagnetic parts of fine bottom ash



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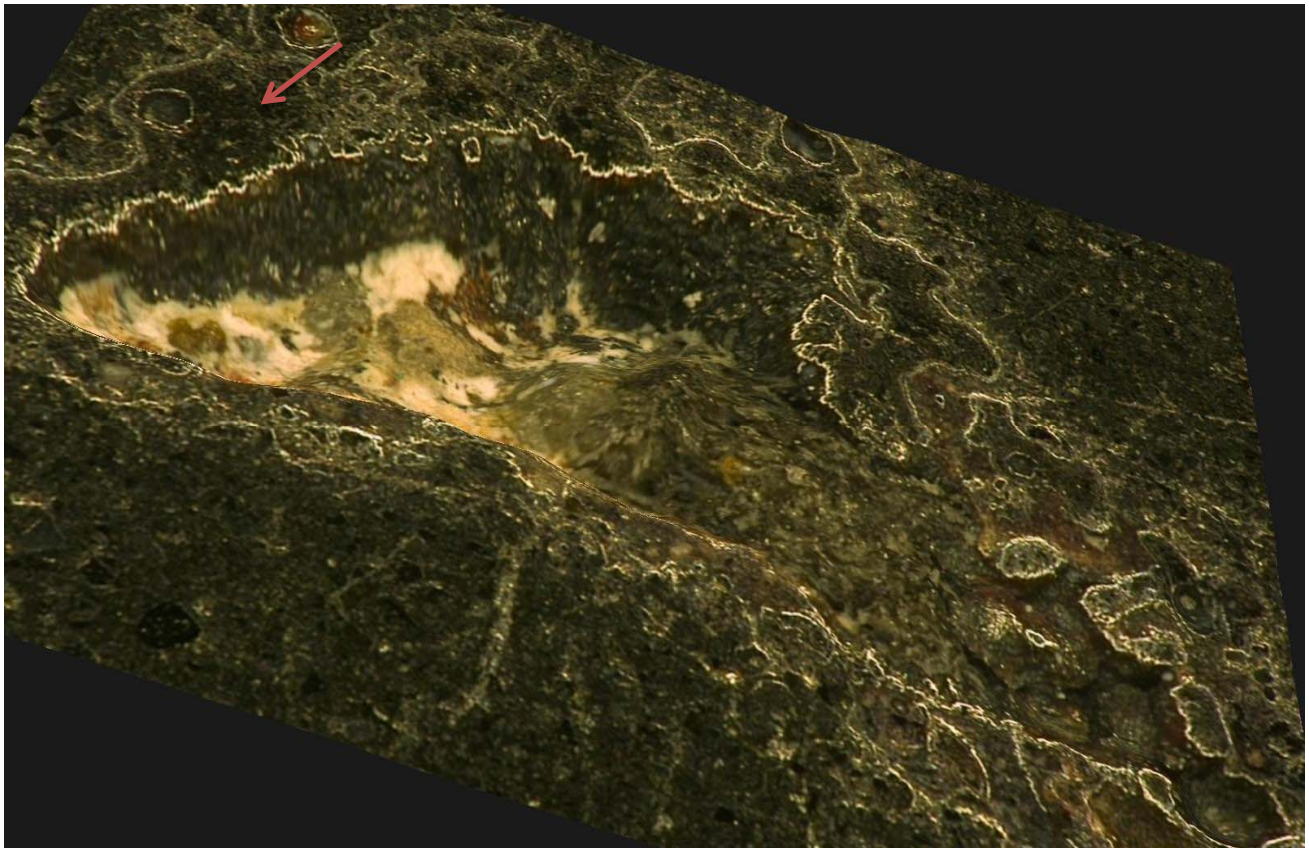
Macroscopic 3D image of bottom ash particles surrounded by a magnetite layer



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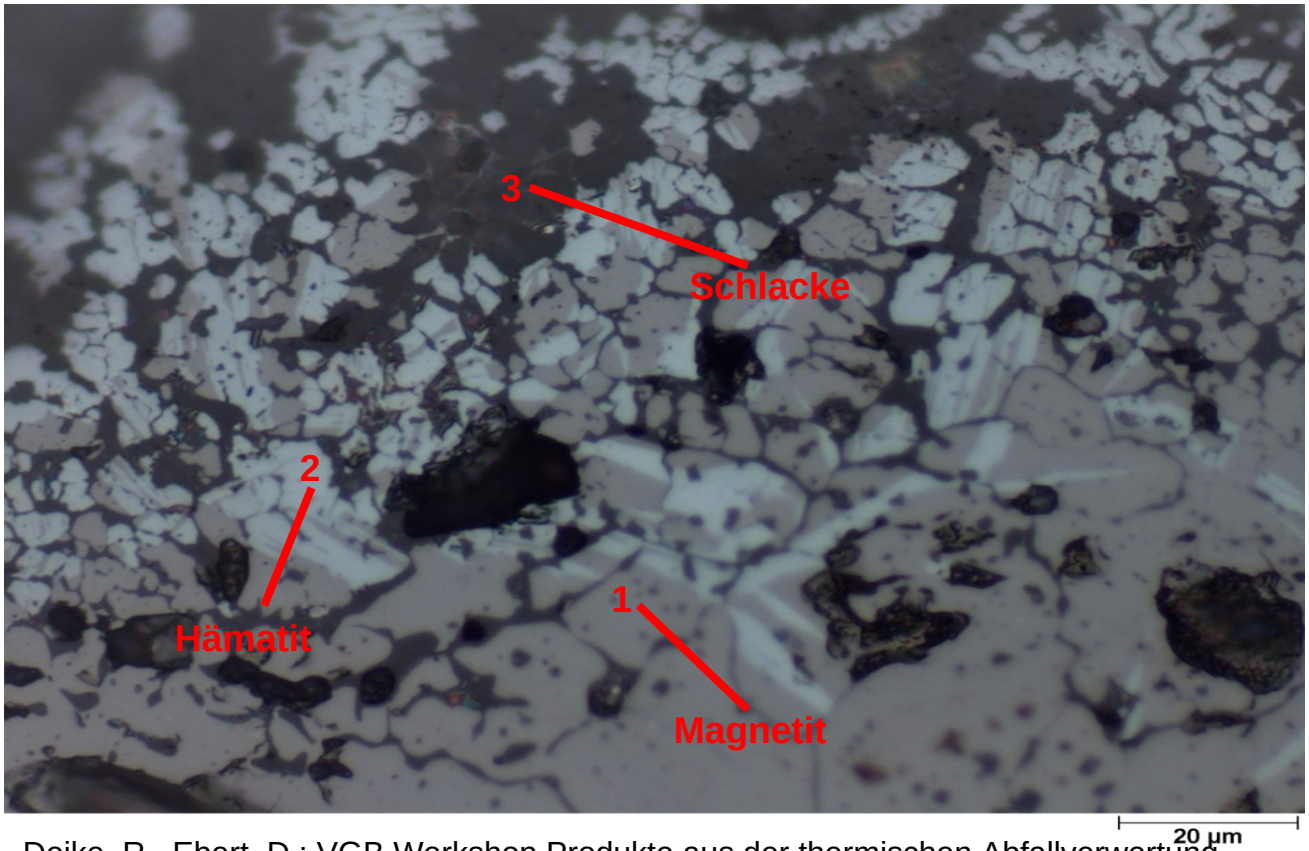
Metallographic analysis of magnetite, hematite and slag in the iron oxide layer in the surrounding of the bottom ash particles



