Future Challenges for Waste Combustion and Co-combustion in FBC
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Decomposition of N_2O catalyzed by the bed material from co-combustion of sewage sludge and wood pellets in CFB boiler

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Kinetics of Catalytic Nitrogen Oxide Reactions in Multifuel CFB Conditions

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Introduction

$$N_2O \xrightarrow{\text{solids from CFB boiler}} N_2 + \tfrac{1}{2}O_2$$

char lime	More active
ash *bed material*	Less active

- **Lack of data in the literature regarding the catalytic activity of solids from fluidized bed during combustion of biomass fuels and wastes**
- **Catalytic activity affected by flue gases, especially water vapor**

Objective. Catalytic activity of bed material from co-combustion of biomass fuels and wastes towards N_2O decomposition was studied as a function of: fuel type, particle size, and presence of water vapor.

Experimental

Tested solids

Bed material from the bottom bed of a 12 MW_{th} CFB boiler:

- **Ch1 – wood pellets**
- **Ch2 – wood pellets & sludge A**
- **Ch3 – wood pellets & sludge B**

– mixture of sand & ash

– char burned off before testing

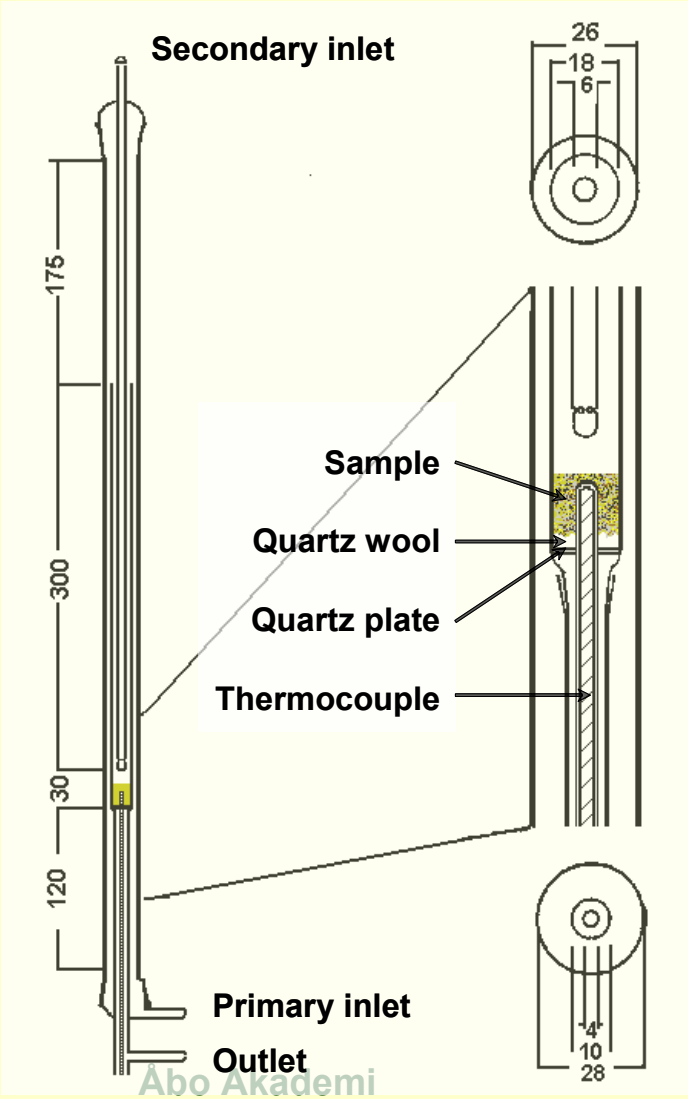
	Wood pellets	Sludge A	Sludge B
Dry mat., wt-% a.r.	99.6	98.0	97.2
Ash, wt-%, dry	**0.4**	**46.8**	**42.1**
Volatiles, wt-%, dry	84.3	52.4	59.5
Nitrogen, wt-% dry	**<0.1**	**2.8**	**2.8**
SiO_2, wt-% of ash	12.8	27.4	21.8
Al_2O_3, wt-% of ash	2.4	14.5	36.8
Fe_2O_3, wt-% of ash	1.7	22.3	5.8
CaO, wt-% of ash	32.5	5.7	5.3
MgO, wt-% of ash	5.4	1.2	1.1
P_2O_5,wt-% of ash	2.8	15.7	13.6
Na_2O, wt-% of ash	0.7	0.14	0.1
K_2O, wt-% of ash	12.9	1.65	1.2
SO_3, wt-% of ash	3.8	5.0	3.8
Cl^-, wt-% of ash	1.0	0.1	0.1
CO_3, wt-% of ash	~24	3.9	1.7

