Fate and behaviour of nanomaterials in incineration processes

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8th CEWEP Waste-to-Energy Congress 2016
16-17 June in Rotterdam

Federal Ministry of Education and Research

NANOEMISSION

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Outline

- Introduction
- Project NanoEmission
- Basic research
- Measurement campaign in WtE plant Weisweiler
  - Methods
  - Results
- Conclusions

Introduction

Definition

Ag

TiO_2

Quantum Dots

CNT

Nanomaterial: „A natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm. …"[1]

CeO_2

$BaSO_4$

ZnO

Source: Recommendation on the definition of a nanomaterial (2011/696/EU), 18.10.2011 (updated on 08.06.2016)
http://ec.europa.eu/environment/chemicals/nanotech/faq/definition_en.htm#top-page

Project NanoEmission

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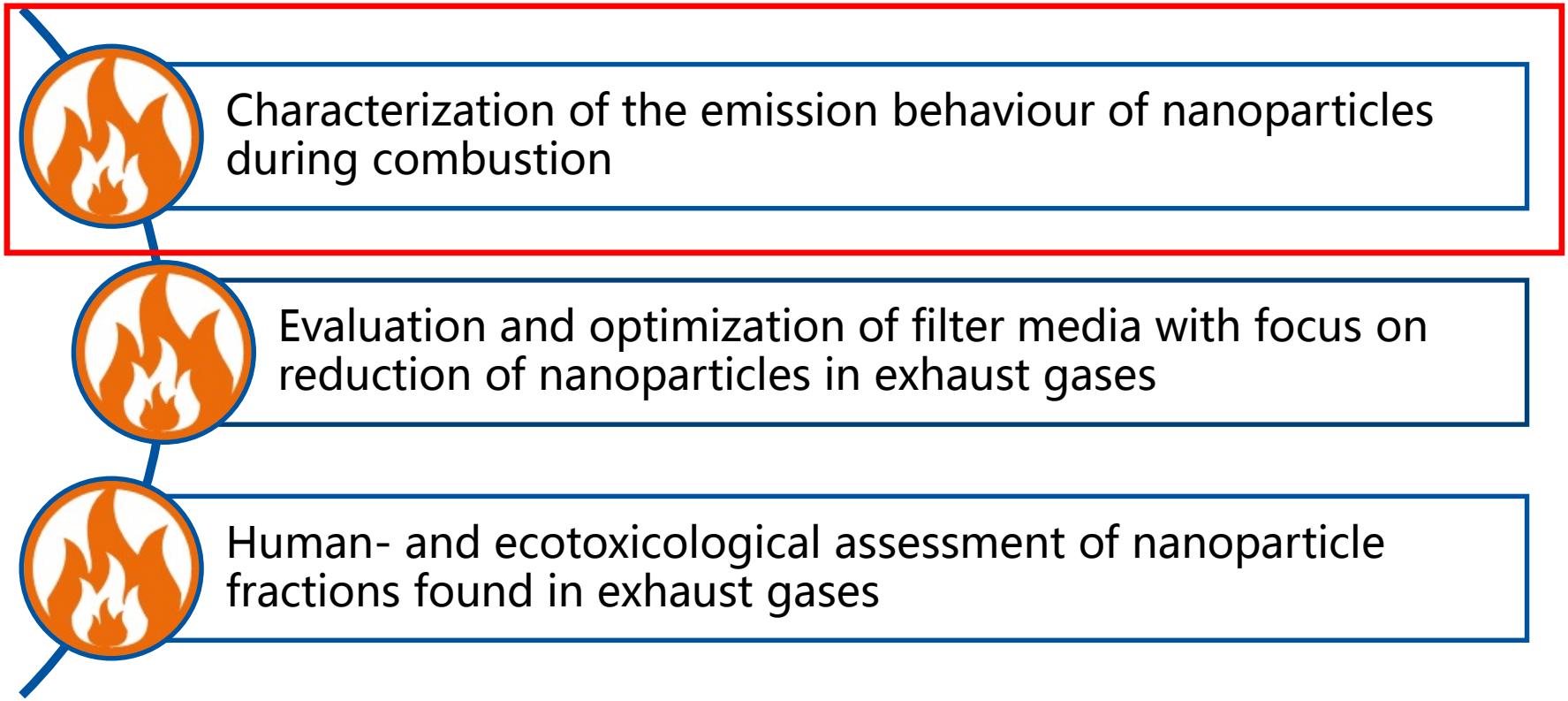
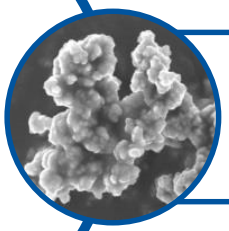
Approach

Extension of the knowledge in the field of emission behavior of nanoparticles in waste incineration process:

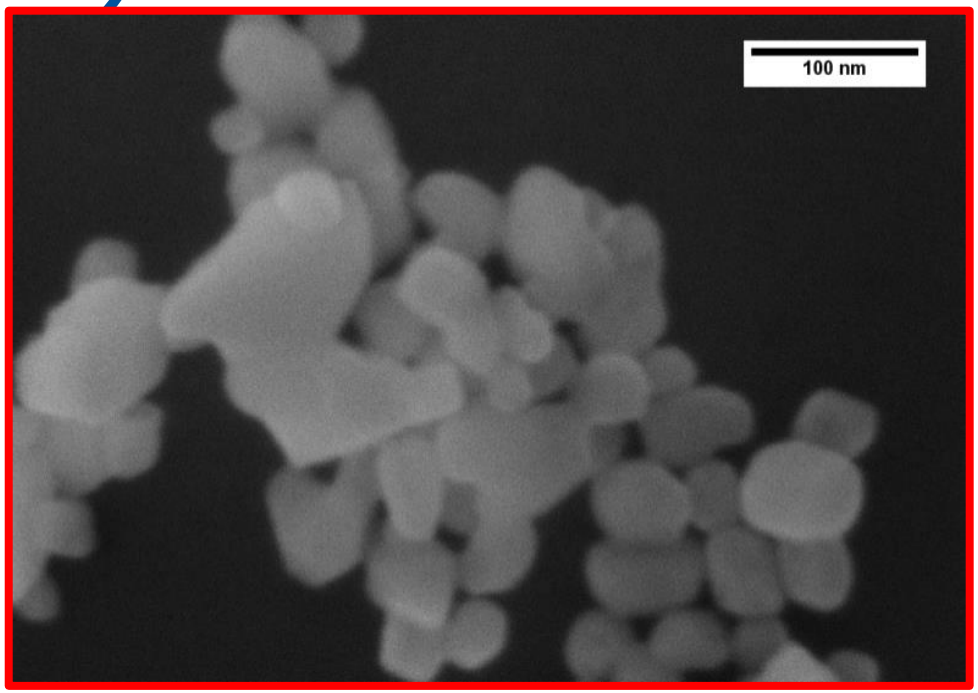


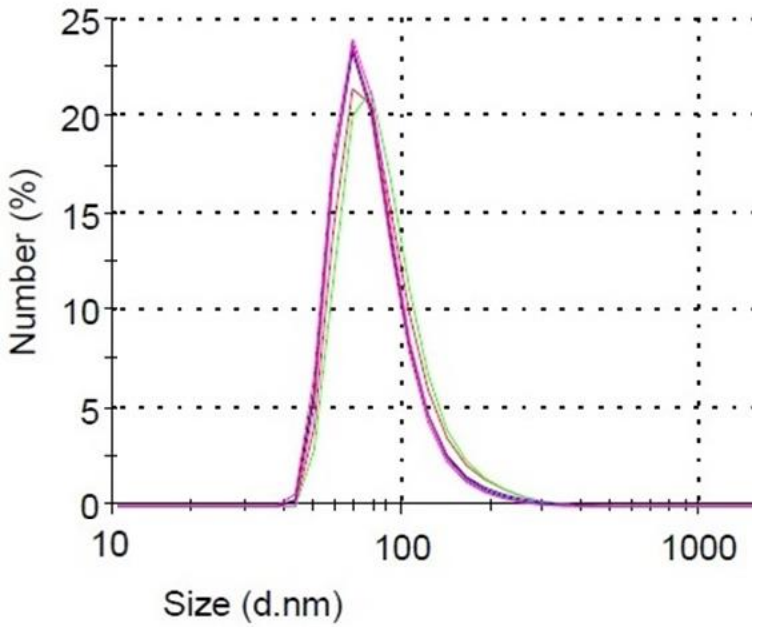
Basic research

Project-specific nanomaterial



Barium sulfate
The primary particle size:~40 nm;
Particle size distribution: d_{50}= ~100 nm





Source: LFG Erlangen, MLU Halle

Fig. 2: SEM picture of $BaSO_4$ agglomerates and particle size distribution by number in aqueous suspension (0,7% Ecodis P-30) (DLS)