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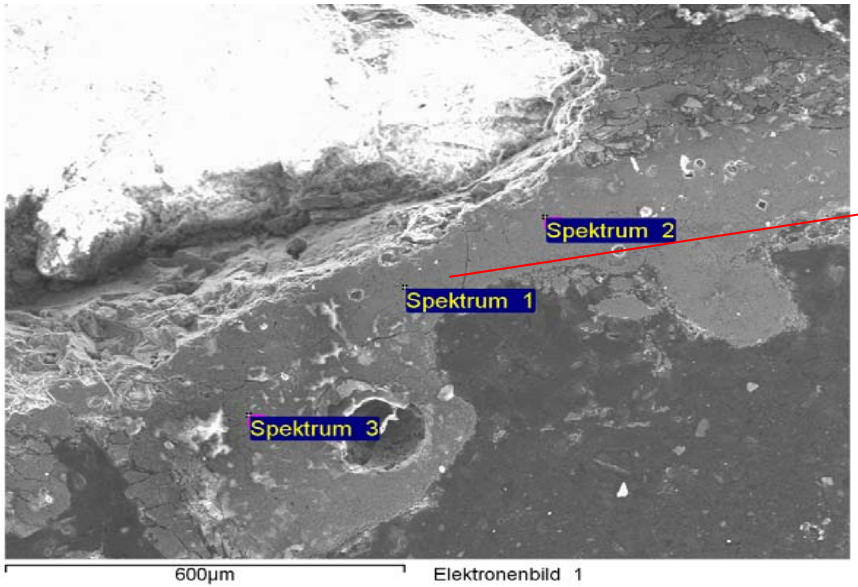
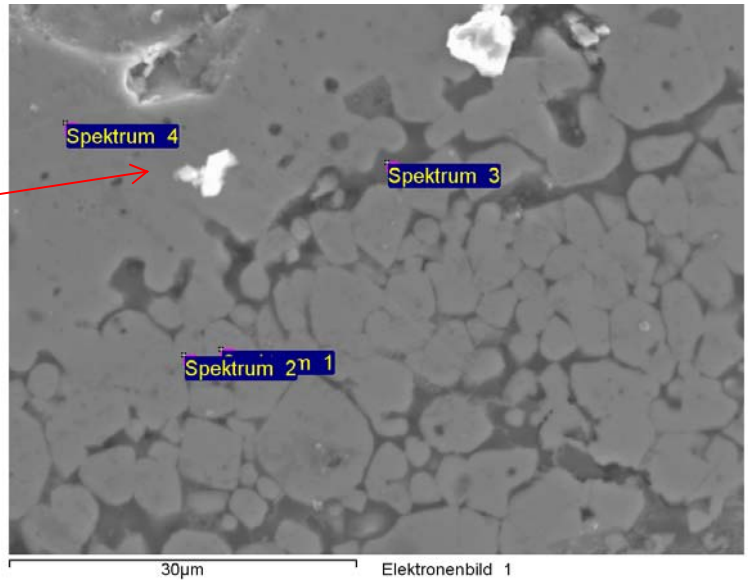
SEM image and EDX analysis of the oxide layer





Spektrum	C	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Ba
Spektrum 1	8	35	0,5		4,2	9,7	0,3	0,4	0,3	0,5	7,4		0,6	30,8	2,4
Spektrum 2	2,6	35,4		0,4	1,3	7,1					4,8	0,2		48,1	
Spektrum 3	8,8	34,3		0,3	1,3	6,1					4,5			44,8	

Spektrum	C	O	Mg	Al	Si	Ca	Mn	Fe	Ba
Spektrum 1	3	31,1		0,3				66	
Spektrum 2	2,9	31,5				0,3		65	
Spektrum 3	3,1	34,6	0,6	0,4	18	14	0,5	28	1,2
Spektrum 4	**2,7**	**30,9**		**0,3**				**66**	

Deike, R., Ebert, D.: VGB Workshop Produkte aus der thermischen Abfallverwertung, Bleicherode, 18.04.2012

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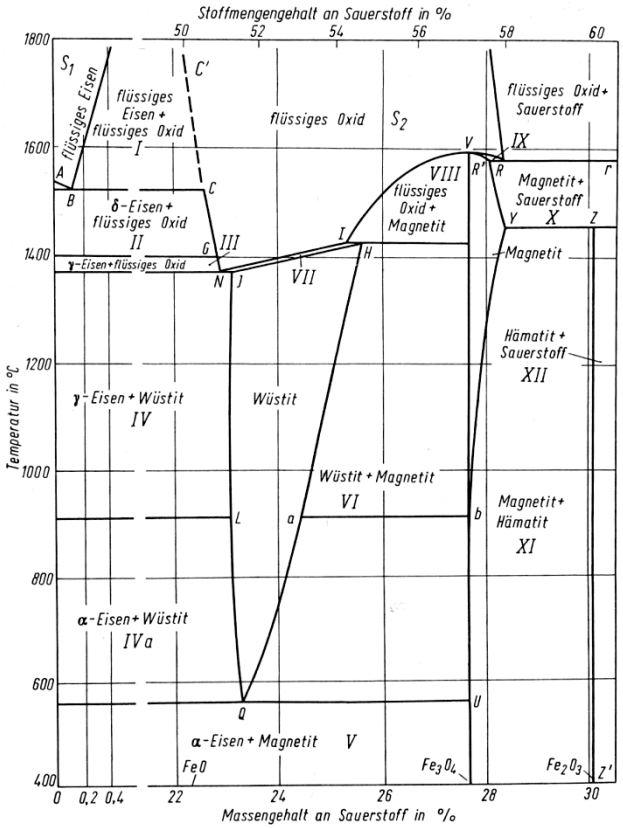
Iron-oxygen phase diagram



Oeters, F. : Metallurgie der Stahlherstellung, Verlag Stahleisen, Düsseldorf 1989

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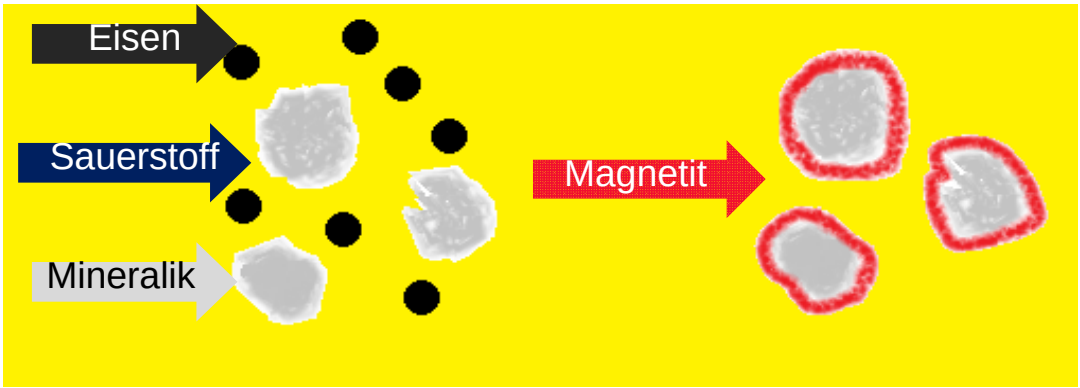
First hypothesis to explain the mechanism of magnetite formation. Nice but not correct !