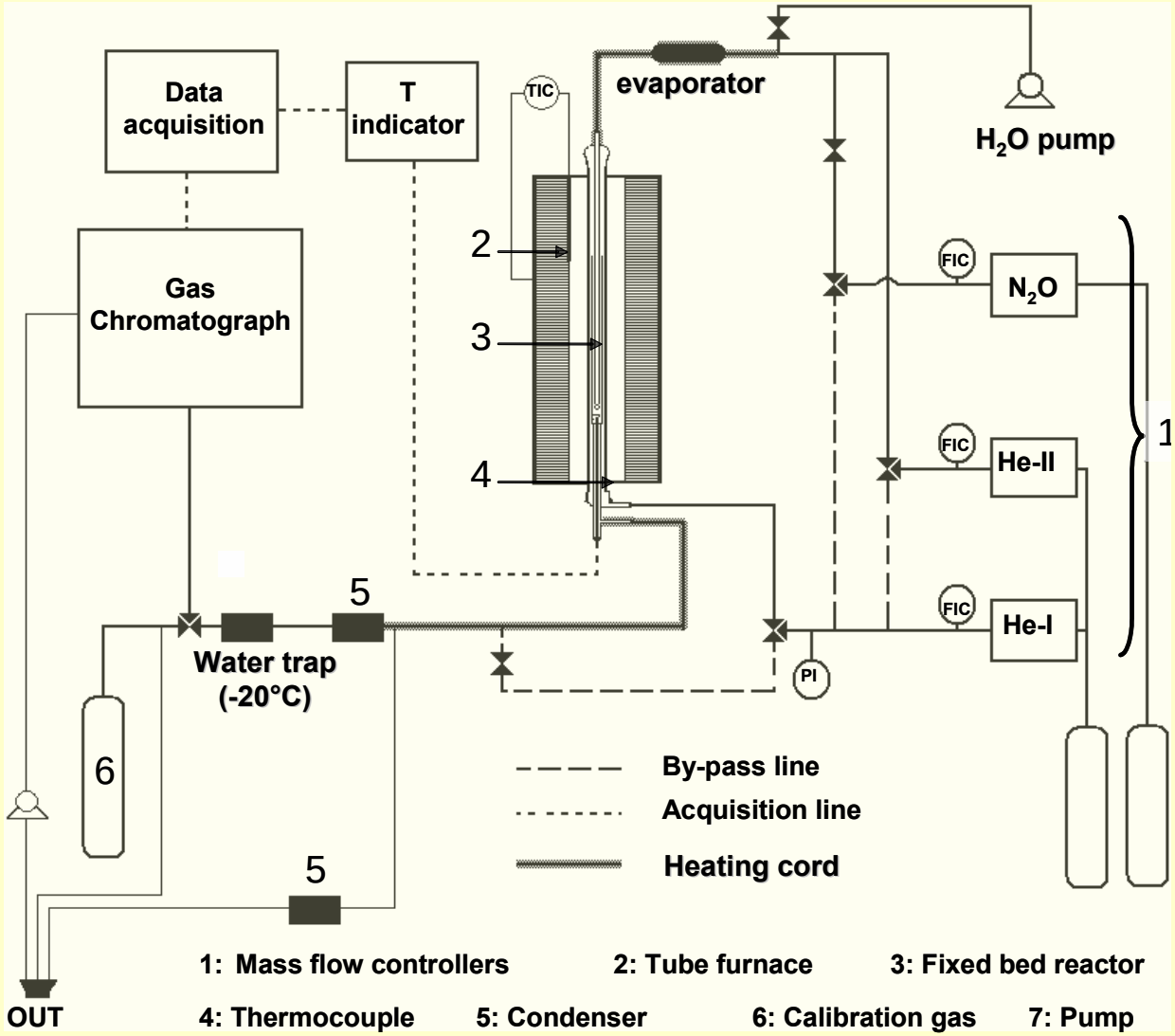
Experimental

Bed material characterization

- **Elemental composition** – X-ray fluorescence (XRF)
- **Total BET surface area** – N_2-physisorption
- **Morphology and elemental composition of the particle's surface** – Scanning electron microscope combined with an energy dispersive X-ray analyzer (SEM/EDX)

