UNIVERSITY OF EASTERN FINLAND

The effect of dilution ratio and wood species on particulate emissions

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2nd INTERNATIONAL REAL-LIFE EMISSIONS WORKSHOP ON SMALL-SCALE COMBUSTION

26.10.2023

Contents

Introduction

Dilution

- Dilutive sampling methods model the dilution of the sample in the atmosphere
- Can affect on the particle concentrations (gas-particle partitioning)
- The effect has not been studied broadly

Wood species

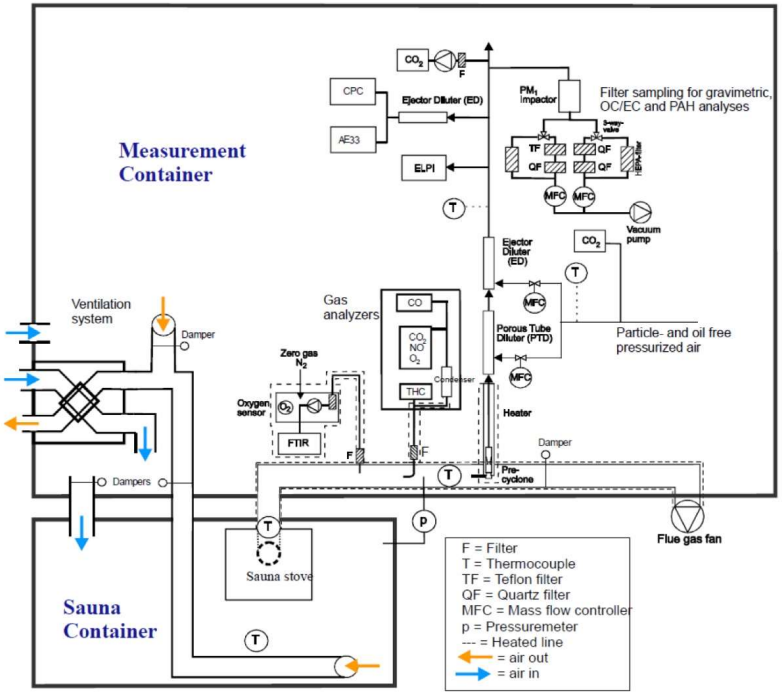
- Various types of wood species are combusted
- Dissimilar concentrations of PM emissions
- Impacts on emission inventories

Objectives

- To examine the effects of different flue gas dilution ratios (DR) on the particulate emissions
  - Comparing of results between different DRs with pine wood
- To observe the extent of particulate emission concentrations from the combustion of different wood species
  - Normal moisture: Pine, BirchA, BirchB, Alder and Spruce (moisture content between 16-18 %)
  - Dry wood: Beech, Spruce and BirchA (moisture content between 6-7 %)
- Identify the better wood species options

Small-scale combustion simulator (SIMO)

https://sites.uef.fi/fine/front-page/simo/

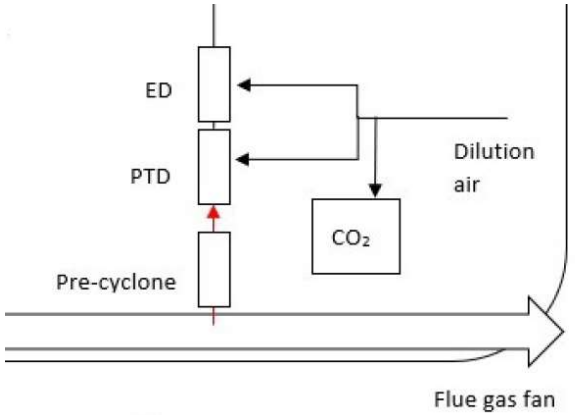


Tissari, J. et al. Fine Particle Emissions from Sauna Stoves: Effects of Combustion Appliance and Fuel, and Implications for the Finnish Emission Inventory. *Atmosphere* 2019, *10*, 775. https://doi.org/10.3390/atmos10120775

