Co-Firing Black Liquor and Biomass in a Laboratory Single Droplet Reactor – Effects on Emissions and Combustion Characteristics

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Study Description

- ***Objective***: Provide initial laboratory data on the impact of four fuels (bark, wood, peat, biosludge) on the combustion properties of BL when mixed in at two addition levels.
- Properties studied:
  - Swelling
  - Duration of burning stages
  - Carbon release
  - NO formation

Content

- Experimental
- Swelling Results
  - Videos – BL, +13,3 wt% Peat; +25,5 wt% Peat; +0,8 wt% BS; +1.8 wt% BS.
- Duration of Combustion Stages
- Carbon Release
- NO formation
- Element addition

Experiments

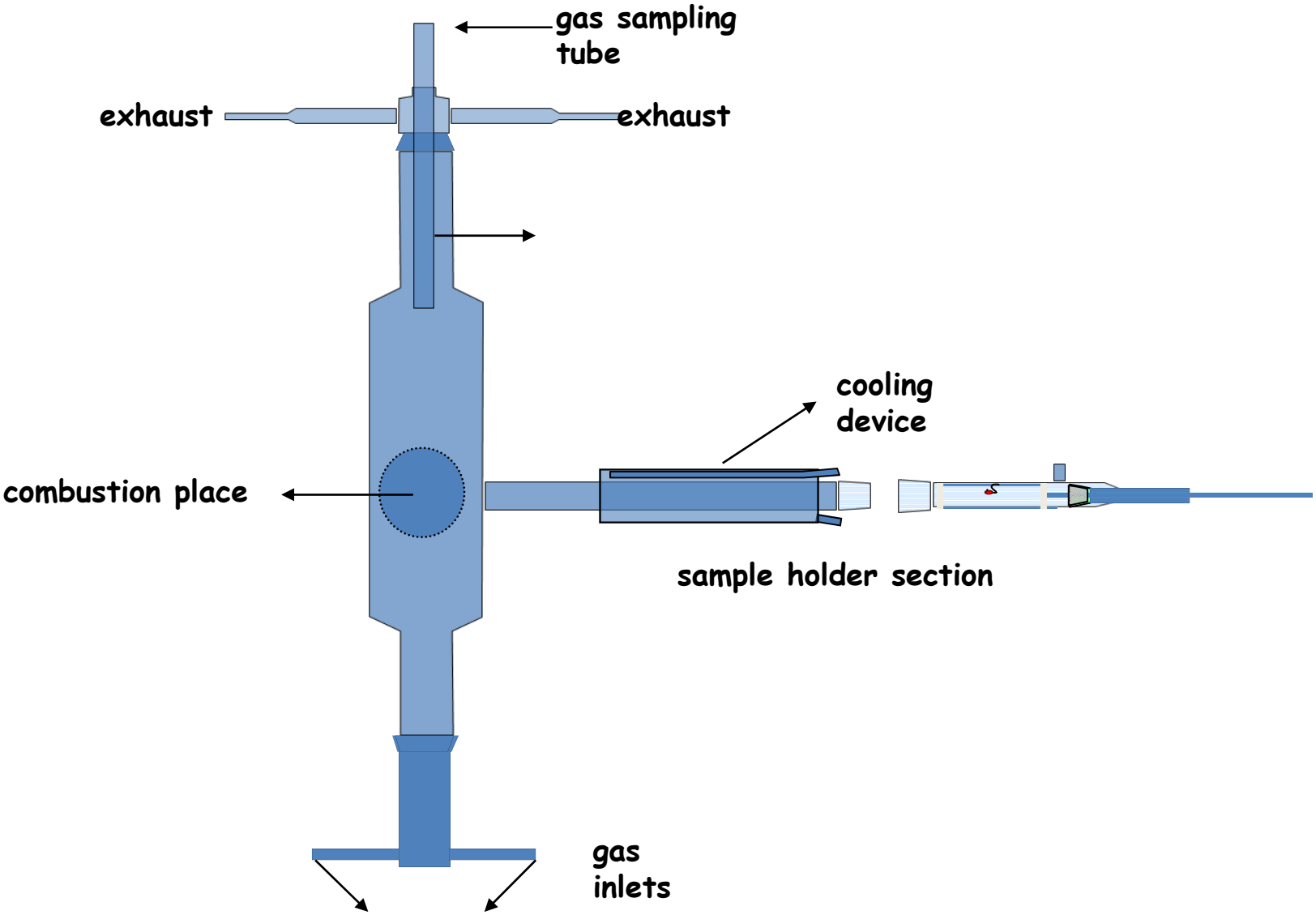
Conditions:

- 3% O_2
- 1100ºC
- 6 repetitions for each run

Raw Fuels:

- BL: Finnish, softwood
- Bark: particle size <1mm
- Wood: particle size ≤ 4 mm
- Peat: particle size = powder
- Bio-Sludge: (21.9% d.s.)

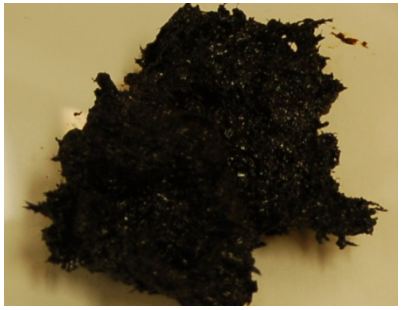
Droplet Furnace



Tests performed

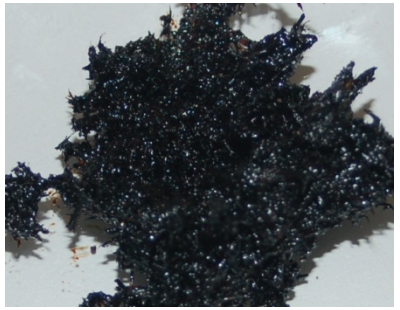
Sample	Biomass Dry Solids (wt %)	Mixture: Mass Fraction Biomass (wt % d.s.)	Mixture (wt % d.s.)
BL	80,4		80,4
Bark	95,0	13,2 / 25,6	82,1 / 83,7
Wood	95,9	13,3 / 26,9	82,2 / 84,1
Peat	94,2	13,3 / 25,5	82,0 / 83,5
Bio-sludge	21,9	0,82 / 1,84	78,7 / 76,6