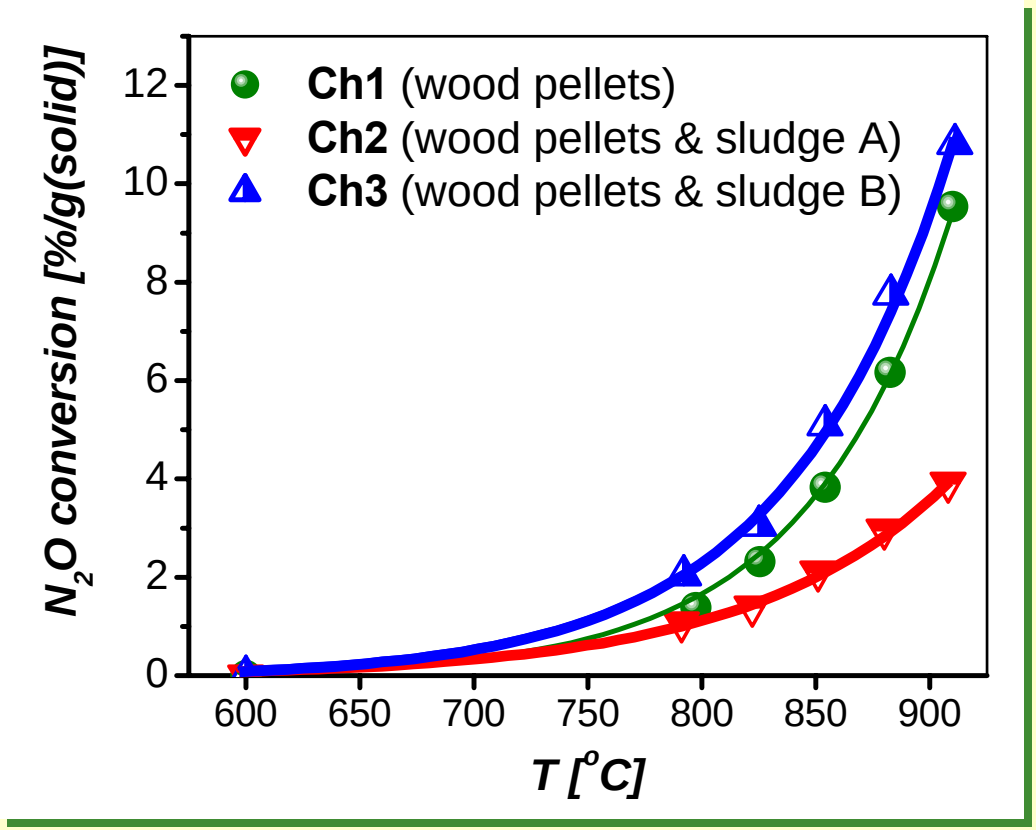
Experimental Setup





Results

Effect of fuel type



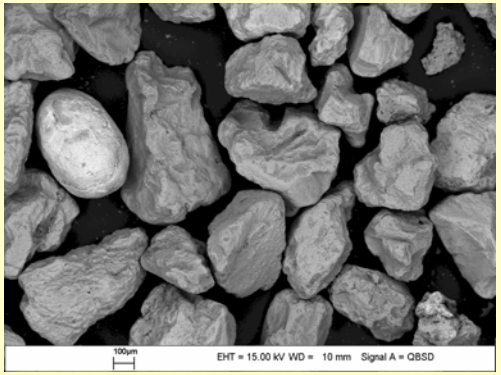
Bed material		Ch1	Ch2	Ch3
Elemental composition, wt-%	SiO_2	93.7	95.0	86.9
	Al_2O_3	**0.6**	**1.0**	**5.4**
	Fe_2O_3	**0.6**	**1.1**	**1.5**
	CaO	**2.6**	**1.0**	**2.3**
	MgO	**0.6**	**0.3**	**0.4**
	P_2O_5	0.6	0.8	2.2
	Na_2O	0.1	0.1	0.2