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Experimental procedure to prove the mechanism of magnetite layer growth

Experiments to produce magnetite layers in bottom ash

- Parameter:
- Heating rate: 5 K/s
- Holding time: 0 min
- Final temperature:
  - Experiment 1: 850 °C
  - Experiment 2: 1000°C

- Amount of bottom ash and iron chips:
  - 1. Experiment: 50g non magnetic fine bottom ash (1-2mm) + 10g iron chips
  - 2. Experiment: 50g fine non magnetic bottom ash (1-2mm) + 10g iron chips

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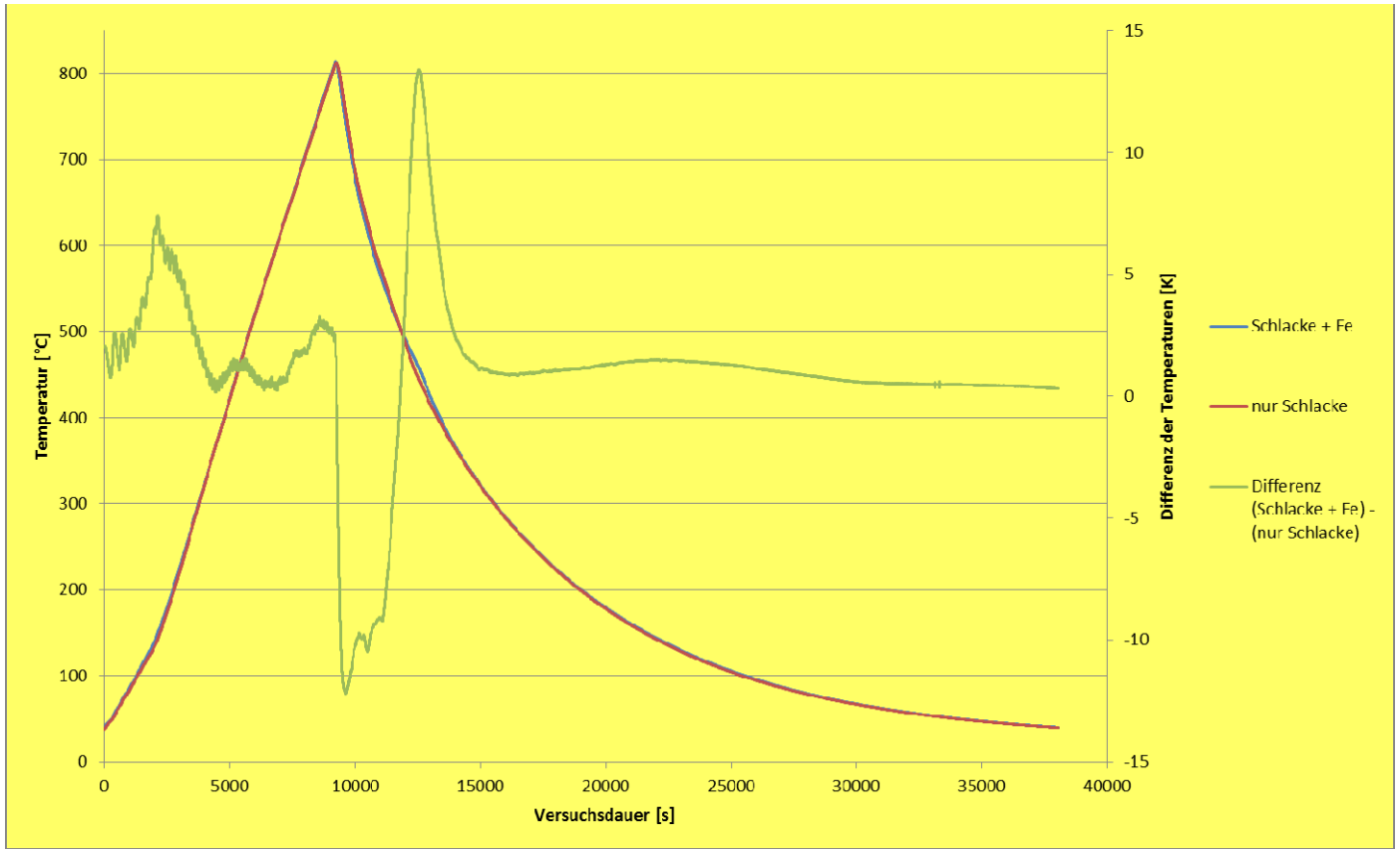
Heating process (temperature vs. time) and temperature difference between bottom ash samples with and without iron.



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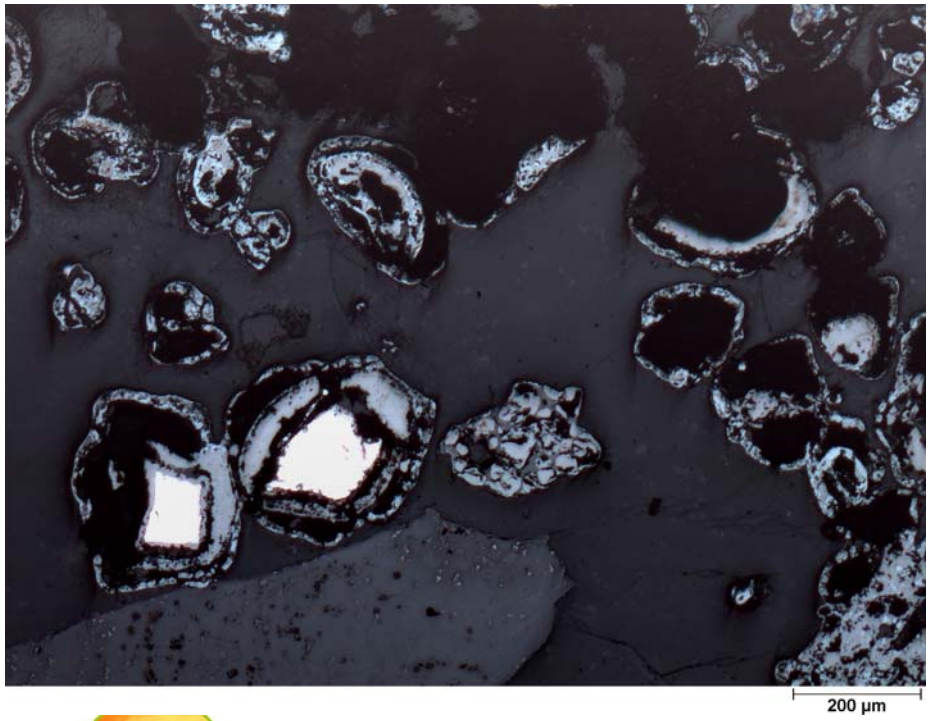
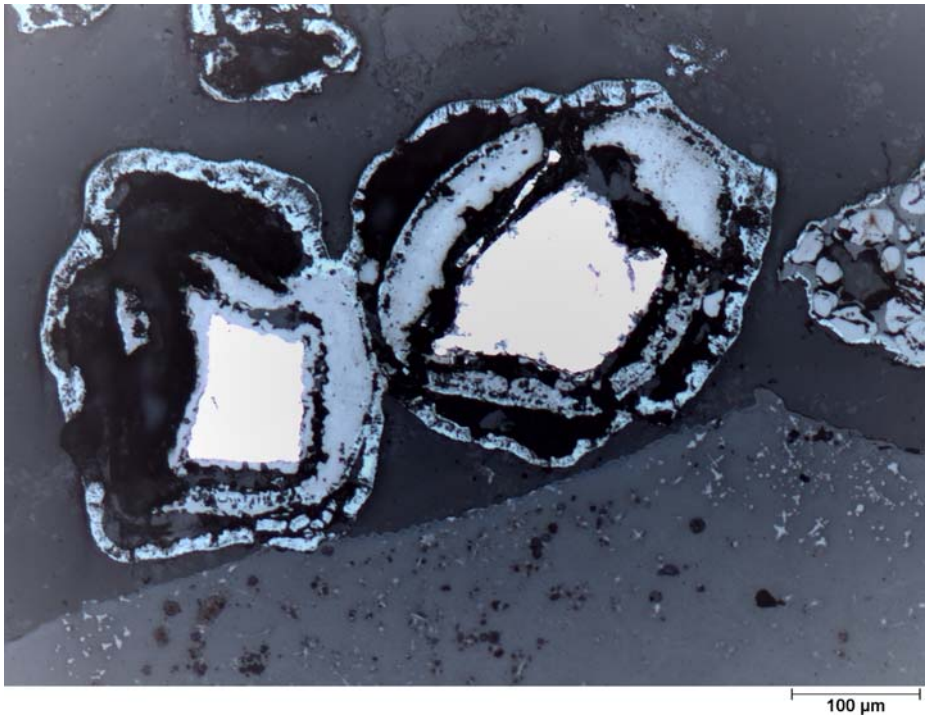
The formation of iron oxide layers at 850°C maximum temperature