BL 468



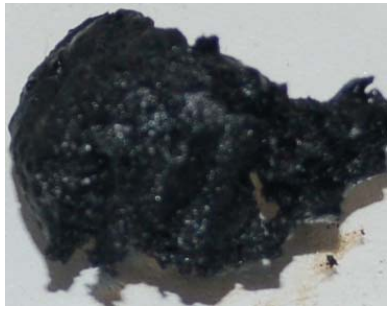
BL + 13,2 %
Bark

BL + 25,6 %
Bark

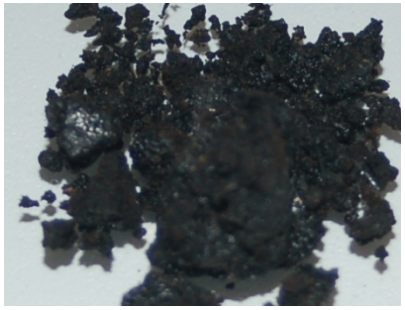


BL + 13,3 %
Wood Chips

BL + 26,9 %
Wood Chips



BL + 13,3 %
Peat



BL + 25,5 %
Peat

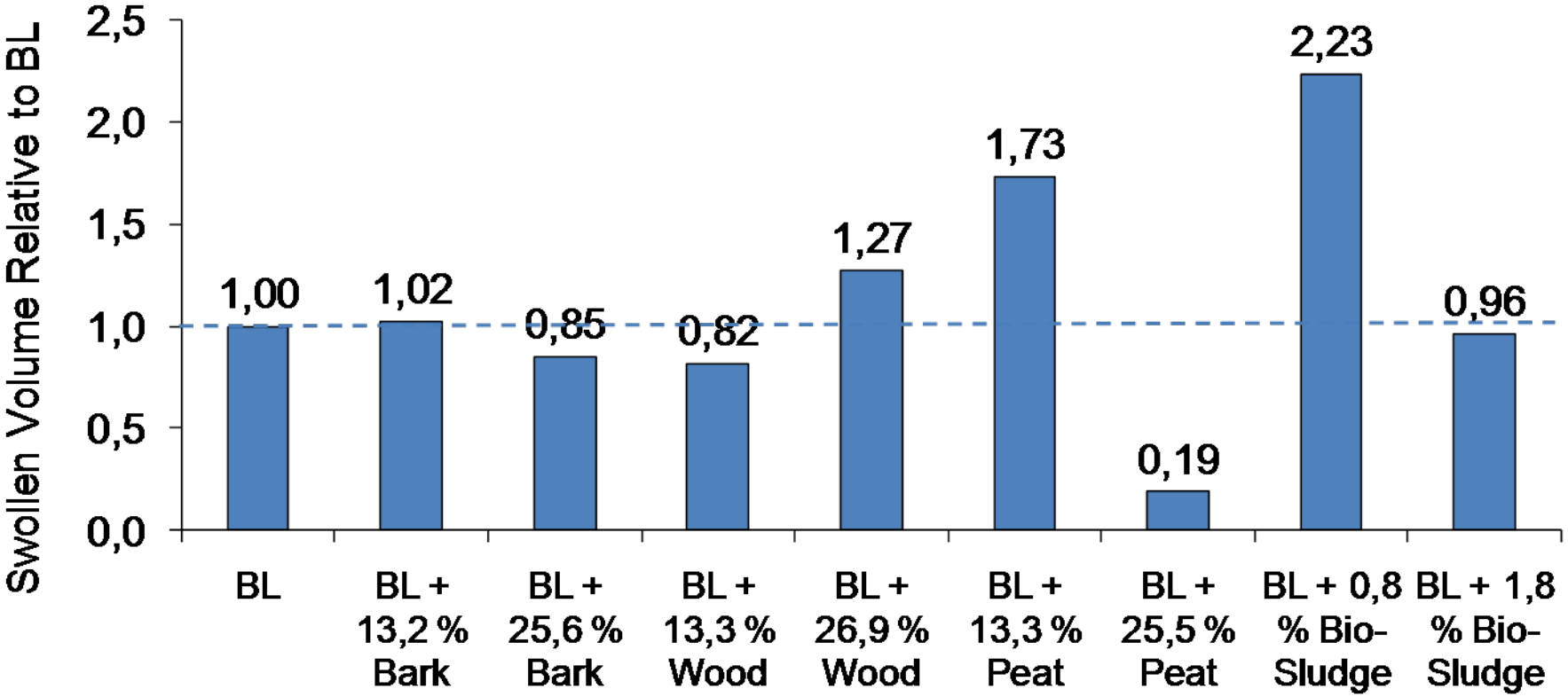
BL + 0,82 %
Bio-sludge

BL + 1,84 %
Bio-sludge

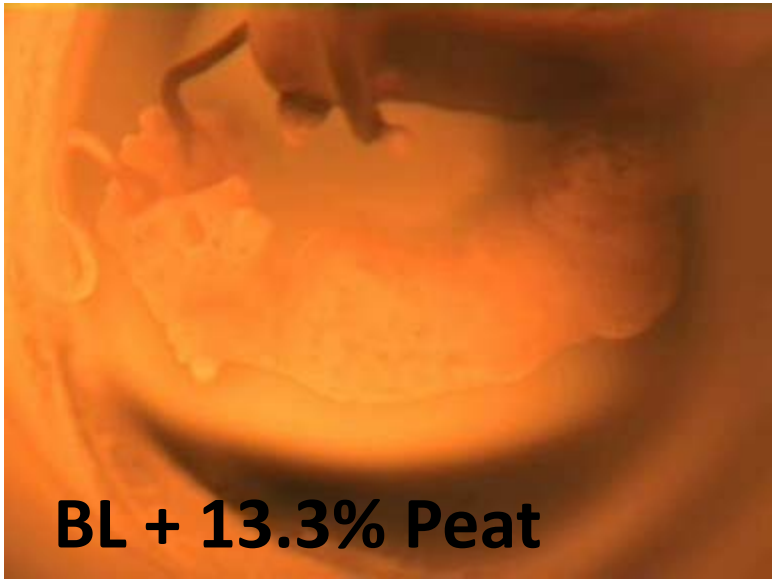
Maximum Swelling

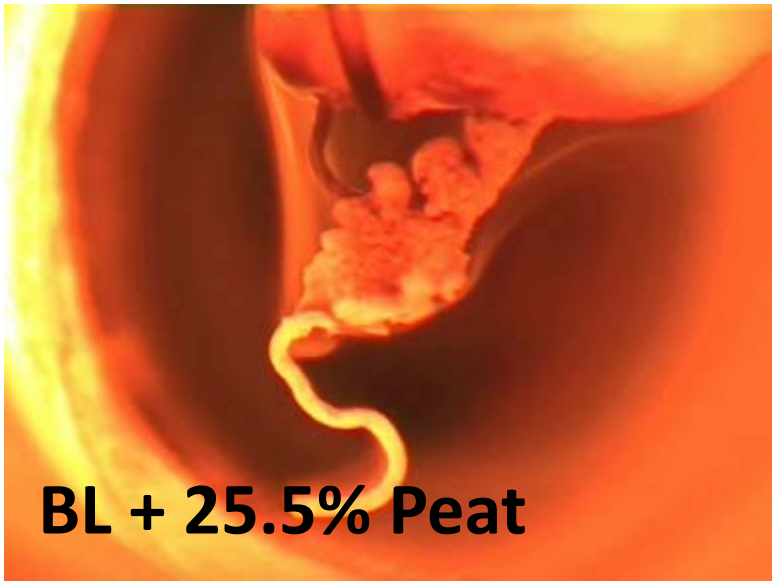
- Measured from 2-D digital image of droplet at maximum swelling
- 2-D surface fit to elipse or circle
- Volume and surface determined for best fit of an ellipsoid or sphere