	K_2O	0.8	0.2	0.4
	SO_3	0.0	0.0	0.0
	sum	99.6	99.5	99.3
Bet surface area, m^2/g		**2.44**	**2.72**	**2.85**

Sample particle size: 125-710, pressure 1 atm, residence time: 0.4 s, N_2O_{in}: 500 ppm_v in He, total gas flow 1800 ml/min.

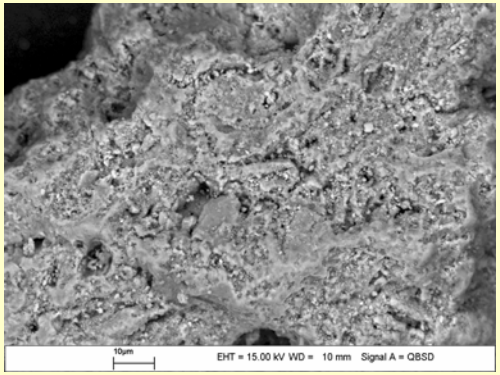
Results

Effect of fuel type

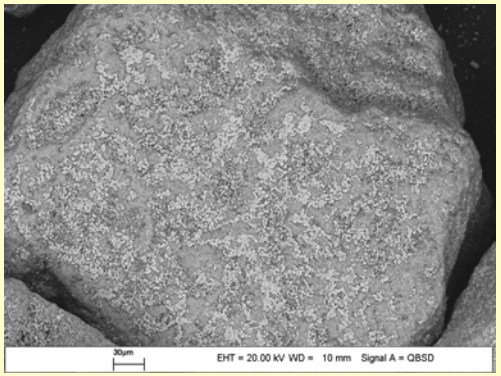
Ch3 (wood pellets & sludge B), 125-710 μm