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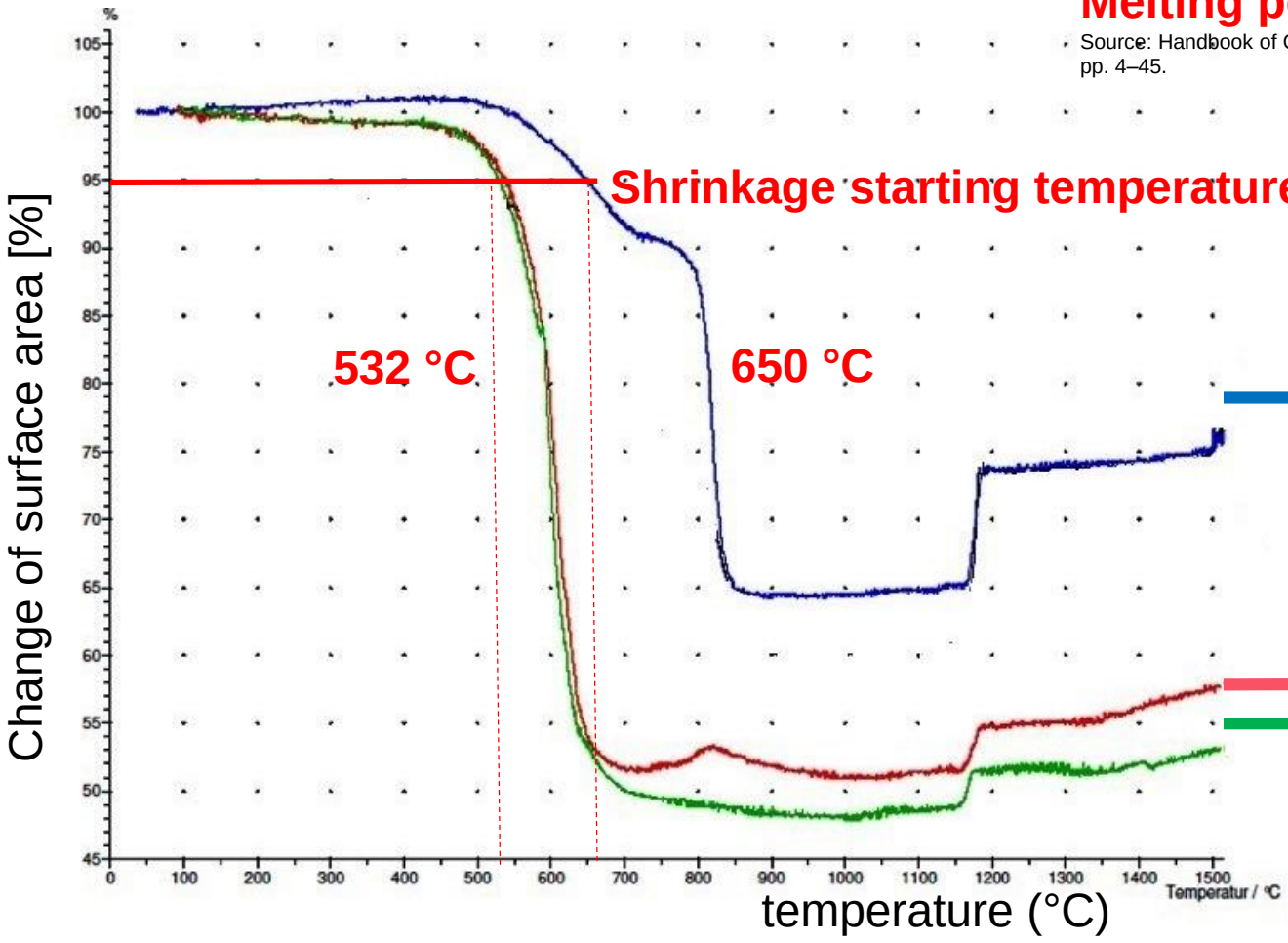
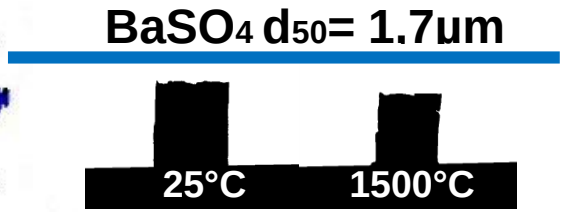
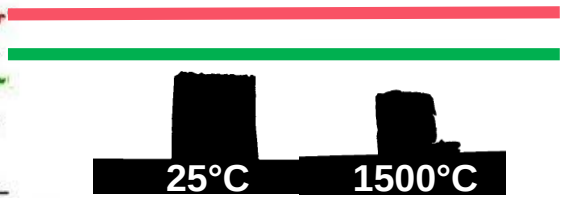
Sintering behaviour of $BaSO_4$

Melting point (Bulk): 1580°C

Source: Handbook of Chemistry and Physics (85th ed.). CRC Press. 2004. pp. 4–45.







Source: TEER RWTH Aachen

Fig.3 Change of the test samples' surface area during heating in the presence of air (heating microscope)

Measurement campaign in WtE plant Weisweiler (Germany)
(16-20.11.2015)

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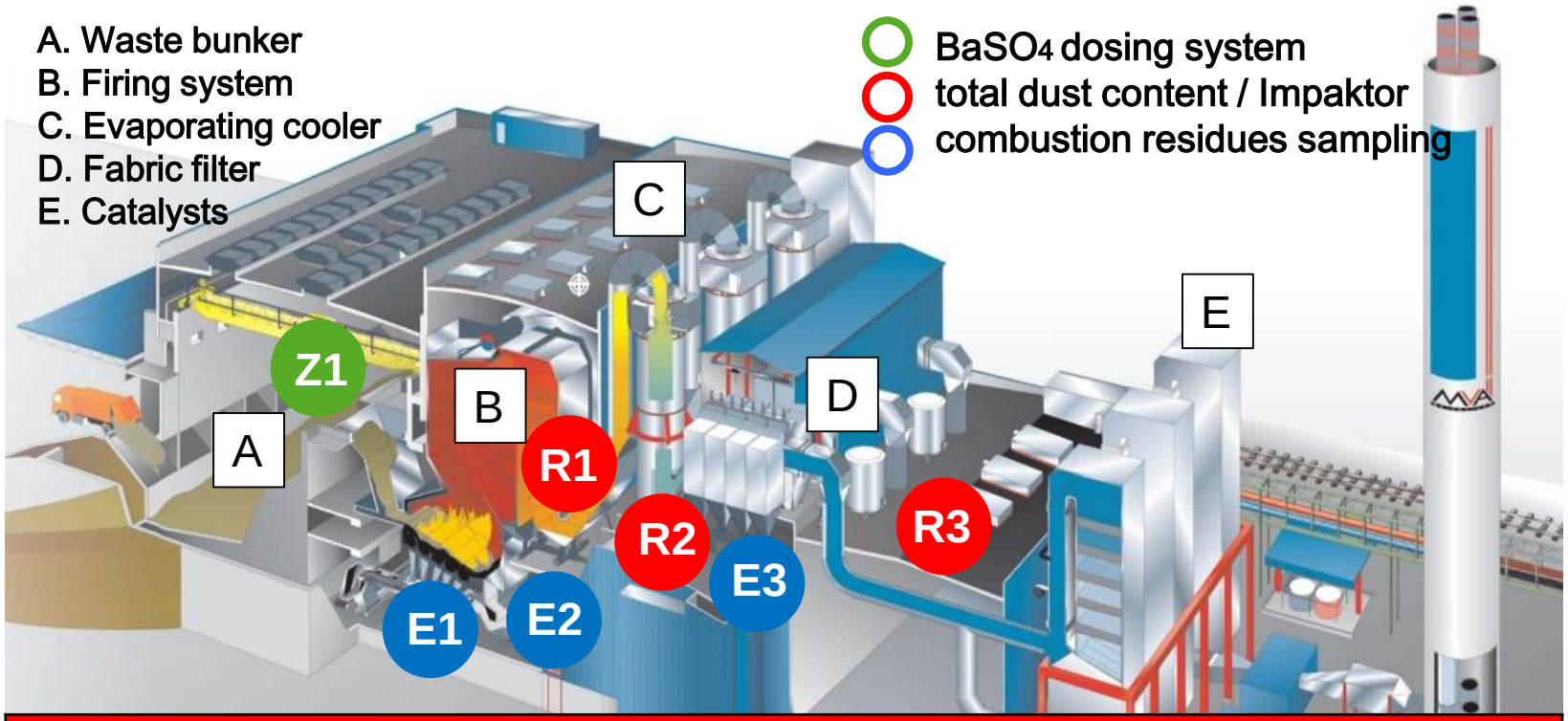
Experiments in waste incineration plant Weisweiler