Average Maximum Swelling

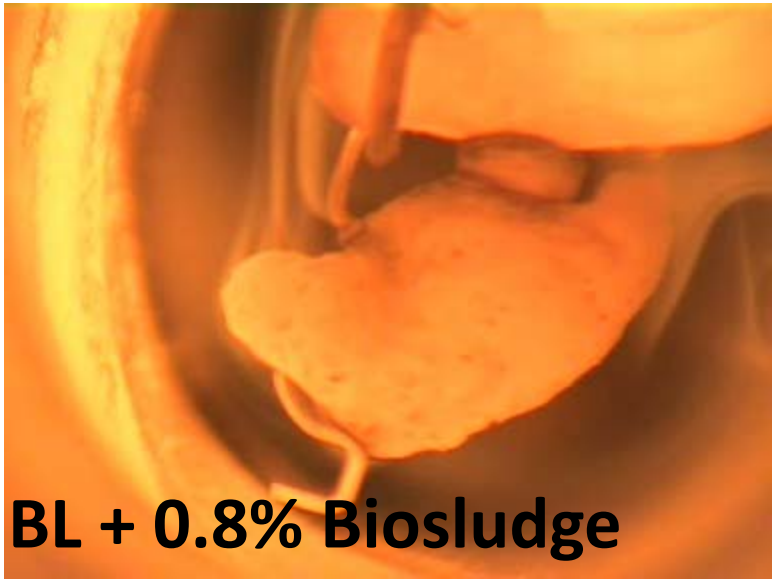


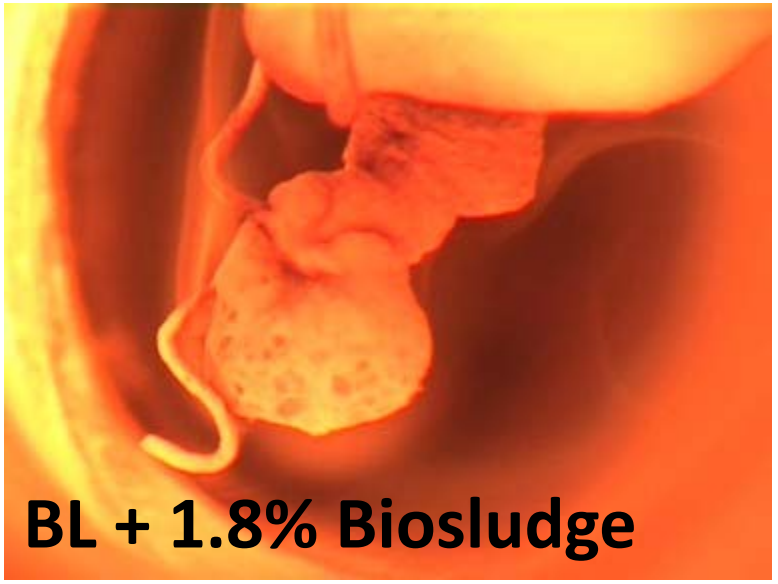

BL


BL + 13.3% Peat


BL + 25.5% Peat


BL


BL + 0.8% Biosludge

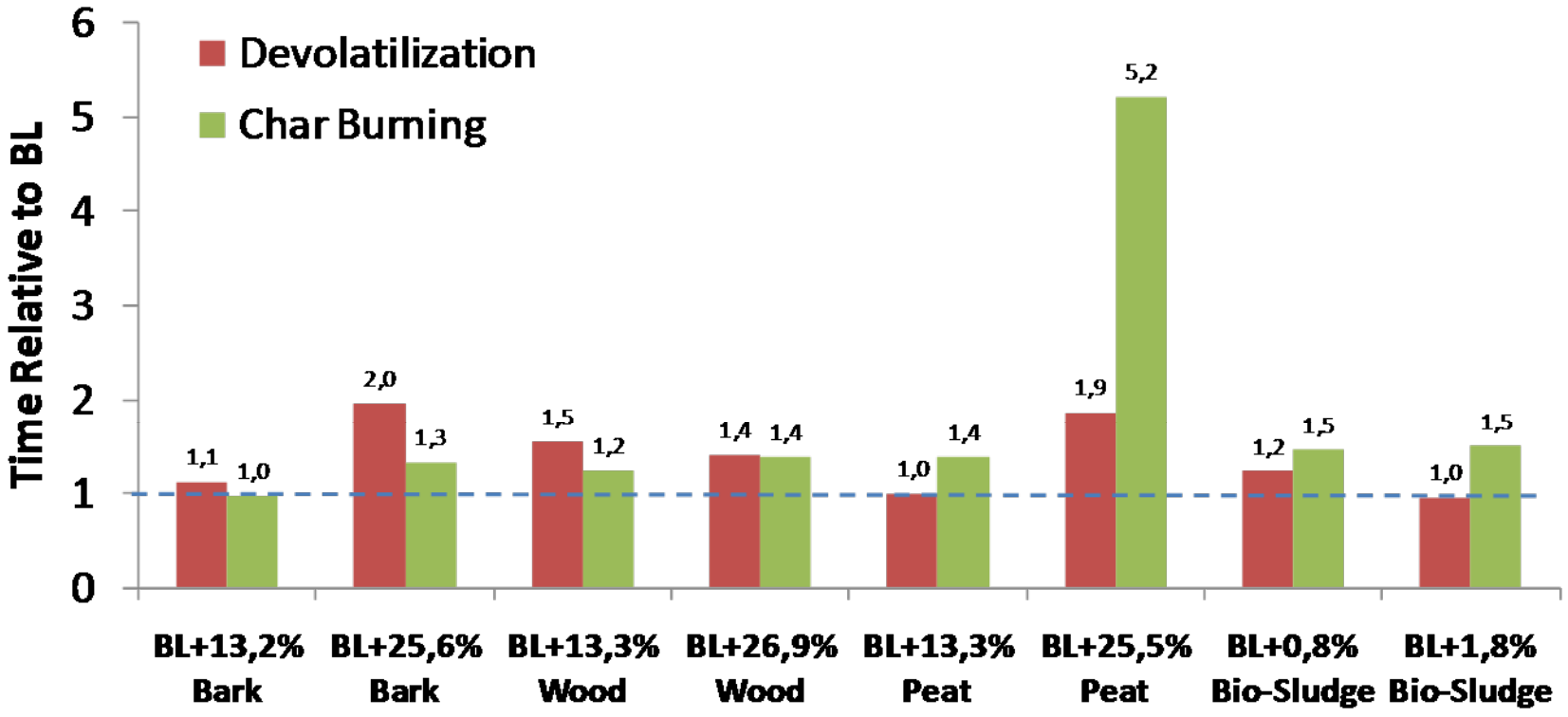

BL + 1.8% Biosludge

Duration of Combustion Stages

- Determined from droplet combustion videos
