Resource-efficient fuel additives for reducing ash related operational problems in waste wood combustion “REFAWOOD”

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Introduction

- **Waste wood and other biomass waste products have become very interesting as fuels for CHP-plants.**
  - \+ Lower cost compared to virgin wood fuels.
  - \- Relative high concentrations of inorganic materials lead to increased risk of ash-related problems during combustion.
  - \- Many waste wood fired power plants in Europe reports about corrosion problems, fouling and slagging in the superheater and on furnace walls → unacceptably short life times and short cleaning intervals.
- **Additives can reduce the alkali chloride-related problems in biomass combustion. Several different mineral- and sulphur containing additives have been proposed (e.g. Wang, 2012).**
- **Investigations of new cheap and resource efficient fuel additives for reducing corrosion, fouling and slagging are of major interest.**

Objectives

- **New additives with**
  - multi-functions
  - high stability and reactivity and
  - low cost (preferable from waste materials with high availability) should be identified and tested.
    - Recycled gypsum or coal fly ash are feasible candidates.
- **Improve the economic and environmental conditions and enlarge the market for the use of waste wood fuels in CHP plants by using resource efficient additives.**
- **Estimation of suitable ranges of additive to fuel ratios, through model calculations.**
  - Testing of proposed additive ratios in a fixed-bed lab-scale reactor.
- **Preparation of design concepts for fuel additives including information concerning suitable additive/fuel mixtures which reduce different ash related operational problems during combustion of waste wood.**

Methodology - Fuels and additives

- **Fuel assortments provided by Fritz Egger GmbH & Co. OG (chipboard production).**
  - Forest wood chips
  - Bark
  - Recycling material not usable for the manufacturing process
  - Four different dust fractions from the manufacturing process
- **Homogenisation and extraction of representative fuel sample**
- **Wet chemical fuel analysis of all different fractions**
- **Fuels investigated (mixtures of fuel fractions provided to the furnace)**
  - 1. fuel: mixture of forest wood chips and recycling material
  - 2. fuel: mixture of forest wood chips, recycling material and different dust fractions
  - 3. fuel: mixture of recycling material and different dust fractions

Methodology - Fuels and additives

- **Additives to decrease the high temperature corrosion risk**
  - Waste gypsum board, iron sulphide (FeS)
- **Additive to decrease the K release, to improve the ash melting behaviour and to partly reduce the high temperature corrosion risk**
  - Coal fly ash (mainly composed of aluminium silicates)
- **Pre-evaluation of appropriate additive ratios under application of fuel indices and high temperature equilibrium calculations (TEC)**
- **Preparation of fuel additive mixtures and pelletisation**
  - Pelletisation of selected fuel mixes without and with additive is required for
    - homogenisation of the fuel and additive mixtures
    - performance of fixed-bed lab-scale reactor experiments

Methodology - Thermodynamic equilibrium calculations (TEC)

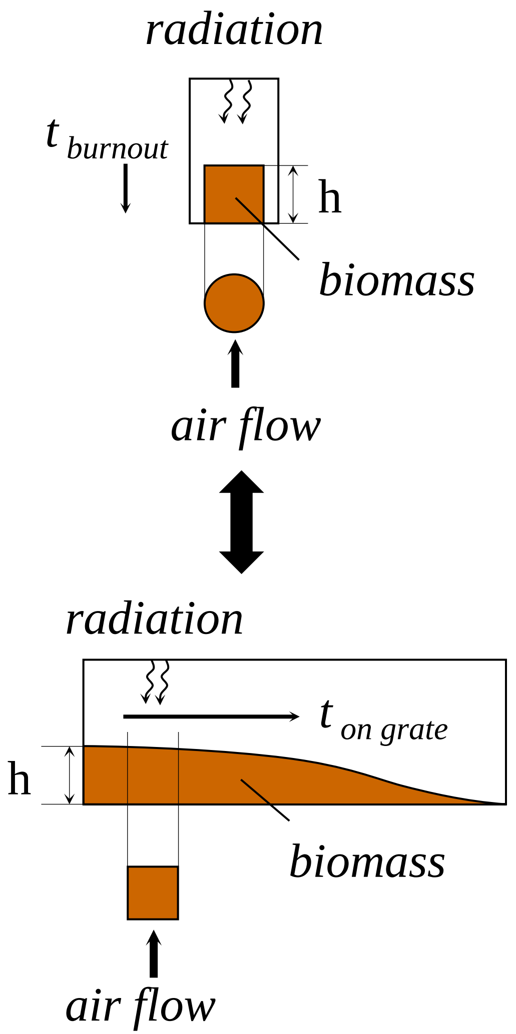
- **TEC provide information regarding**
  - Ash composition and fractionation of individual elements in solid, liquid and gaseous phases
  - Composition of phases formed
  - Release of relevant aerosol forming elements (S, Cl, K, Na, Zn, Pb)
  - Ash melting behaviour
- **Software**
  - FactSage 7.0 – Modul: EQUILIB
- **Calculation model applied**
  - More than 1,000 components
  - 9 mixed phase (selection of stable, thermodynamic relevant phases)
  - Temperature range evaluated: 500° - 1,600°C
  - 2-step model considers the devolatilisation and charcoal combustion phase