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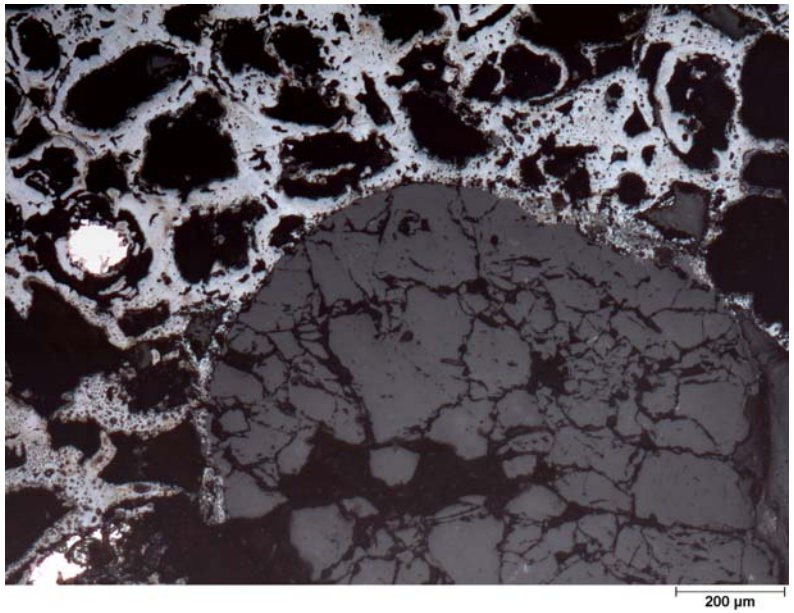
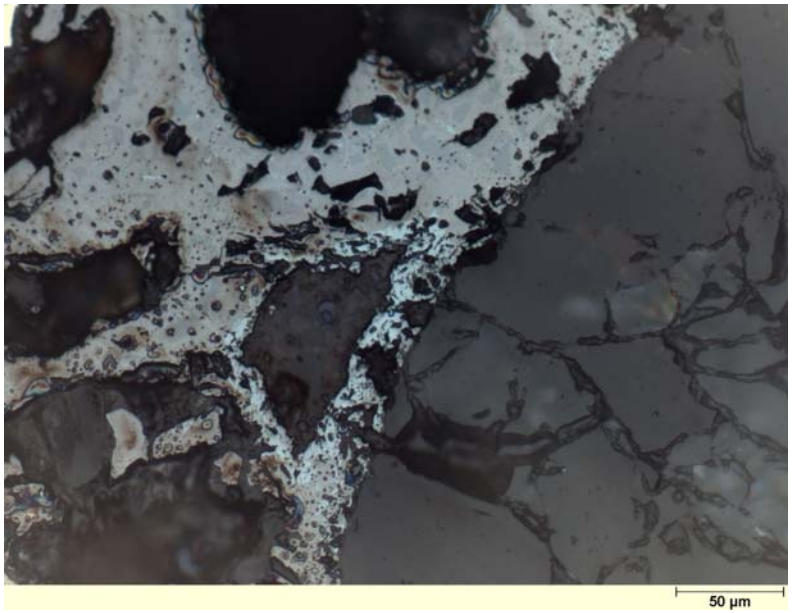
Sintering of iron oxides particles and reacting with bottom ash particles at 1000°C





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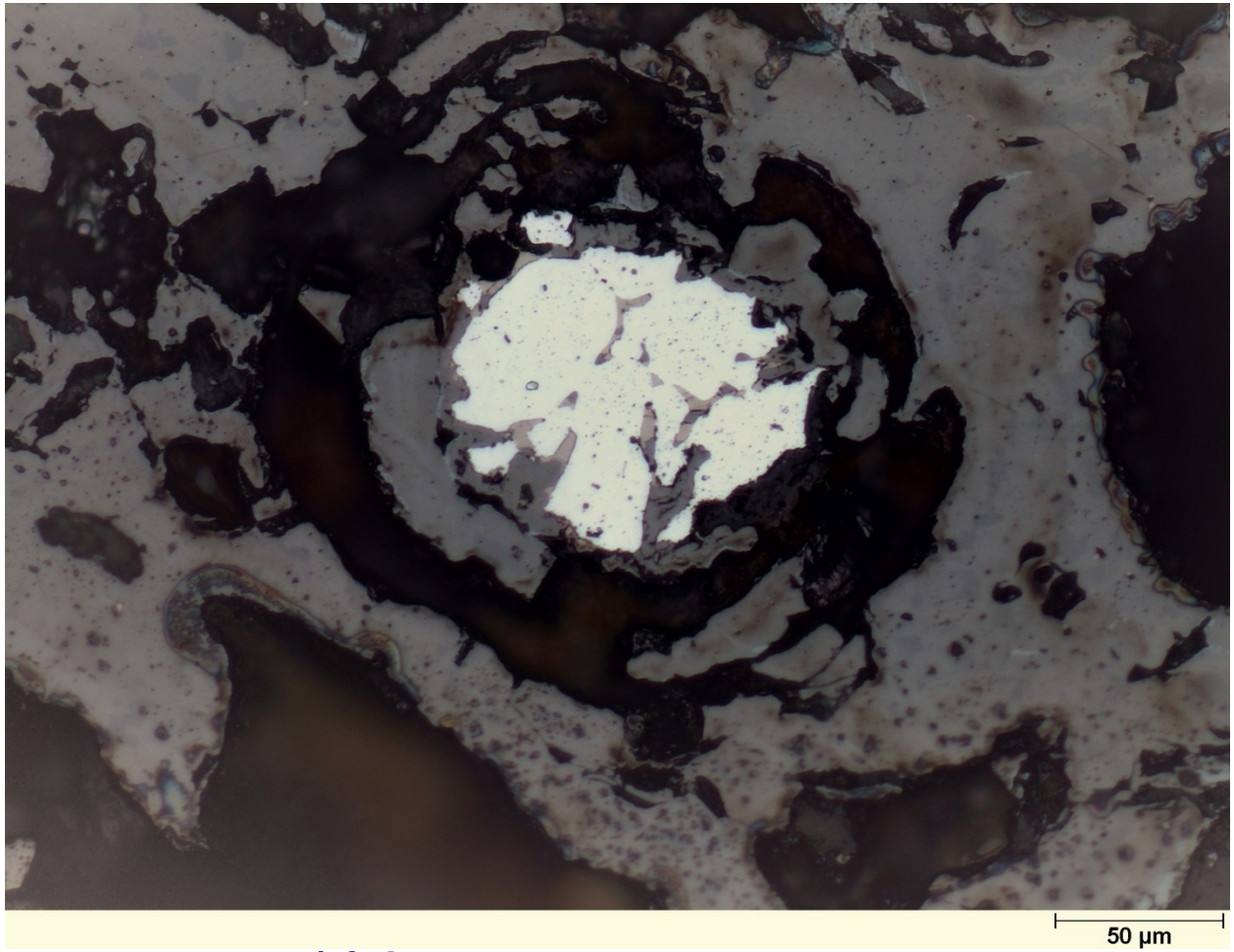
The continous oxidation process of iron at 1000 °C