- **Drying*** – time between insertion and flame
- **Devolatilization** – time from beginning to end of flame
- **Char burning** – time from end of flame to char collapse

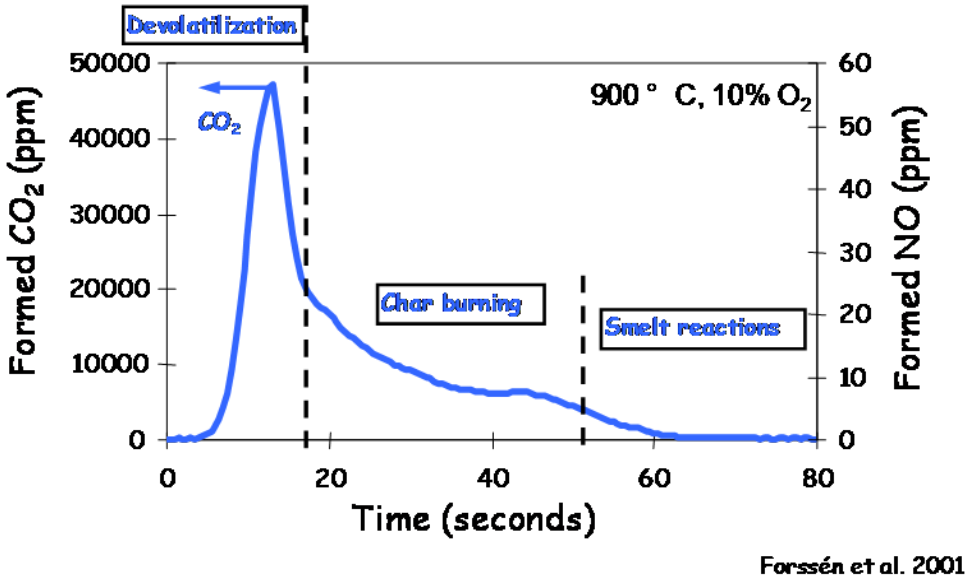
*Drying not reported as some drying occured already before insertion due to high reactor temperature