Methodology - Fixed-bed lab-scale reactor

- **Batch type reactor to simulate the fuel decomposition behaviour in real-scale grate combustion systems**
- **Tests with the lab-scale reactor provide results on:**
  - Combustion behaviour
  - Release of NO_x precursors
  - Release of volatile and semi-volatile elements from the fuel to the gas phase
  - First indications about the ash melting tendency (optical evaluation)

Methodology - Fixed-bed lab-scale reactor

- **Energy input:**
  - Via radiation from the upper heating element (radiation section)
  - Into the bed zone via the lower heating element (bed section)
  - The upper and the lower heating element can be controlled separately.
- **Primary combustion air is supplied from below the grate**
- **Under consideration that the fuel transport along the grate can be compared with a plug flow, the time dependent results of the lab-scale reactor can be correlated to the local burning conditions on a grate.**



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Results - Determined mixing ratios

- **2 additive ratios for each fuel mix were investigated in the lab-scale reactor**
  - Low → first effect of the additive can be observed
  - High → distinct effect of the additive and identification of the effect of overdosing

	Low (wt.%)	High (wt.%)	Expected improvements by the additive
1. fuel with gypsum	2.00	4.5	High temperature corrosion, ash melting behaviour
2. fuel with coal fly ash	1.00	3.0	Decreased K release, ash melting behaviour and partly improved high temperature corrosion risk,
3. fuel with FeS	0.25	0.5	High temperature corrosion

Results – High temperature corrosion risk based on molar 2S/Cl ratio

- **Sulfation of alkali metals or heavy metal chlorides in tube near deposition layers is relevant regarding corrosion in biomass-fired boilers → Cl is released which attacks the tube surface (so-called active oxidation)**
- **Fuels with a high 2S/Cl-ratio → formation of a protective sulphate layer**
- **For fuels with a high 2S/Cl-ratio higher 4 → minor corrosion risk**

Molar 2S/Cl ratios for the pure fuels and the additive mixtures

		1. fuel			**2. fuel**			**3. fuel**		
		amount of gysum			**amount of coal fly ash**			**amount of FeS**		
	wt%	0.0	2.0	4.5	0.0	1.0	3.0	0.0	0.25	0.5
2S/Cl	mol/mol	2.1	7.7	18.8	2.9	1.9	3.7	2.5	4.0	4.9

- **Increased high temperature corrosion risk for all pure fuels and the 2. fuel with 1% coal fly ash.**
- **Significant reduction of the high temperature corrosion risk for 1. fuel with 2% gypsum.**
- **Considerable reductions of the high temperature corrosion risk for 2. fuel with 3% coal fly ash and 3. fuel with 0.25% and 0.5% FeS.**

Results - Pictures of the ash residues after fixed-bed lab-scale reactor combustion test runs