Measurement points	
R1. after boiler	**E1.** Bottom ash discharger
R2. after evaporating cooller	**E2.** Boiler ash discharger
R3. after fabric filter	**E3.** Residue from fabric filter

Methods

Z1: Addition of nanomaterial

Fig.4: Production and dosing of nanosuspension

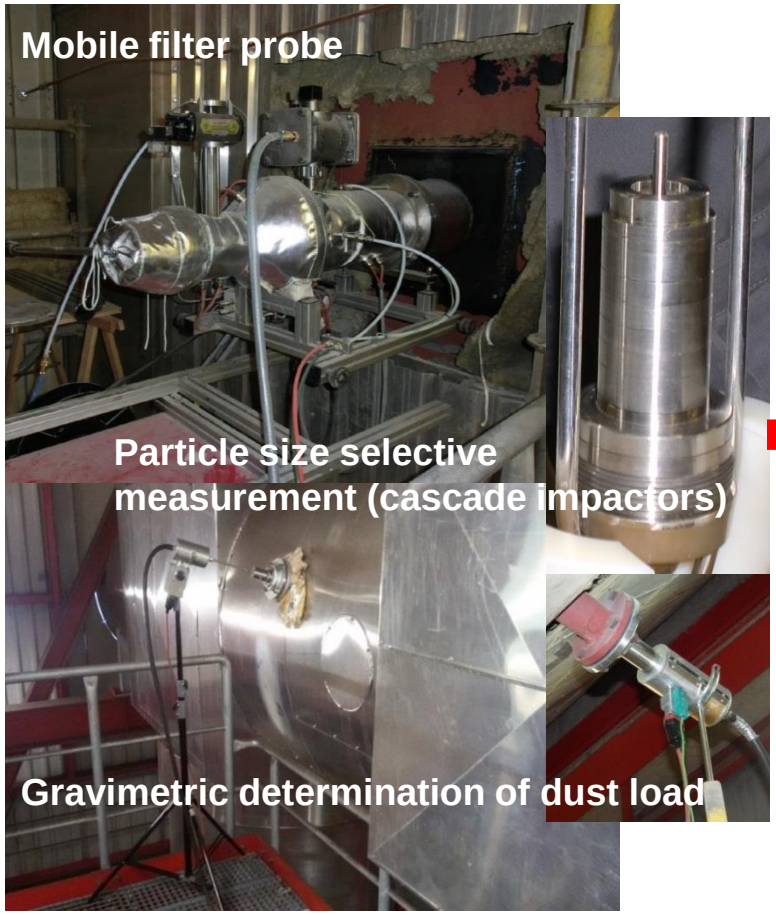
E1-3: Sampling points for combustion residues

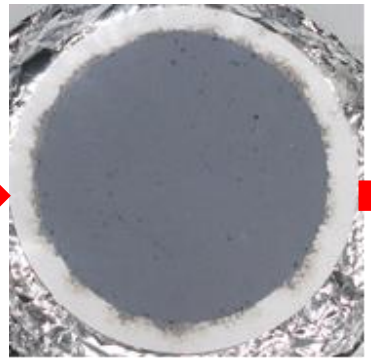
E1: Bottom ash **E2: Boiler ash** **E3: Residue from fabric filter**

Fig.5: Sampling und preparation of combustion and filtration residues conducted according to DIN 22022 and DIN 51701