Duration of Combustion Stages



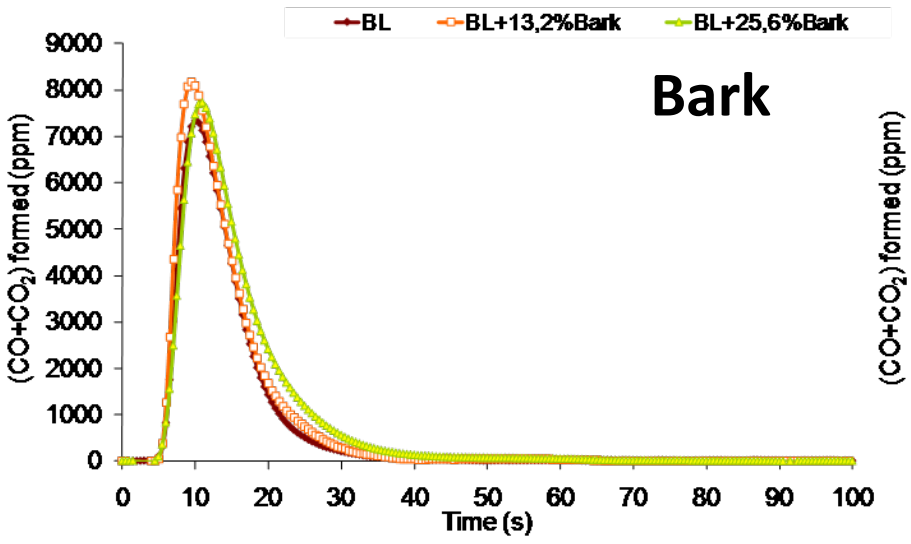
Carbon Release

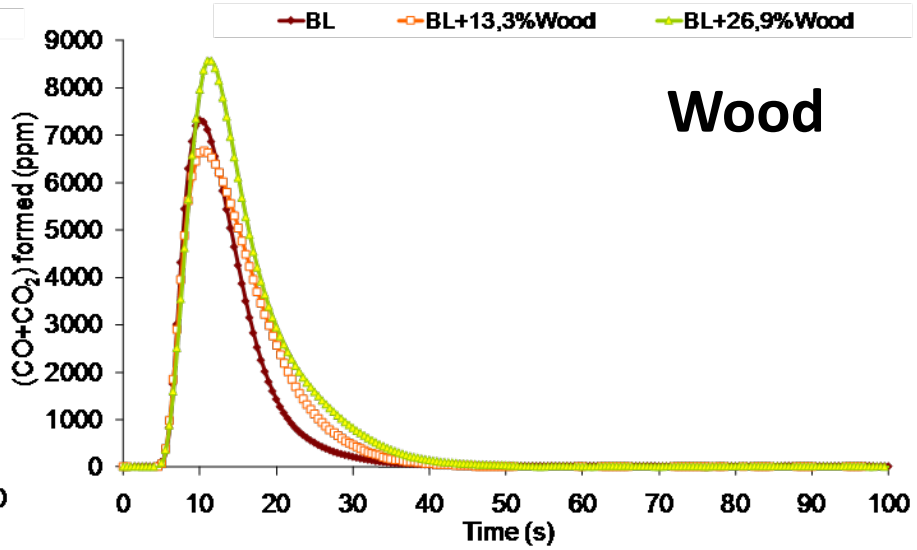
- CO and CO_2 measured with on-line infrared analyzers
- CO and CO_2 release can be divided into devolatilization and char burning stages

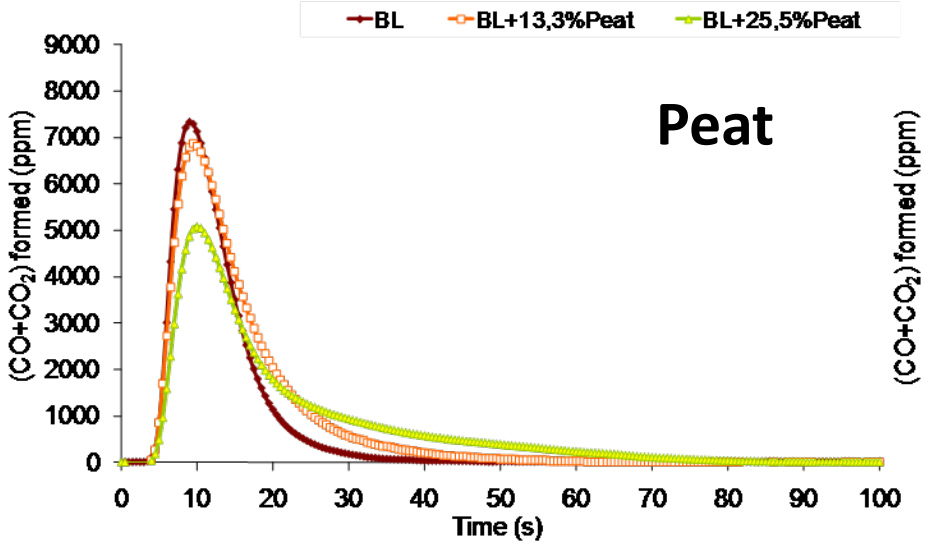


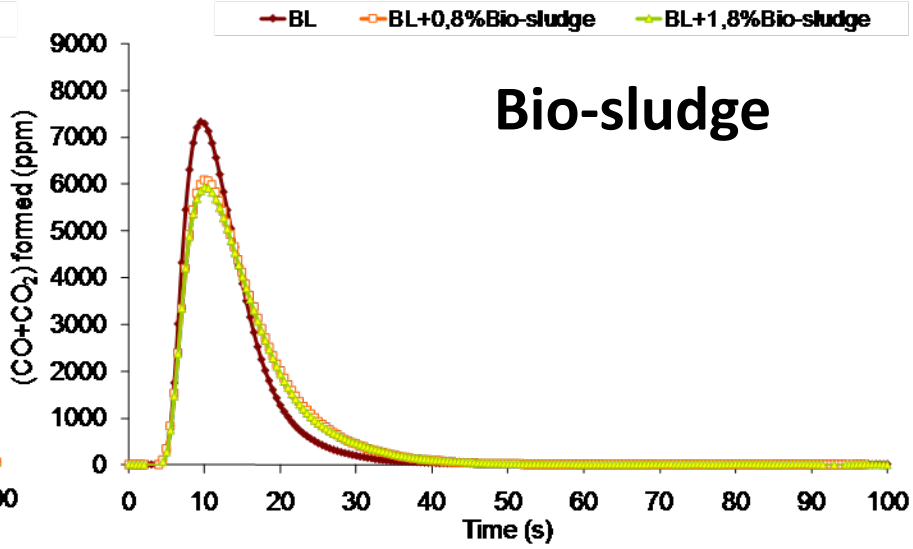
Forssén et al. 2001

Carbon Release Curves ($CO+CO_2$)