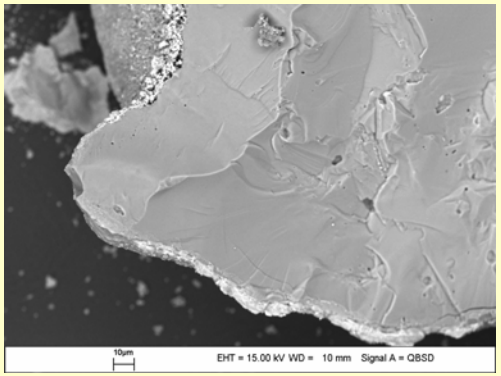


a group of particles

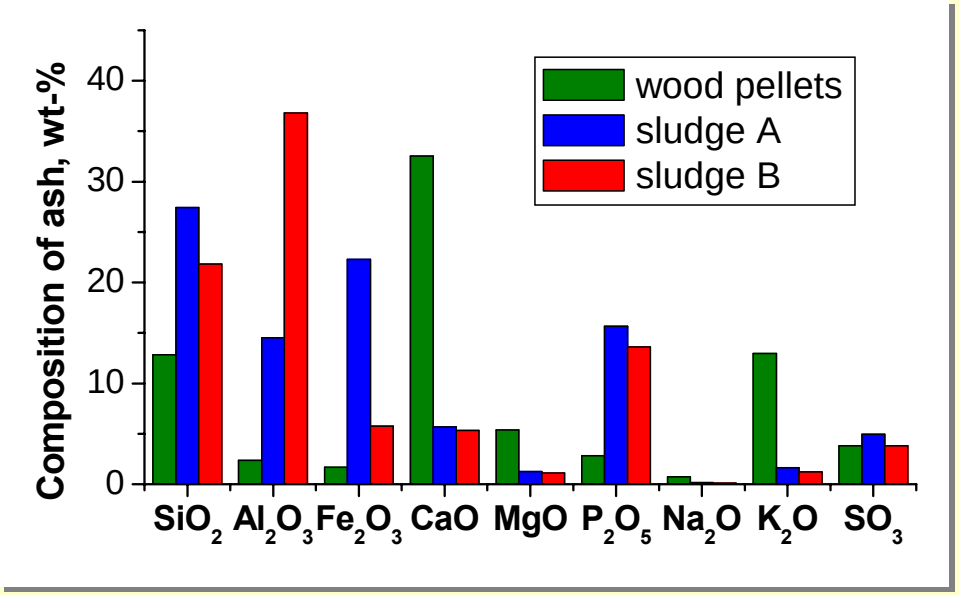


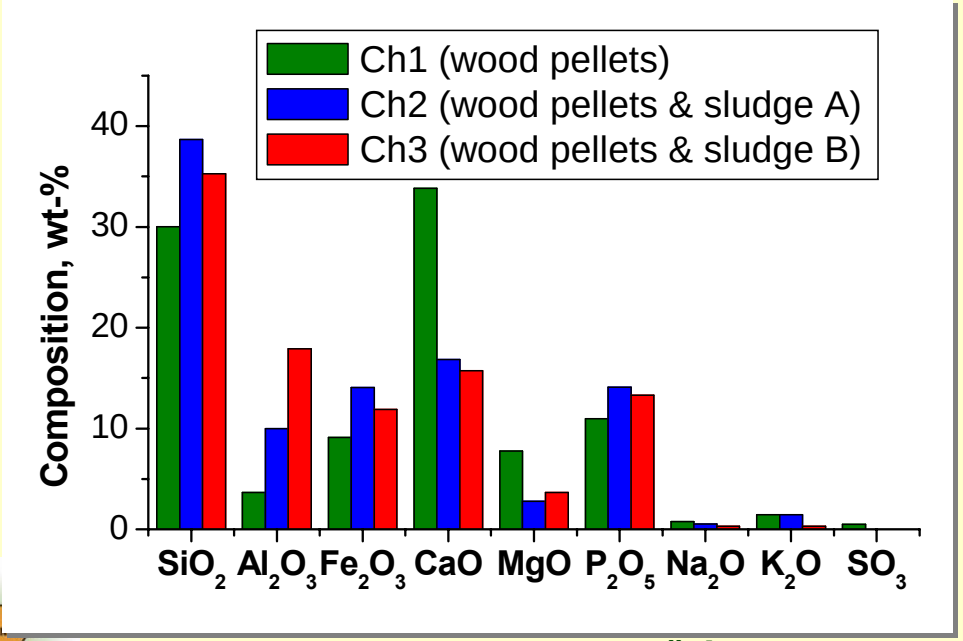
ash particle





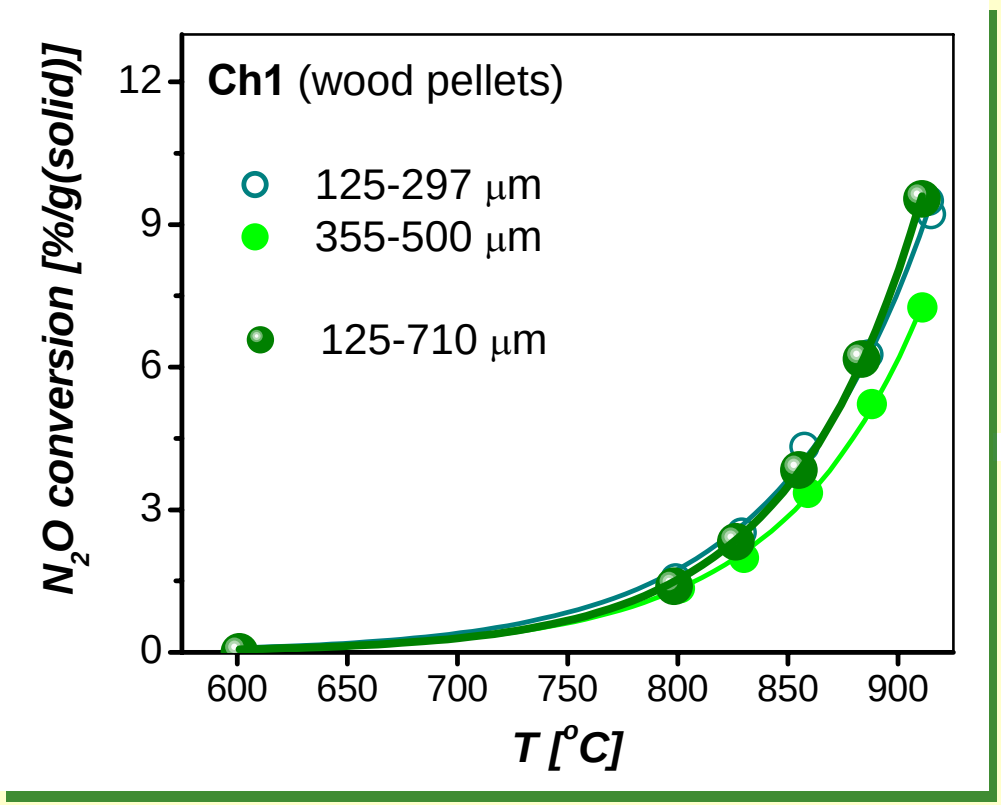
sand particles

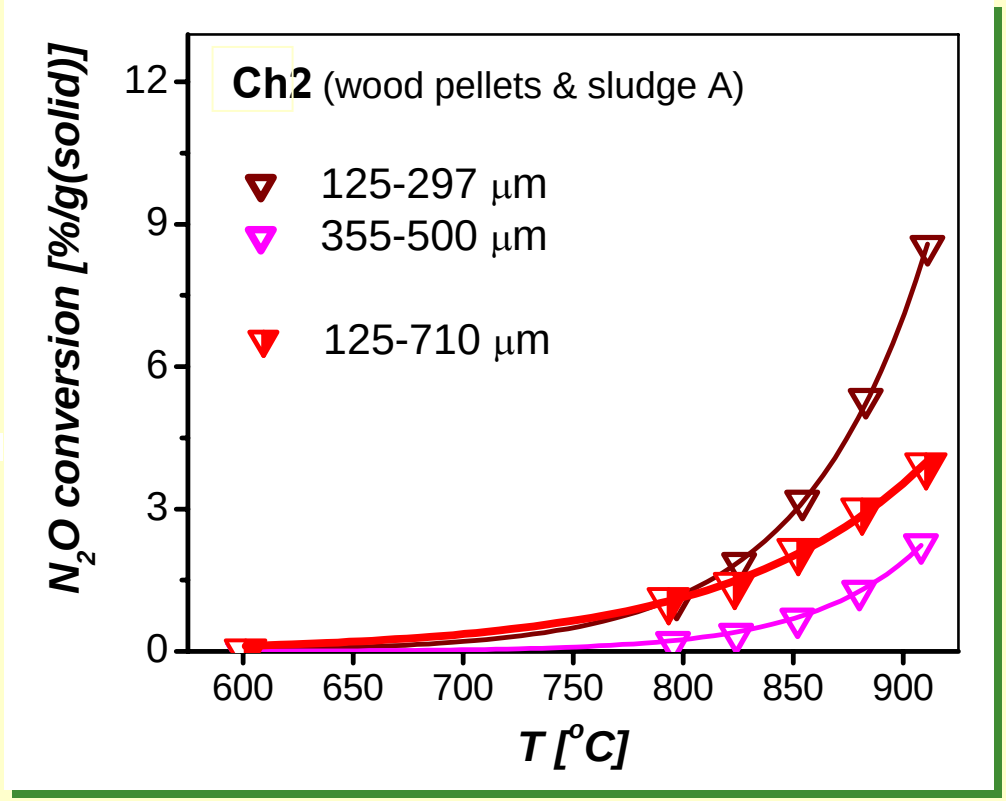




Results

Effect of particle size



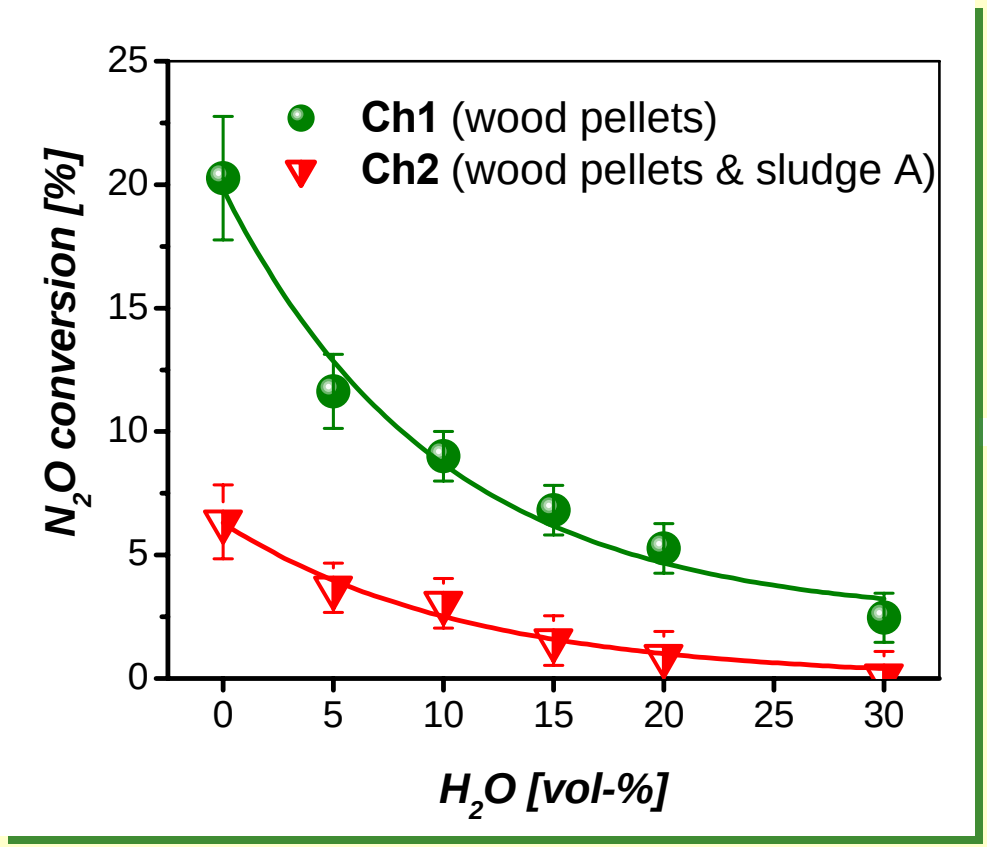


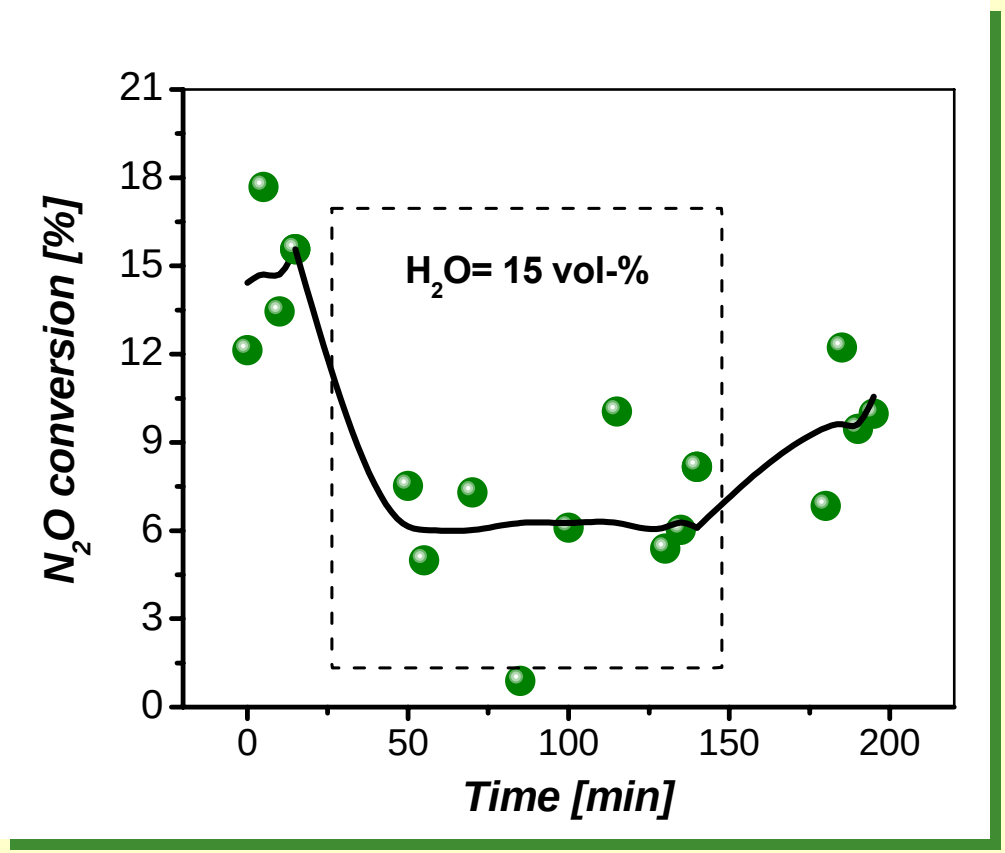
Fraction 125-297 μm: ~8 wt-%; 355-500 μm: ~48 wt-%; 125-710 μm: ~97 wt-% of original sample

Pressure 1 atm, residence time: 0.4 s, N_2O_{in}: 500 ppm_v in He, total gas flow 1800 ml/min.