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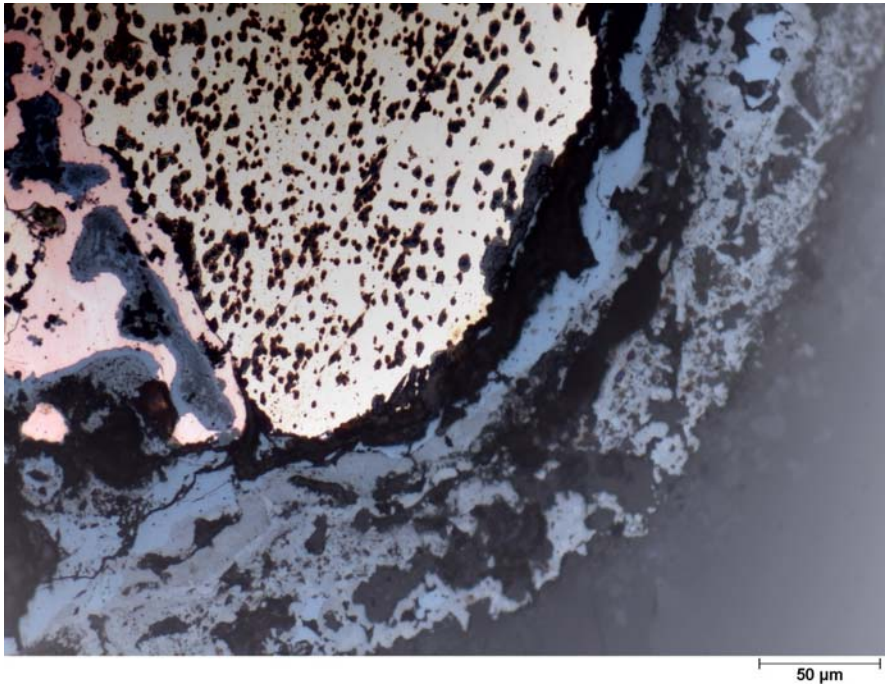
The oxidation of copper rich alloys as constituents of bottom ash



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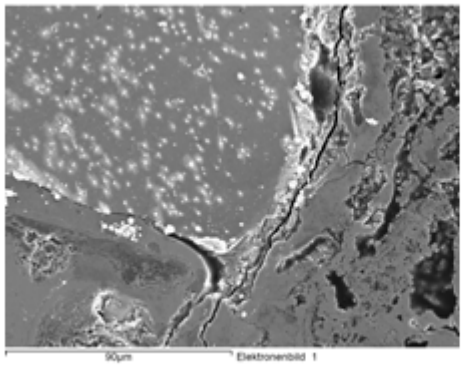
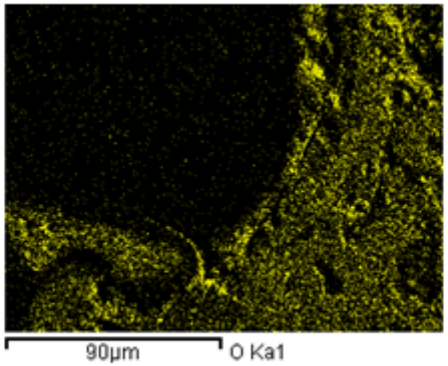
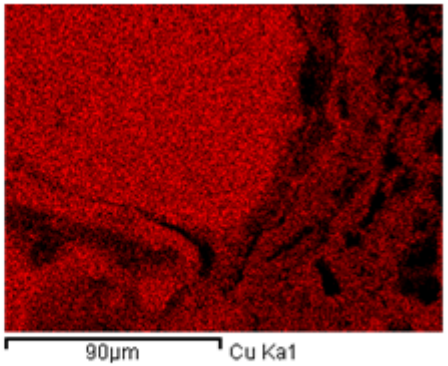
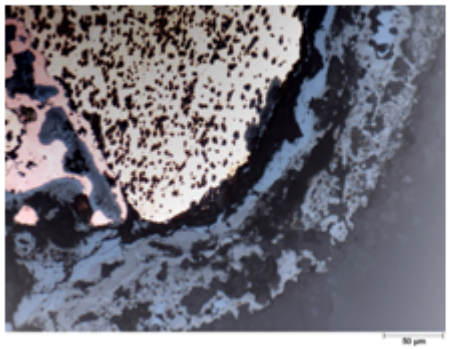
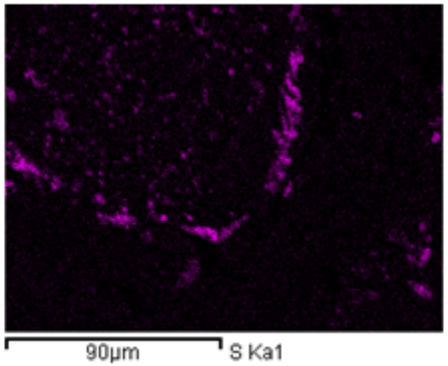
EDX element mapping of the oxidised copper particle and the adherent oxide layer

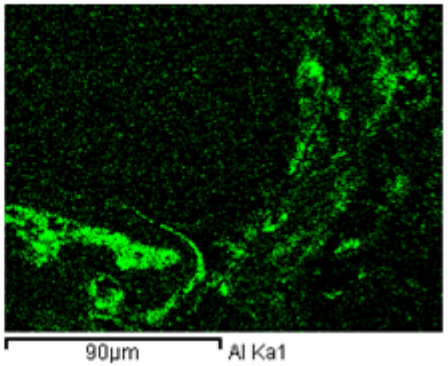












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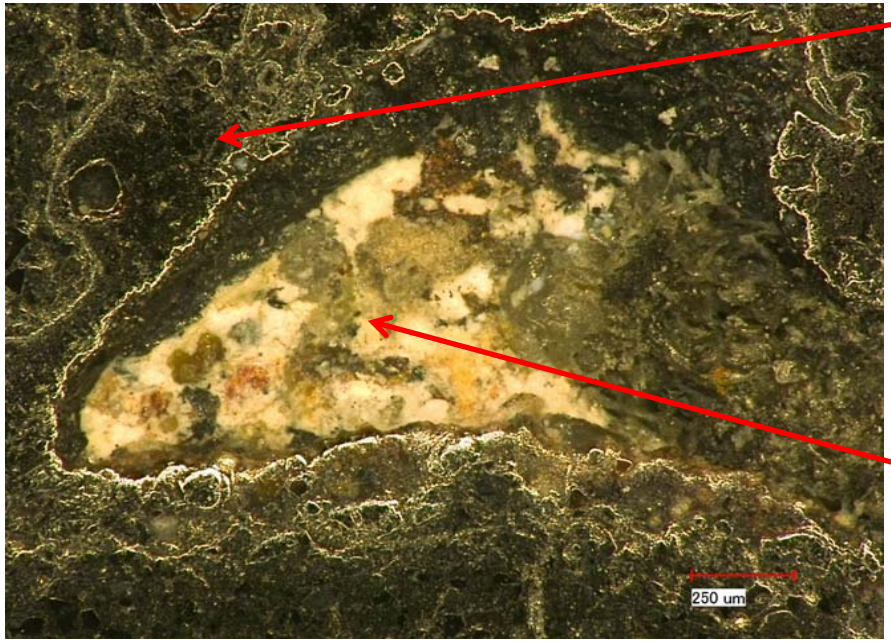
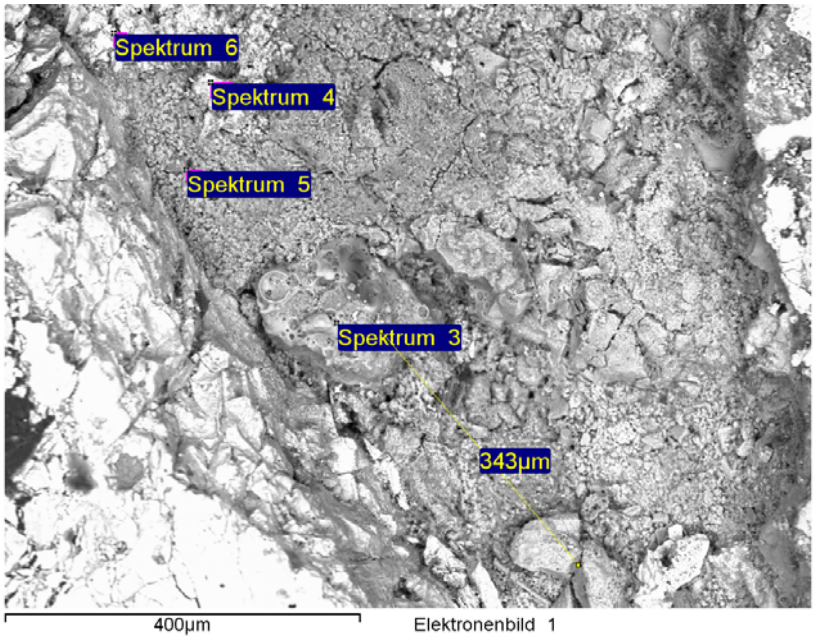
Second hypothesis to explain the mechanism of magnetite formation.