Determination of Ba concentration → ICP-MS Analysis

R1-3: Dust measurement techniques



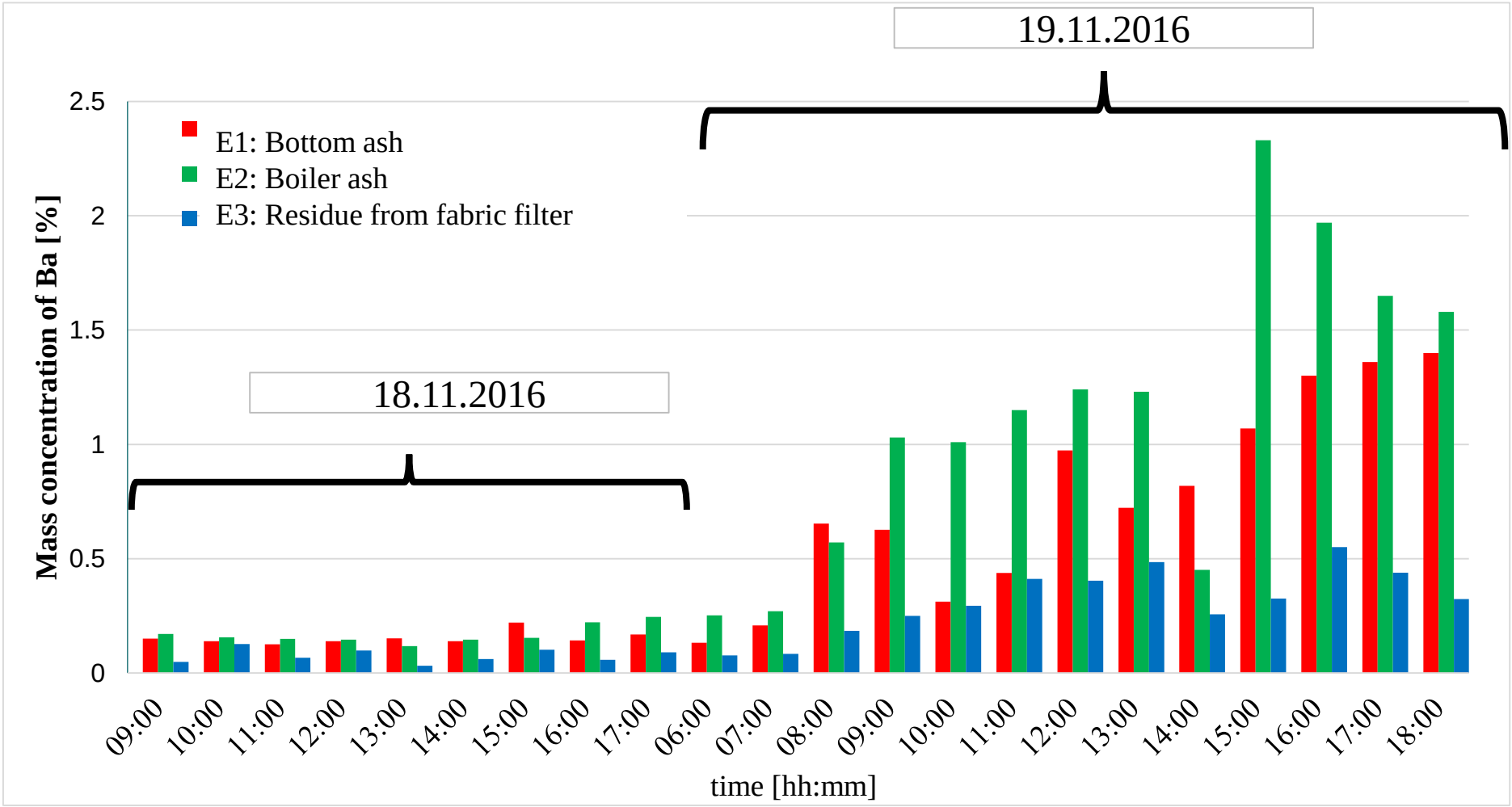


- → **Determination of Ba concentration → ICP-MS Analysis**
- → Determination of dioxin and heavy metals content
- → toxicological examinations