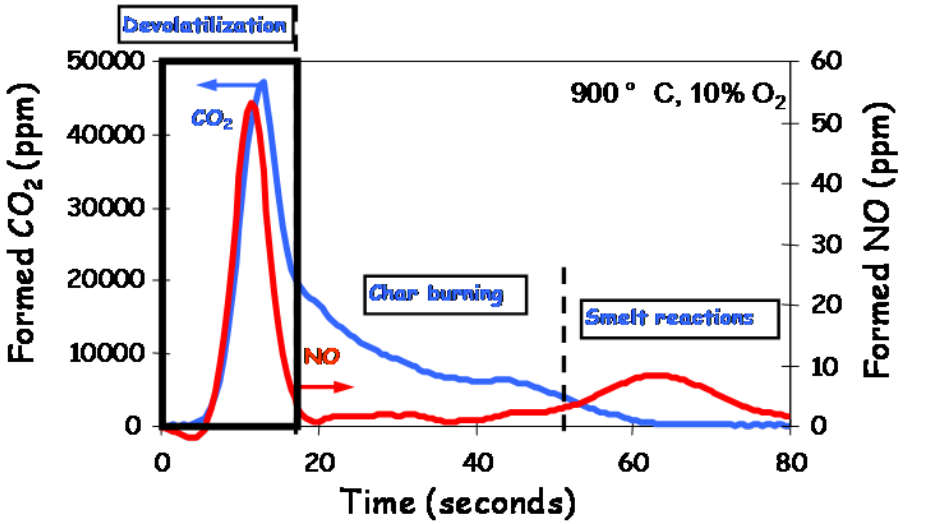






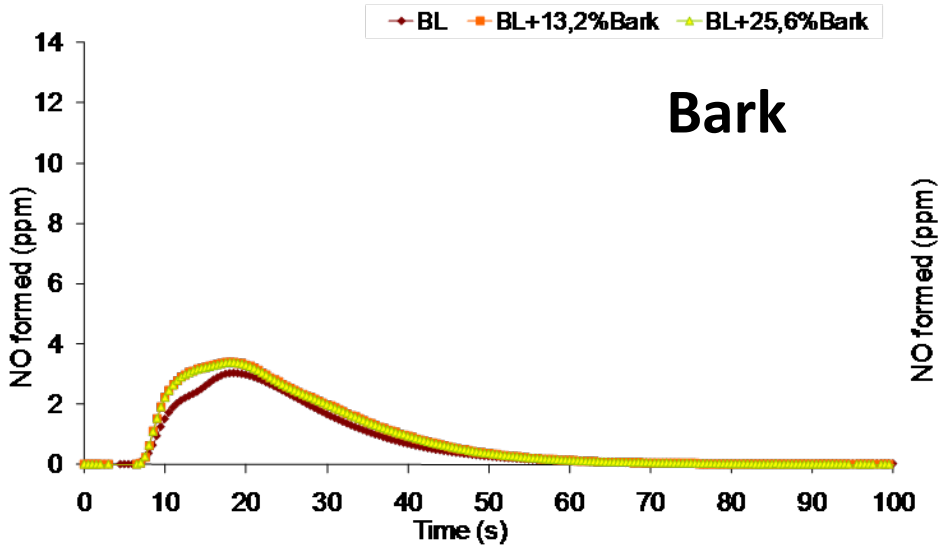
NO formation

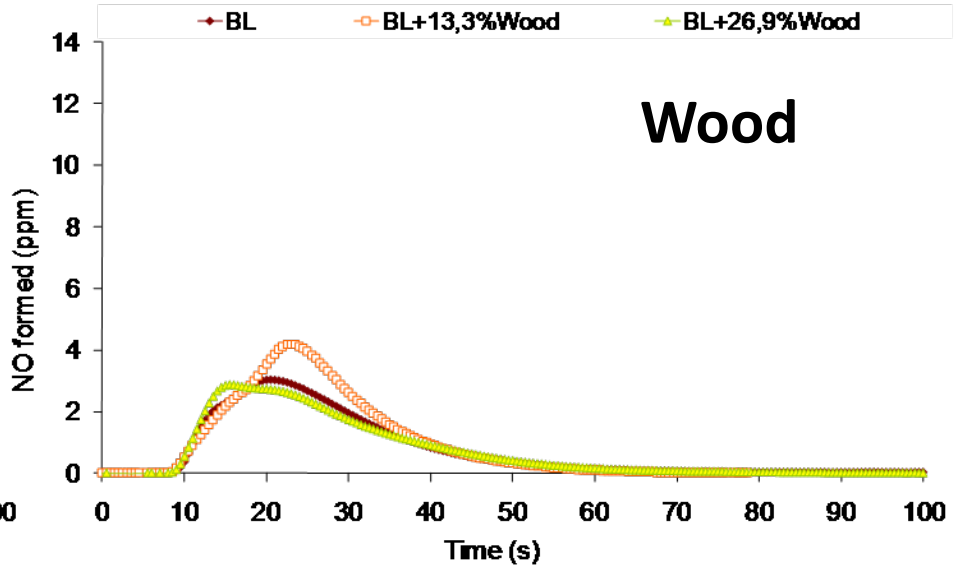
- NO measured by an online chemiluminescence analyzer
- Below 900 °C, expect separate NO peaks for devolatilization and char burning stages
- Above 900 °C, there is overlap and only one peak in droplet tests