1. The oxide shell is the result of the oxidation of an iron particle.
2. The oxidation stopped when the total iron has been consumed.
3. That seems the main reason for the hole but some breakout during the preparation of the sample is also possible.
4. The bottom ash particles at the ground were at the beginning beneath the iron particle, which is now totally oxidised.
5. The oxide layers sinter together even with bottom ash particles.

SEM image and EDX analysis of single dots of the bottom ash particles at the ground



Spektrum	C	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Fe	Cu	Zn	Re
Spektrum 3	9,2	49	1,2	1,3	2,4	11	1,1	3,2	0,7	0,7	16	0,5	0,3	2,19		0,66	0,11
Spektrum 5	5,3	56,1		9,1	3,1	1,1		1,6	2,2	0,2	15	2,8		2	0,7	1,72	-0,33
Spektrum 4	5,6	45,5	1,3	1,2	5,5	14		1,1	0,3	2,3	4,4	0,2		13,7		5,18	
Spektrum 6	4,1	42,6		0,5	3,5	5,1		0,5	0,2	1	2,5			27,4		12,55	

Determination of the metal content in bottom ash by a slag remelting process

Deike, R, Ebert, D., Warnecke, R.; Vogell, M.: 11. VDI Fachkonfererenz Feuerung und Kessel, Bremen, 13.06.2012

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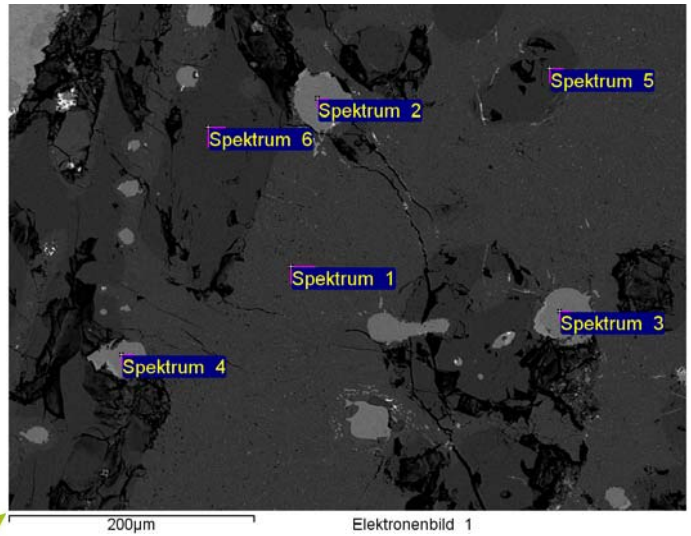
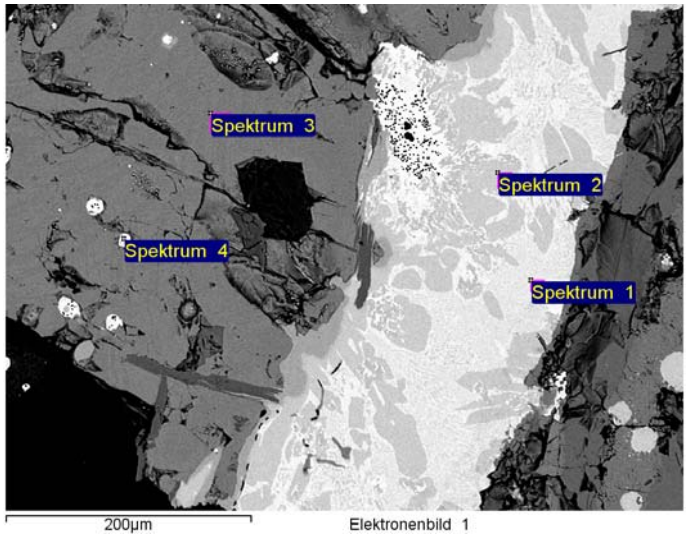
EDX analysis of the metallic fraction after remelting the slag

	C	O	F	P	S	Cr	Fe	Ni	Cu	Sn	Sb
Spek.1	4,68		2,16	10,62	0,4		78,12	0,69	3,32		
Spek 2	3,87						1,8		80,7	10,4	3,2
Spek.3	4,75	3,18					1,34		77,8	9,94	3
Spek.4	2,92						2,04		81,5	10,2	3,4
Spek.5	5,54			21,54	0,32	0,6	72				
Spek. 6	6,32		3,24	20,59		0,74	69,11				

Spektrum	C	O	S	Mn	Fe	Cu	Sn	Sb	Pb
Spek. 1	2,55	1,5				66,8	19,98	9,18	
Spek. 2	3,91					82,03	10,53	3,52	
Spek. 3	6,69		24,09	0,78	10,9	57,54			
Spek. 4	6,58				1,42	72,54	11,15	4,65	3,66





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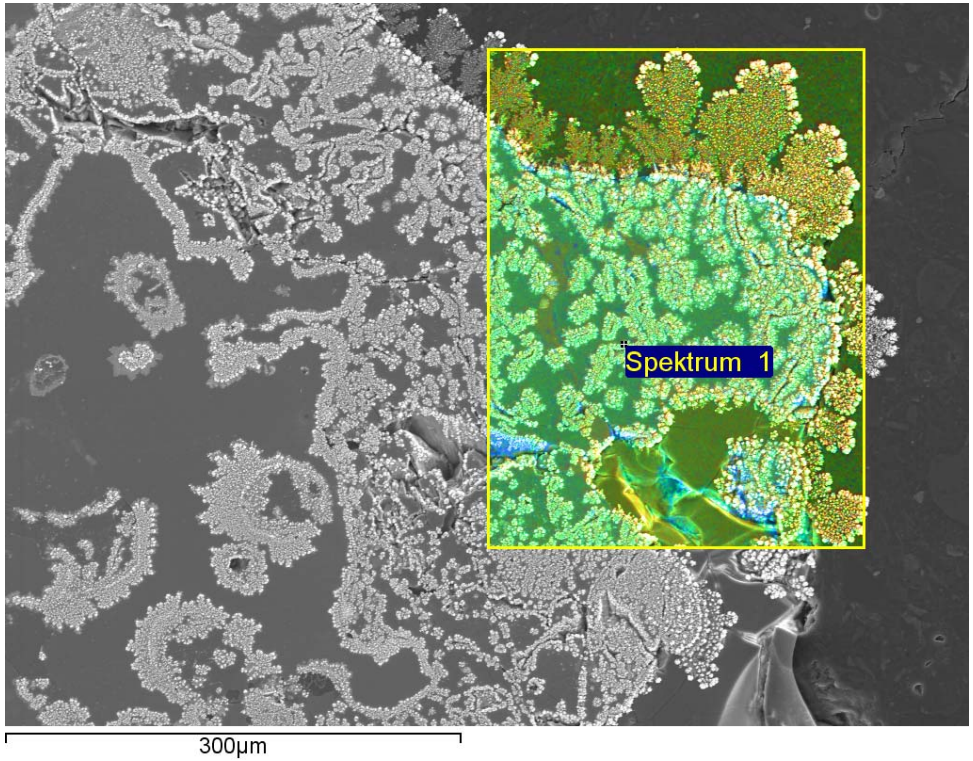
Element mapping of a particle after slag remelting