1. fuel pure

1. fuel - 2% gypsum

1. fuel - 4.5% gypsum

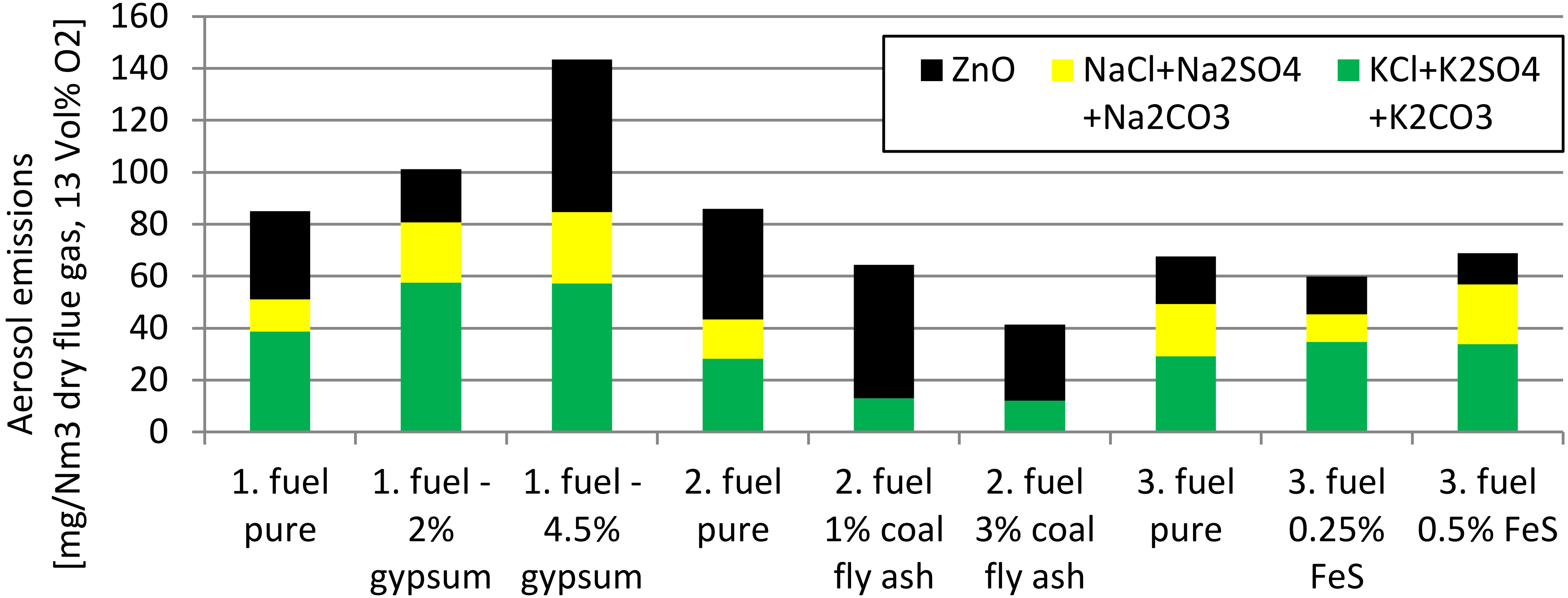
2. fuel pure

2. fuel - 1% coal fly ash

2. fuel - 3% coal fly ash

- Decreasing slagging tendency with rising additive ratios for the 1. and 2. fuel

Results - Estimated aerosol emissions based on fixed-bed lab-scale reactor combustion test runs



- **ZnO has a strong contribution concerning the aerosol emissions → typical for waste wood**
- **Increased aerosol emissions by addition of gypsum**
- **Aerosol emission decreases with coal fly ash addition → decreased K and Na release from the fuel to the gas phase**
- **FeS doesn't influence the aerosol emissions.**