Results

Effect of water vapor





Sample particle size: 125-710, pressure 1 atm, temperature 850°C, mass of sample ~3 g, residence time: 0.4 s, N_2O_{in}: 500 ppm_v in He, total gas flow 1800 ml/min.

Conclusions

- **All investigated materials act as a catalyst, in the temperature range 800-910ºC, and their activities were affected by fuel type.**

- **The elemental composition of the bed material, mostly sand particles, gave good correlation with the activity. The measured catalytic activity of the bed material samples increased with the amount of the catalytically active oxides (CaO, MgO, Fe_2O_3, Al_2O_3).**

- **The elemental composition of the coating layer of the sand particles changed according to the composition of the ash from the parent fuel.**

Conclusions

- **In case of the bed material sampled while burning wood pellets with small amount of ash, different size fractions of bed material had similar activities.**

- **In case of the bed material sampled while burning wood pellets and sludge with high amount of ash, the activity of different size fractions of bed material decreased when particle size increased from 125-297 to 355-500µm.**

- **The higher activity of 125-297 µm fraction was attributed to a higher content of particles of ash (sludge), which are more porous and have a higher amount of catalytically active oxides.**

Conclusions

- **Increase of water up to 15 vol-% caused a significant decrease in the activity of bed materials, but from 15 vol-% to 30 vol-% there was only a minor further decrease.**

- **The decrease of activity was attributed to both sintering and coverage of active sites by H_2O molecules.**

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