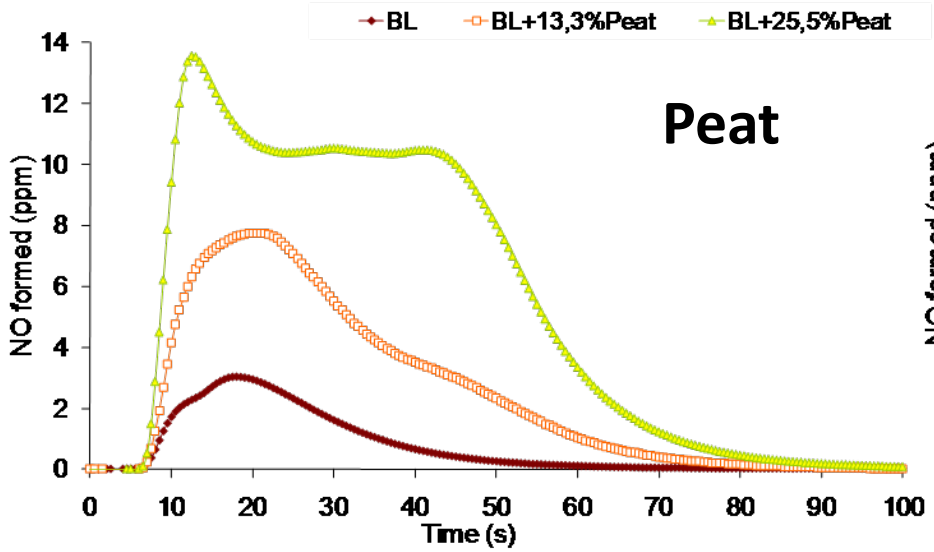


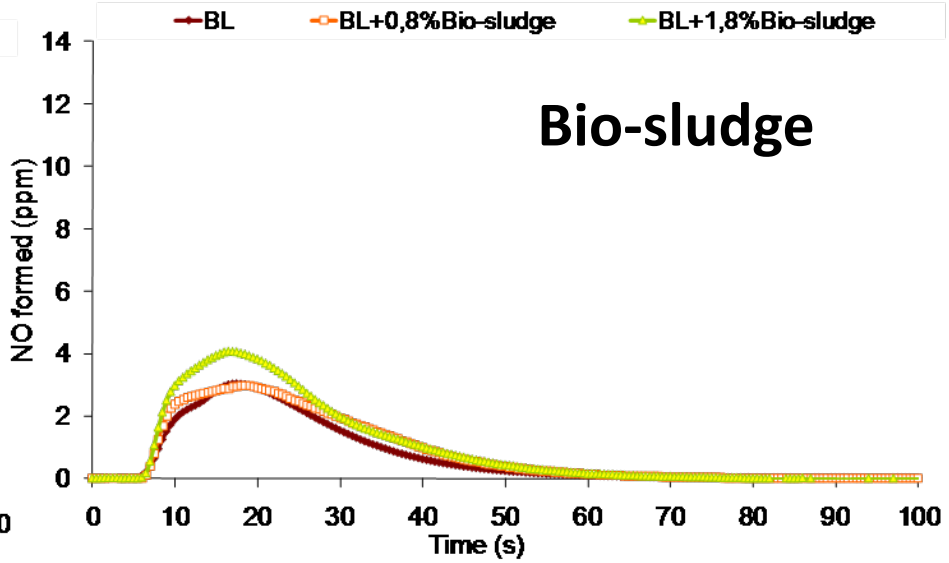
Forssén et al. 2001

NO formed (ppm)