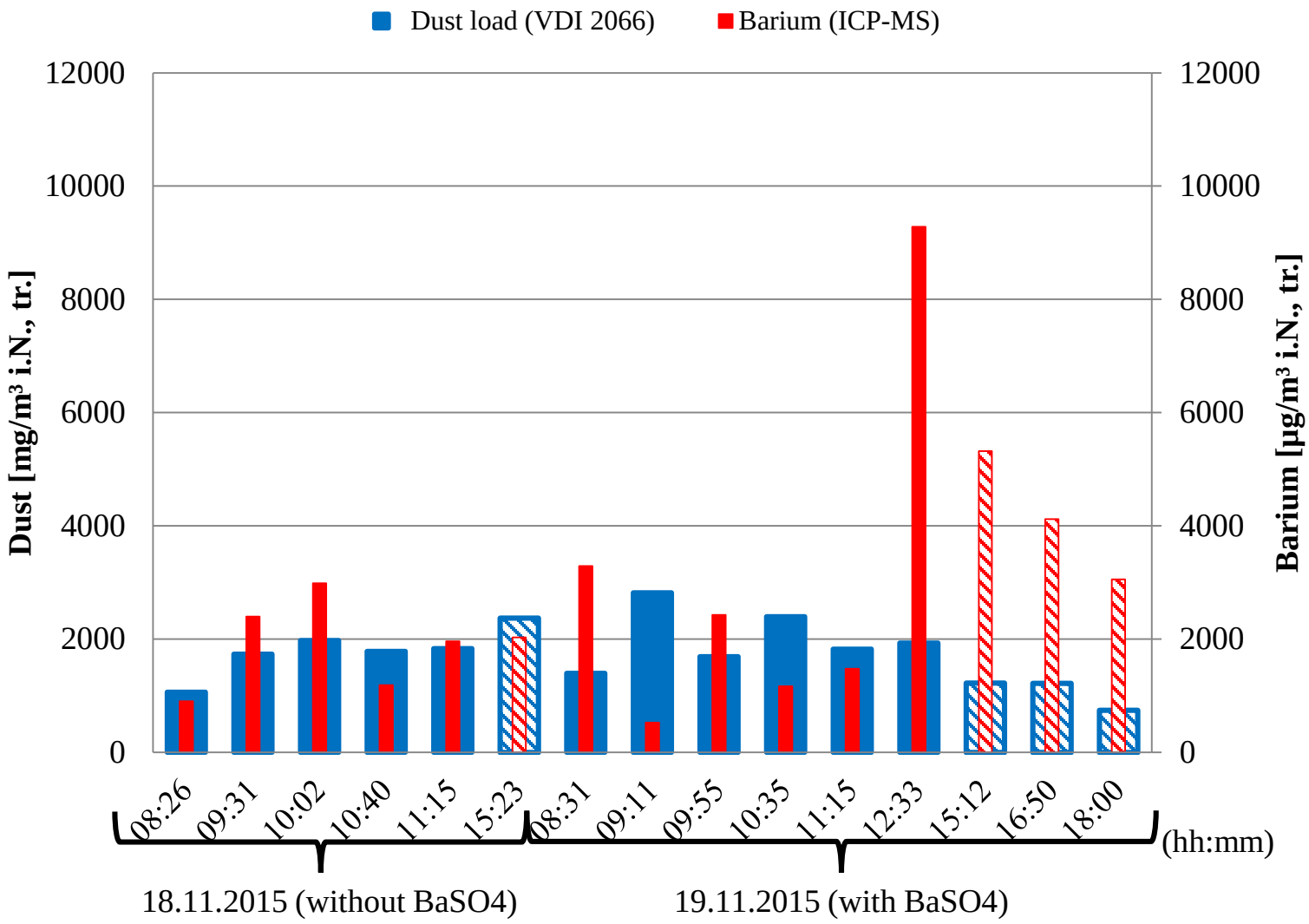
Fig.6: Devices for the dust measurement (left), principle of particle impaction (right, above) and precipitator with collected dust (right, below).

Results

E1-3: Mass concentration of Ba in combustion residues



R1: Gravimetric determination of particle mass concentration flue gas after boiler



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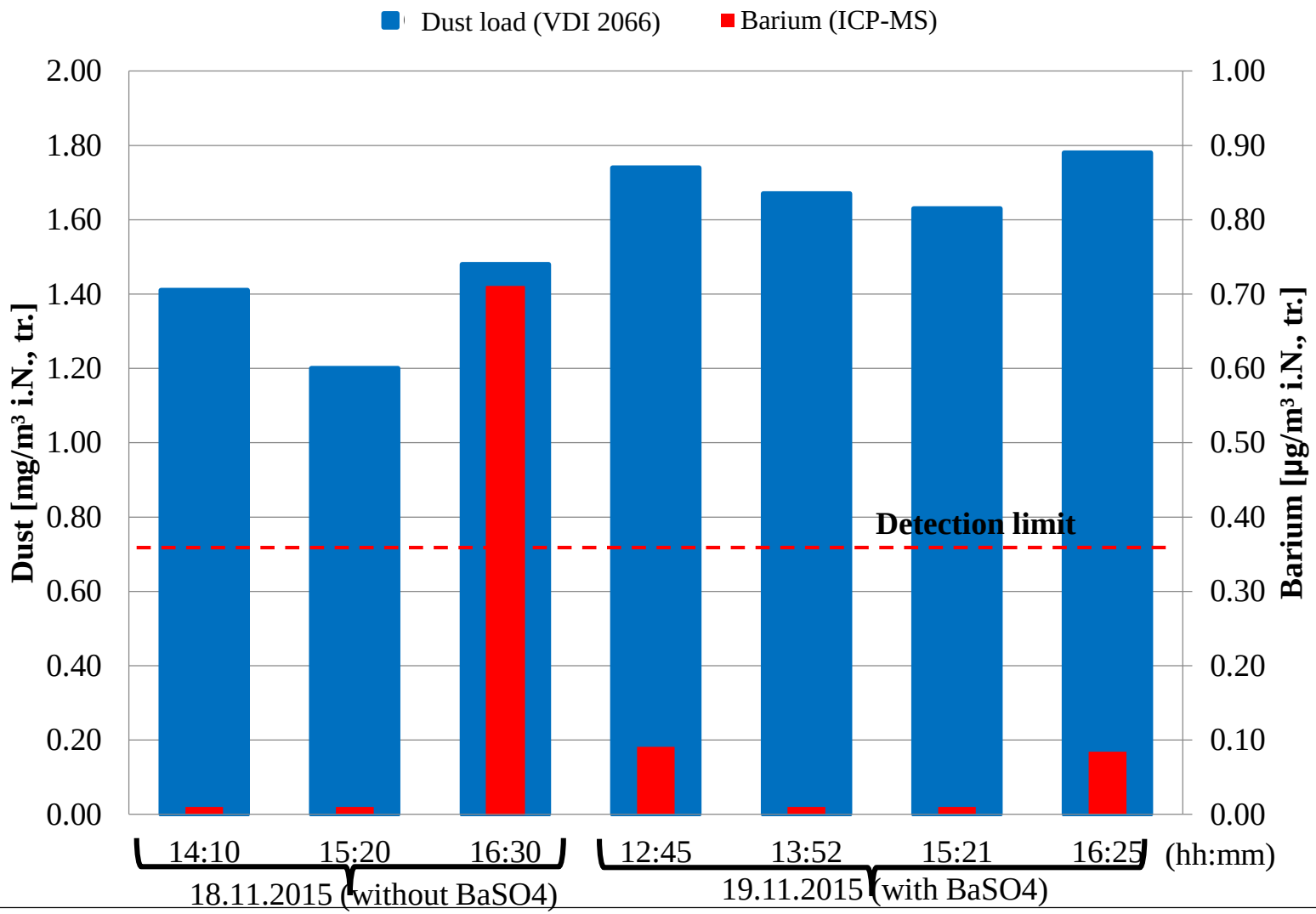
R4: Gravimetric determination of particle mass concentration clean gas after fabric filter