O	Al	Si	S	Ca	Fe	Cu	Pb
5,8500	0,0200	0,1300	24,2100	0,2700	38,0100	31,2500	0,2600

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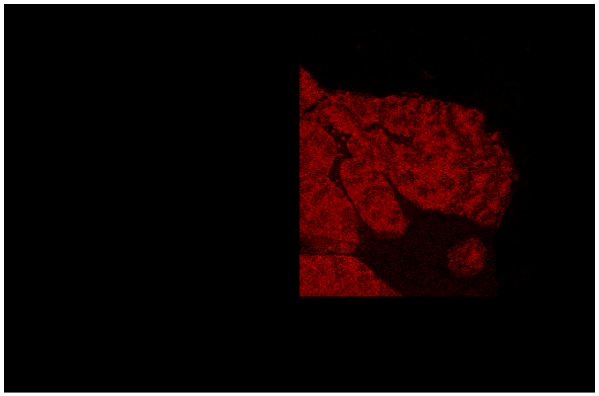
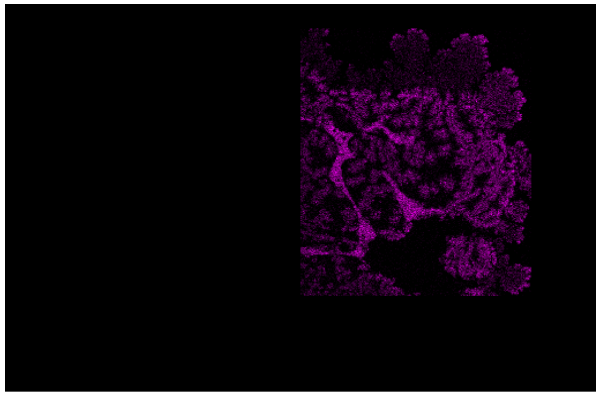
Element mapping of a particle after slag remelting