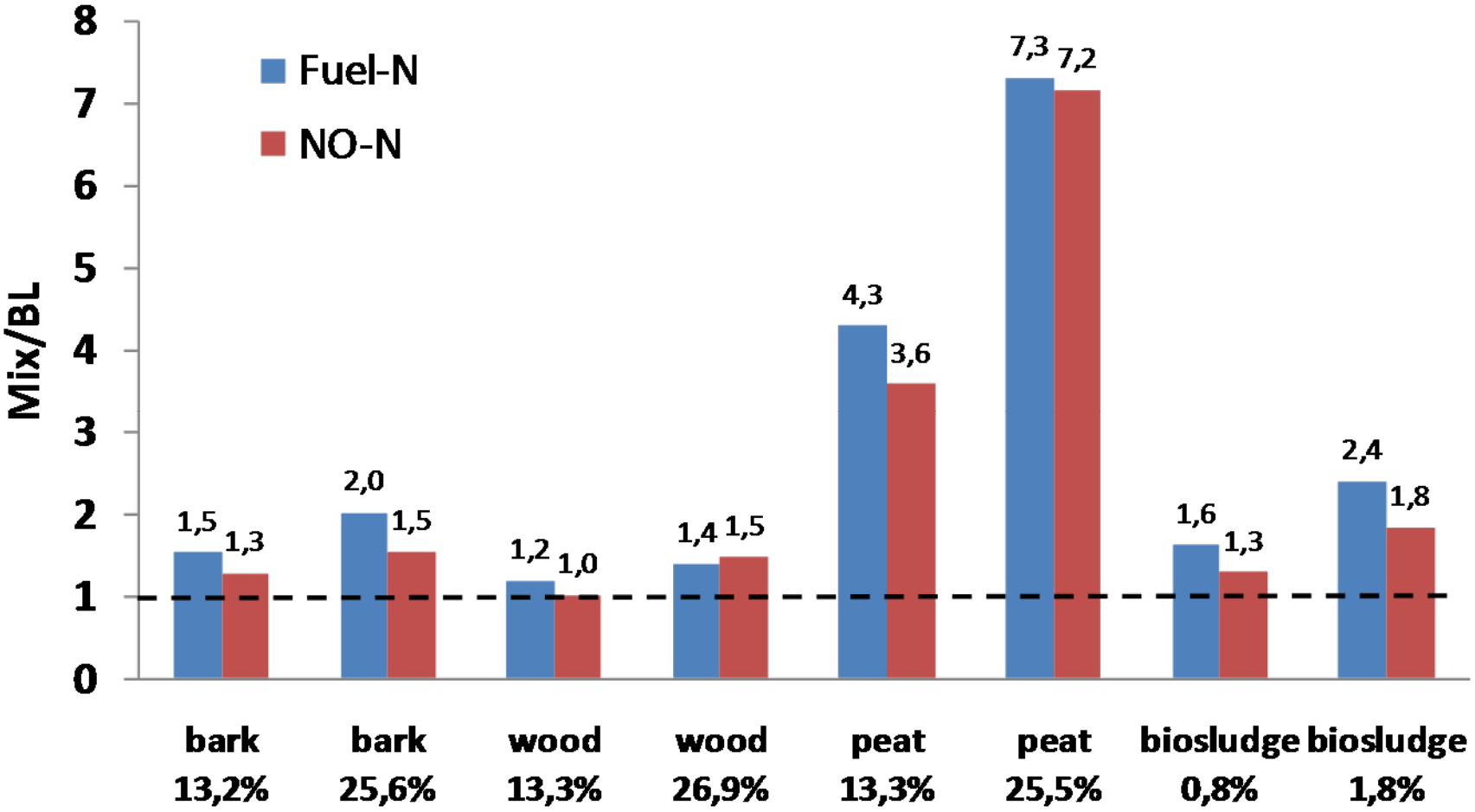








N – Relative to BL

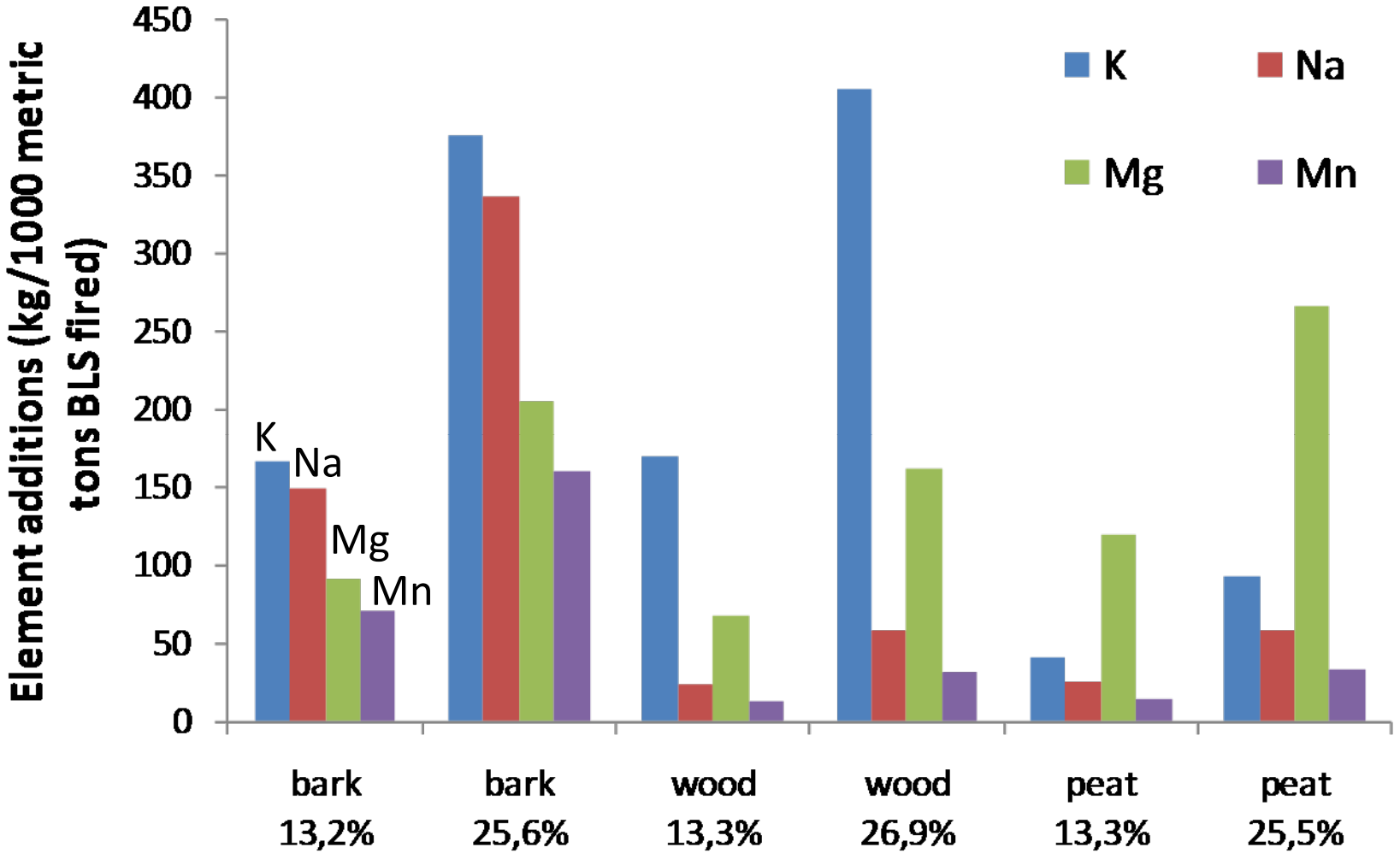


*Biosludge N assumed from analysis of an earlier sample from same mill, others analyzed

Elemental Composition

Element	Bark	Wood	Peat
K (mg/kg d.s.)	1090	1100	270
Na (mg/kg d.s.)	978	160	171
Mg (mg/kg d.s.)	599	440	780
Mn (mg/kg d.s.)	465	87	97

Additions of Some Elements



Summary

- Droplet homogeneity difficult to ensure
- Peat had the largest overall impact
- Changes in swelling difficult to explain
- Char burning marginally increased by all fuels except 13,3% bark (no change) and 25,5% peat (large change)

Conclusions

- Results show promise for co-combustion
- Increases in NO can largely be controlled by air staging
- Additional information needed:
  - Different combustion conditions
  - Mixing BL + biomass
  - Spraying