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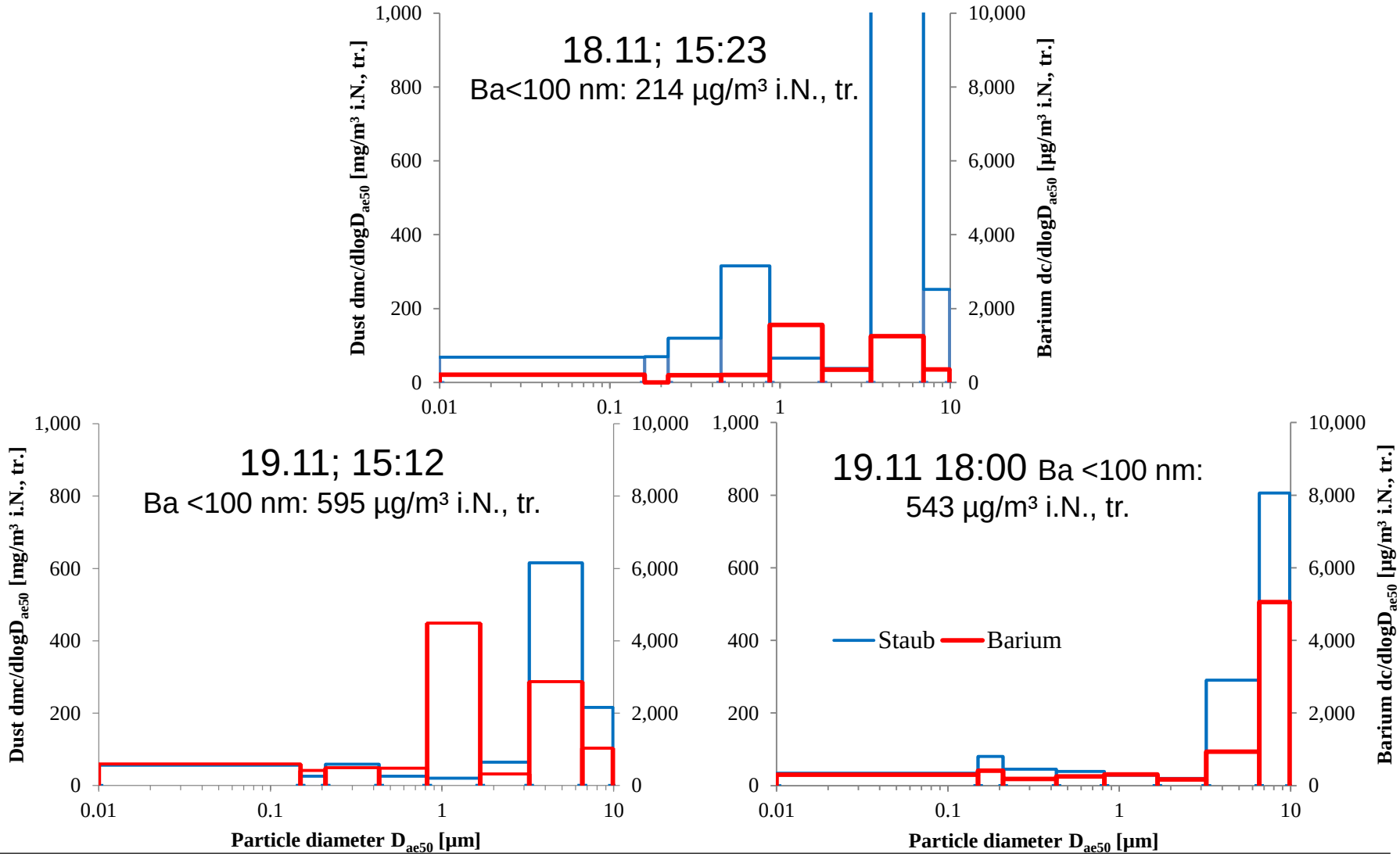
R1: Determination of particle size distribution (cascade impactor) flue gas after boiler