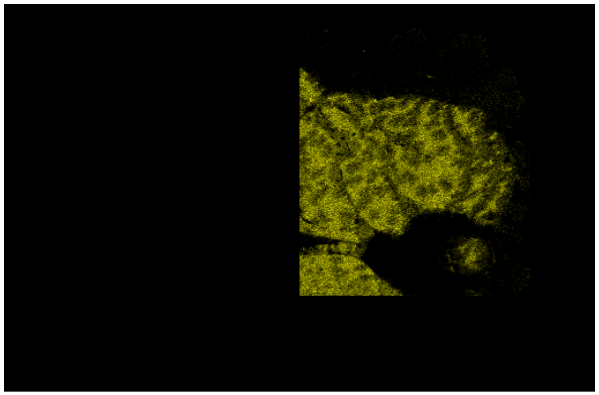
Eisen



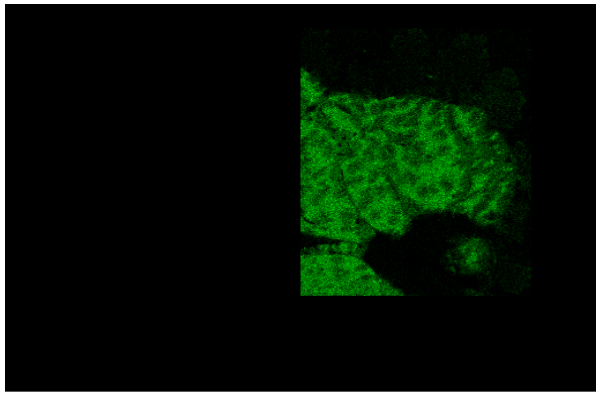
Kupfer



Schwefel

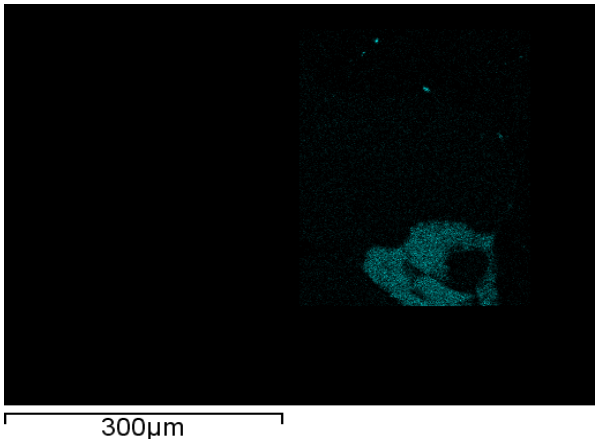


Blei

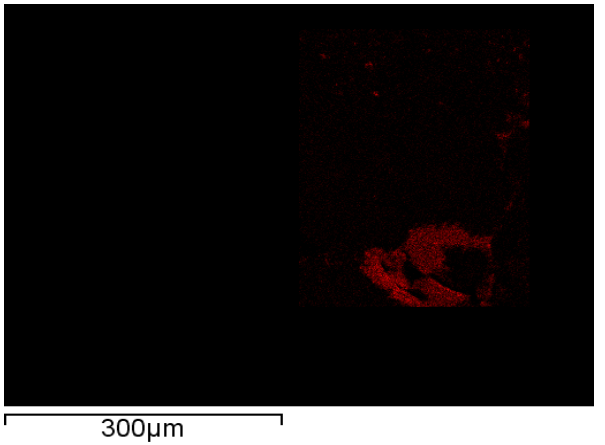


Element mapping of a particle after slag remelting

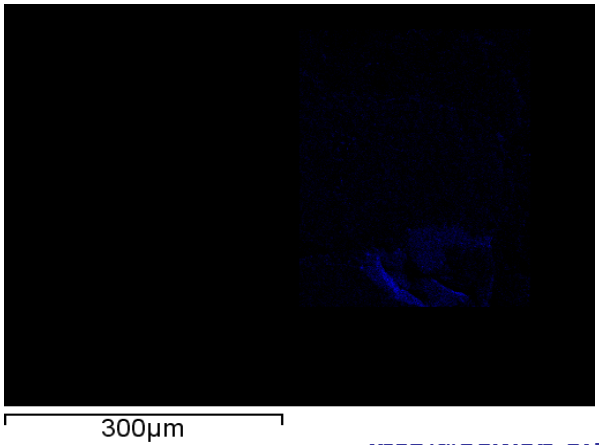
Calcium



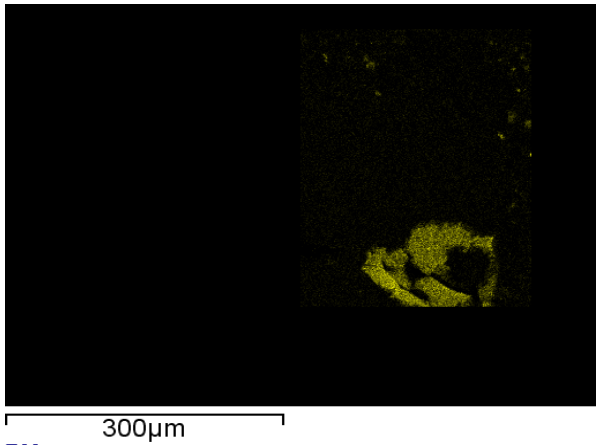
Aluminium



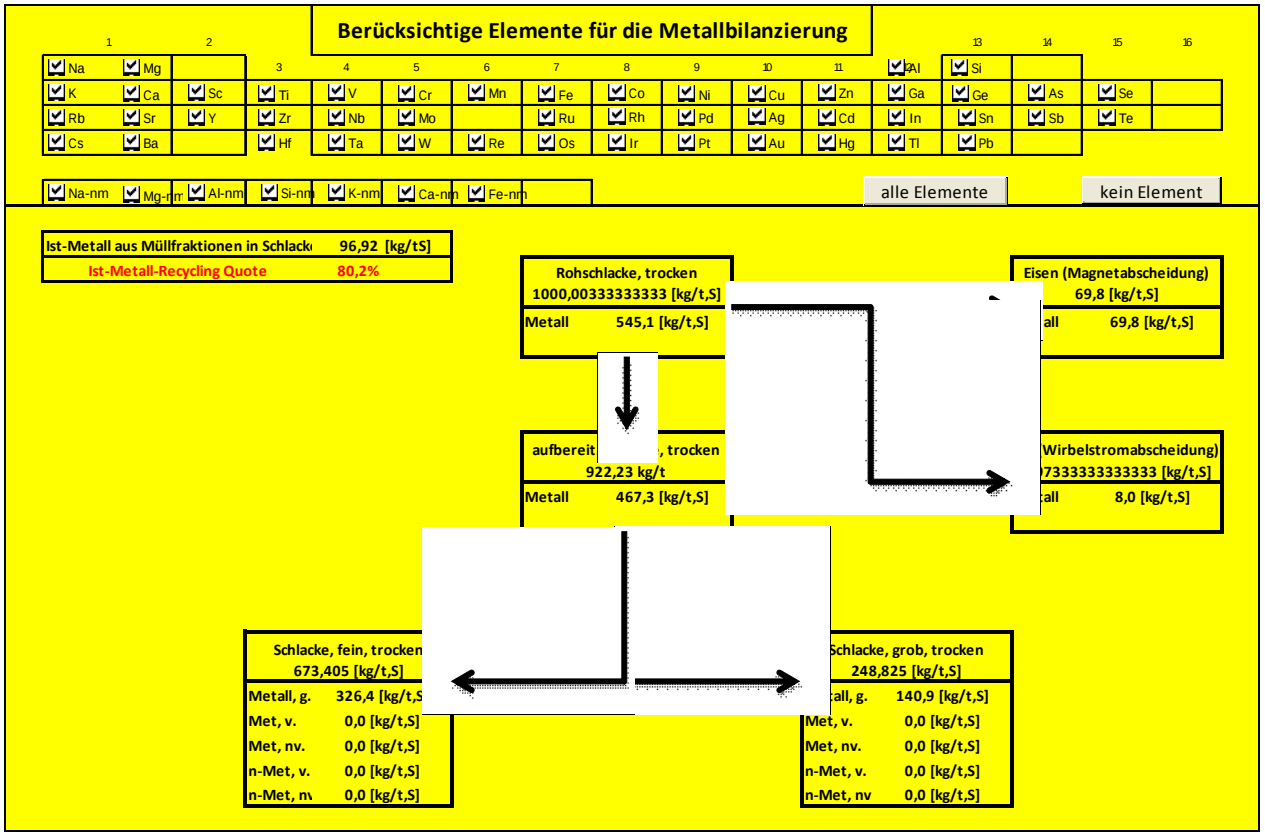
Sauerstoff



Silicium



Metal content of bottom ash, current recycling rate and future recycling potential



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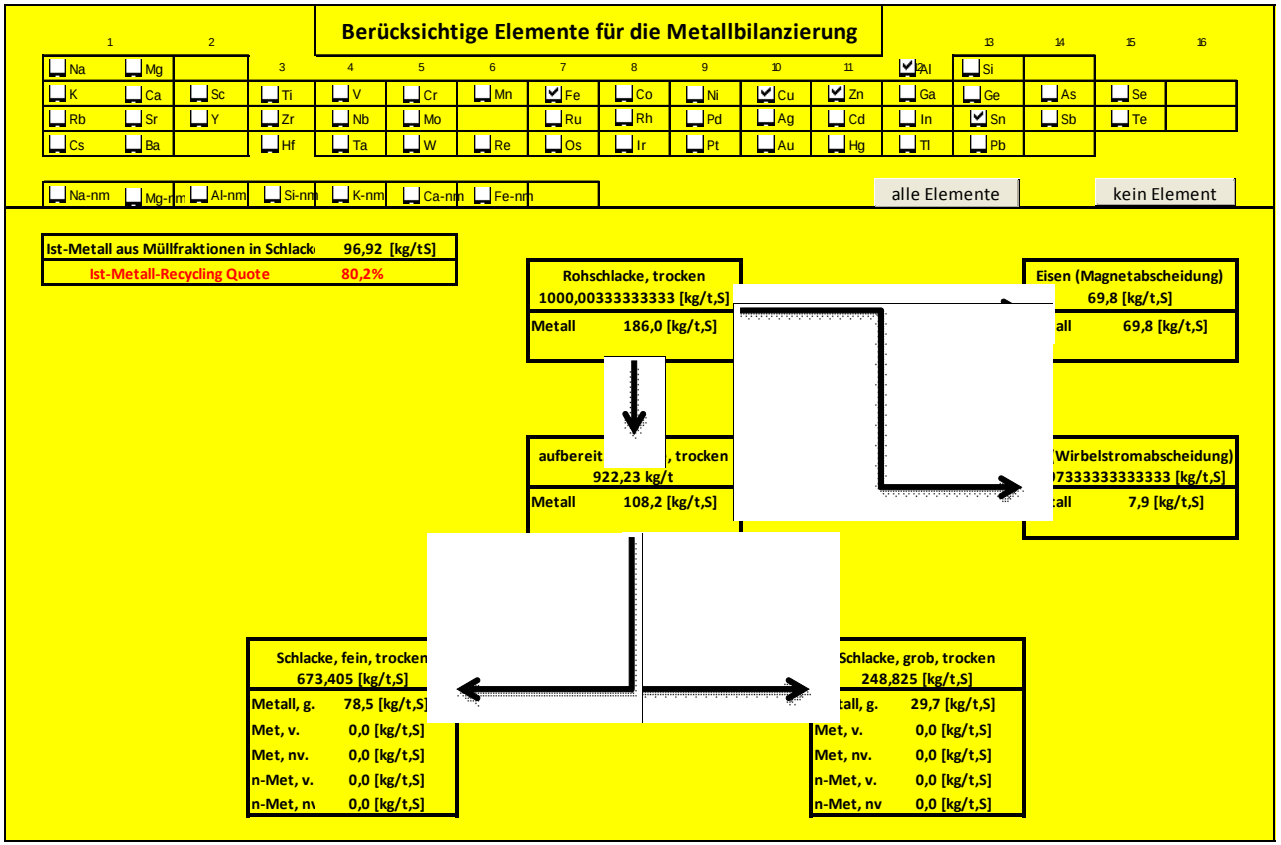
Metal content of bottom ash, current recycling rate and future recycling potential



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Thank for your attention!

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