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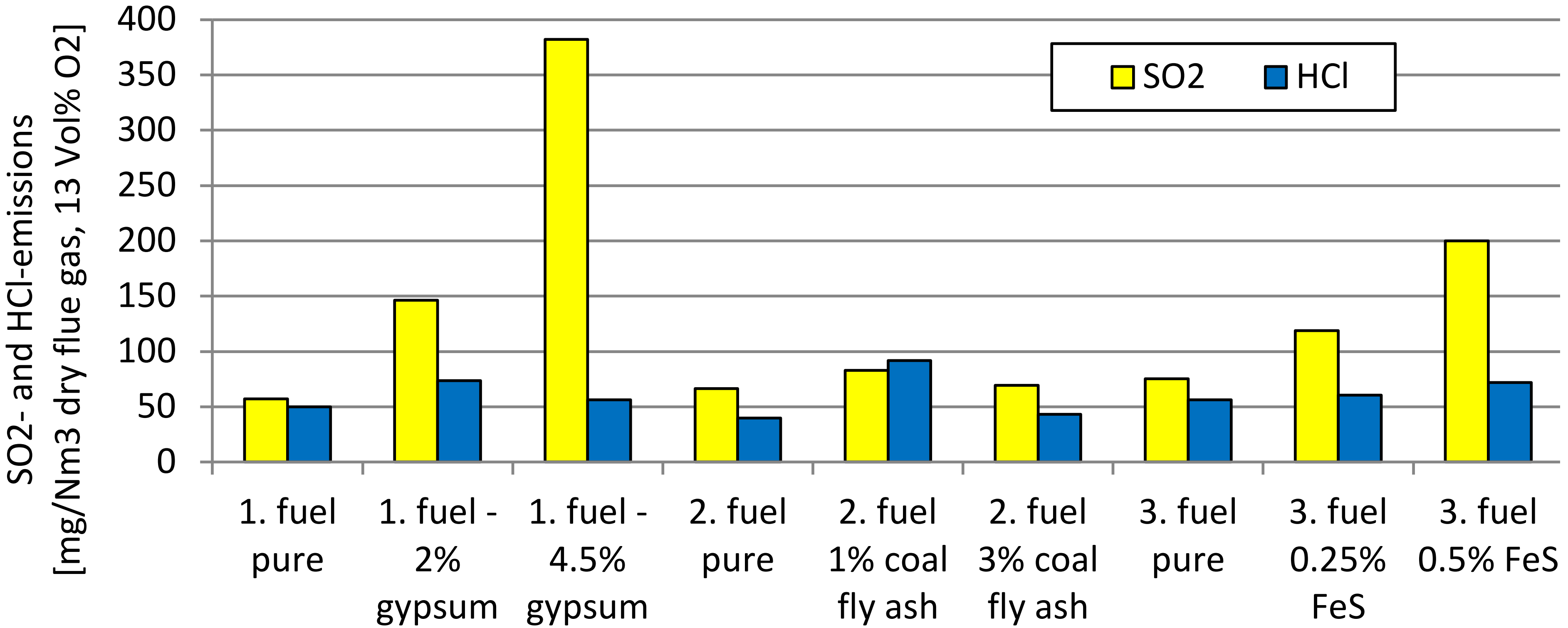
Results - Estimated SO_2- and HCl emissions based on fixed-bed lab-scale reactor combustion test runs



- **The increased SO_2 emissions by addition of gypsum and FeS can decrease the high temperature corrosion risk, but the emission limits for SO_2 needs to be considered.**
- **No influence on the gaseous SO_2 and HCl emissions have to be expected by addition of coal fly ash.**

Summary and conclusions

- **2% gypsum, 0.25% FeS and 3% coal fly ash minimises the high temperature corrosion risk (based on molar 2S/Cl ratio).**
- **An improved ash melting behaviour can be expected with addition of gypsum and coal fly ash (optical evaluations and TEC).**
- **The addition of 2% gypsum only cause to slightly increased aerosol emissions and also the increase of the SO_2 emissions is on a moderate level; 2% → best additive ratio tested**
- **The addition of coal fly ash led to a reduction of the aerosol emissions, whereas the SO_2 and HCl remain constant; 3% → best additive ratio tested**
- **The addition of FeS doesn't influence the aerosol emissions, whereas the SO_2 emissions increase.**
  - FeS will not be tested in real scale trials → only improvement concerning high temperature corrosion is expected
- **By TEC and fixed-bed lab-scale reactor experiment appropriate additive ratios for the fuels investigated can be identified.**

Ongoing work & outlook

- **Real scale combustion test runs with optimum additive ratios of gypsum and coal fly ash**
- **Compilation of legal framework conditions for utilisation of waste wood, new additives and ash**
- **Case studies for reductions in operating and maintenance costs**
  - Full scale test run data will be used to calculate the possible cost reduction due to:
    - Extended maintenance intervals
    - Increased plant efficiency
    - Reduced heat exchanger replacement costs
- **Case studies for fly ash and bottom ash utilisation**
  - Evaluation if the use of additives gives rise to alternative ash utilisation options based on test run data

Thank you for your attention!

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