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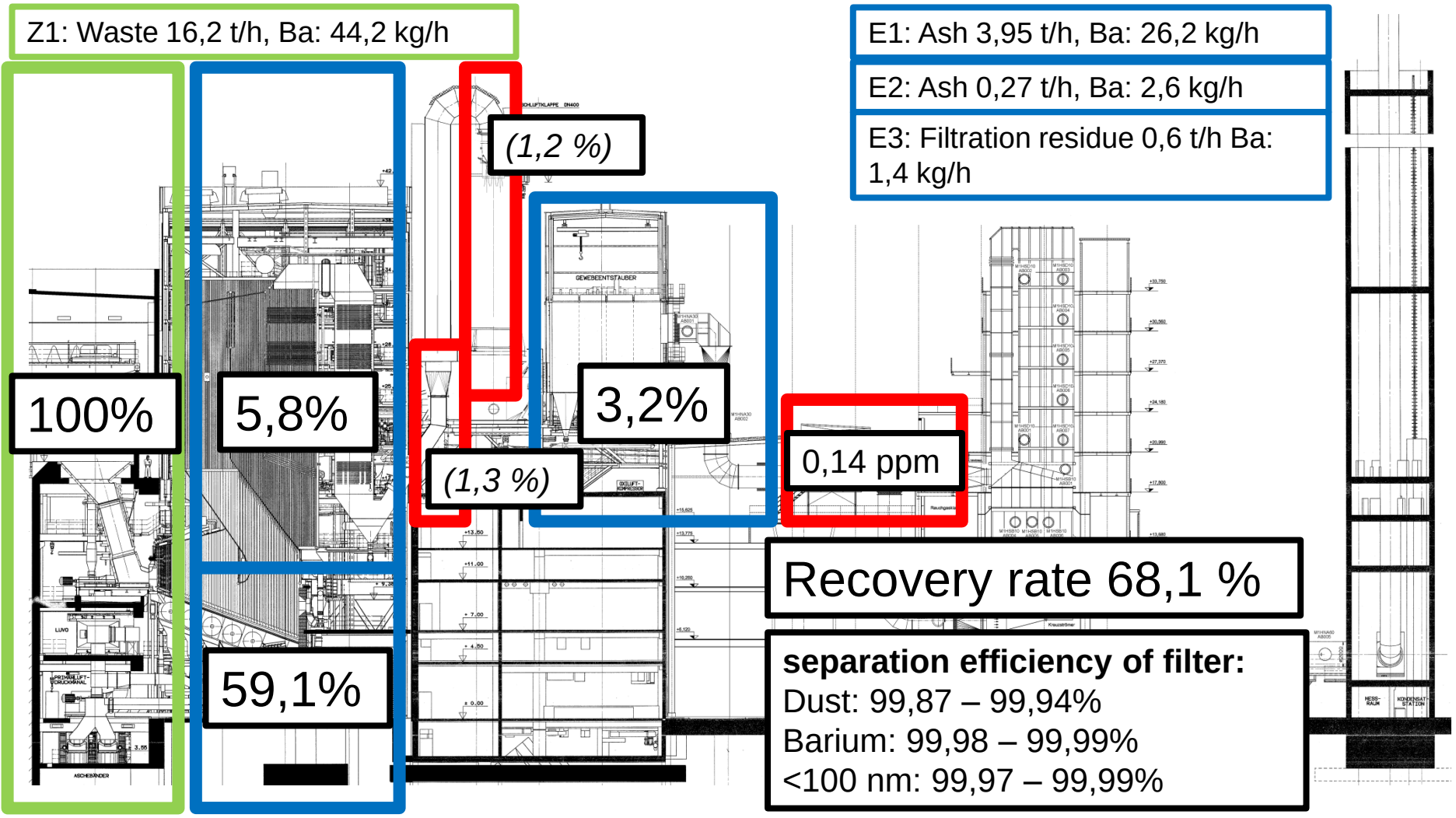
Mass balance



Barium background concentration has been substructed

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Comparison

Research group / Incineration plant	ENM	Mass distribution			Separation efficiency
ETH Zürich / Municipal waste incineration plant *	nano-CeO_2	Slag: 81% Ce	Fly ash: 19% Ce	Quench water: 0,02% Ce	Electrostatic precip. C1: 99,9 % (Ce)
KIT Karlsruhe / Hazardous waste incineration plant **	nano-CeO_2	Boiler: 10,6 %Ce	Quench water: 68,7 % Ce	Fly ash: 0,1% Ce	Electrostatic precip. 99,99 % (Ce)
Fraunhofer Umsicht / sewage-sludge-incineration plant	nano-TiO_2	Bottom ash & boiler: 89,9% Ti	Adsorber & fabrik filter residue: 10,7% Ti		Fabrik filter: 99,99% (Ti)
NanoEmission / Municipal waste incineration plant	nano-$BaSO_4$	Bottom ash: 59,1% Ba	Boiler: 5,8% Ba	Fabrik filter res 3,2 % Ba	Fabrik filter: 99,98% (Ba)

Source:
Walser, T.; Limbach, L. K.; Brogioli, R.; Erismann, E.; Flamigni, L.; Hattendorf, B.; Juchli, (2012) Persistence of engineered nanoparticles in a municipal solid-waste incineration plant.
Liesen, I.-M., Baumann W., Hauser M., Mätzing H., Paur H.-R., Seifert H., Untersuchung zur Freisetzung von synthetischen Nanopartikeln bei der Börner et al. Abfallverbrennung , Energie aus Abfall Band 12, 2015 Tagungsband
Untersuchung möglicher Umweltauswirkungen bei der Entsorgung nanomaterialhaltiger Abfälle in Abfallbehandlungsanlagen

Conclusions

Conclusions

- Emission behaviour dependent on thermochemical properties of ENMs
- High total dust content → agglomeration tendency
- Fluctuating background concentration of trace elements in waste and long residence time of NP → difficulties in accurate estimation of the nanoparticle's path distribution

- Most significant distribution pathway of ENMs is the bottom ash (50 – 90%)
- High separation efficiency in existing flue gas cleaning systems
- Fate and behavior of ENMs in combustion residues is still to clarify

Thank you for your interest!

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