Experiments

- Combustion appliance
  - Elliptical shaped soapstone covered stove with baking oven
- Experiments were performed with same protocol
  - Six batches
  - BirchA logs in first batch in all tests
  - DR experiments with pine wood
  - Wood specie experiments with DR = 90

Dilution system



- Two-phase dilution system for particle measurements (combination of porous tube diluter (PTD) and ejector diluter (ED))
  - 10 µm pre-cyclone
  - PTD minimizes the losses and transformation of the particles and water vapor condensation
  - ED stabilizes the sample flow
- Additional ED for the most sensitive instruments
- DR was calculated from the measured CO_2 concentrations
  - Raw gas, background air and diluted gas

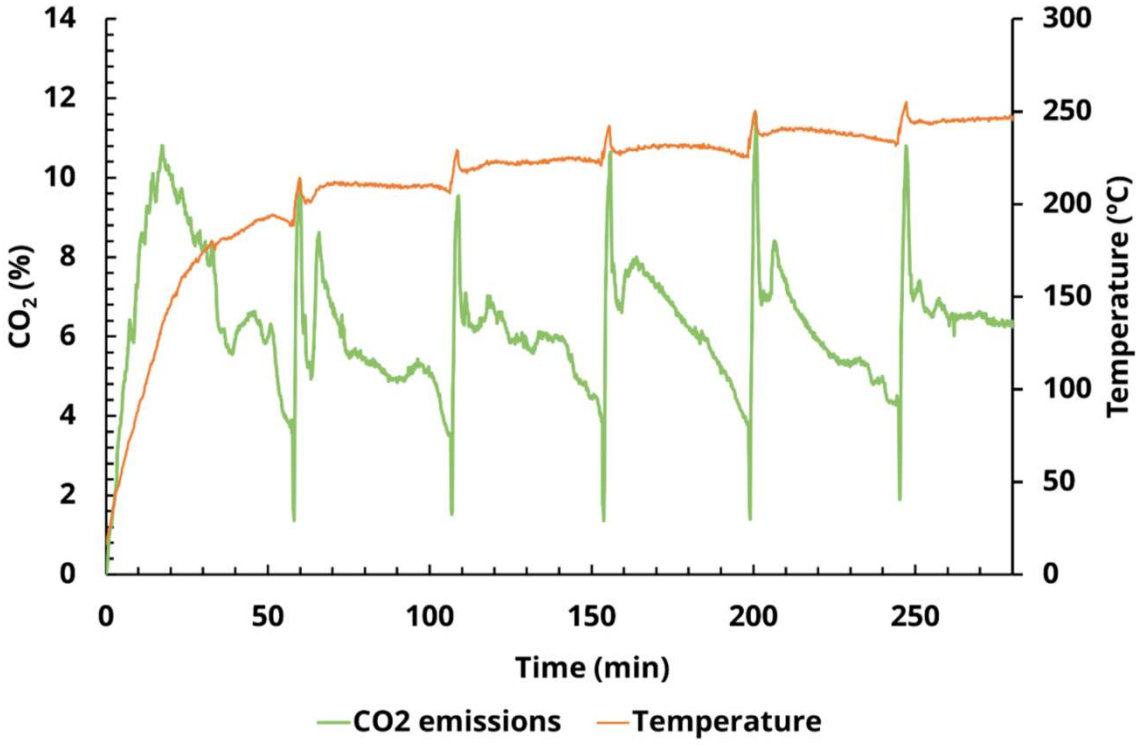
Measurements

- Gas analyses
  - THC, CO, CO_2, NO (gas analyzer), VOCs (FTIR)
- Real-time particle measurement and analyses
  - Particle number concentration (CPC), mass concentration and numbers size distribution (ELPI), Black carbon mass concentration (aethalometer), human lung-deposited surface area of particles (NSAM)
- Filter sampling from each batch
  - OC/EC analysis (thermal-optical carbon analyzer)
  - Analysis of 30 PAH compounds (gas chromatograph mass spectrometer)

The effect of dilution ratio

- CO_2 levels of first and second batch differed from other batches
- Flue gas temperature increased considerably during first and second batch

→ batches 3-6 were considered when comparing results

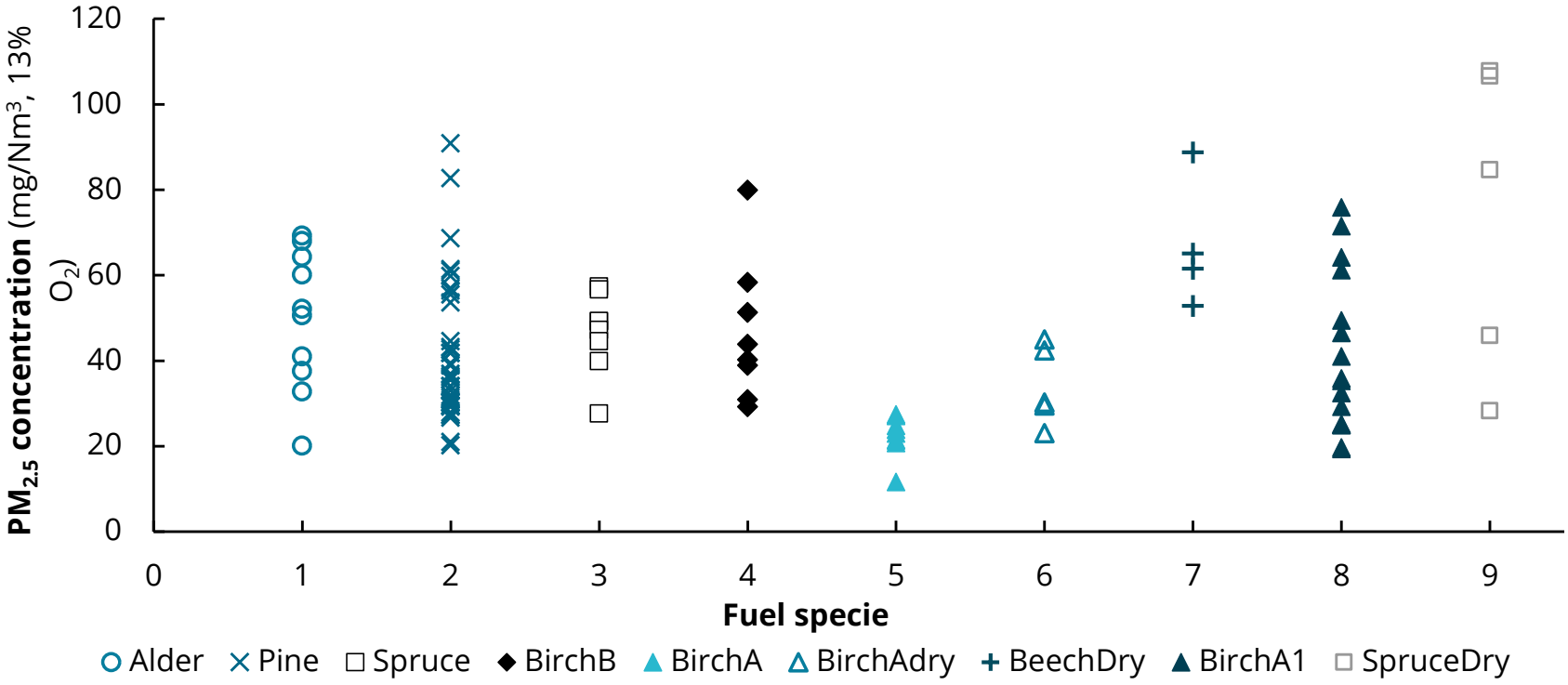


Effect of DR on particulate emissions (Batches 3-6, N=4-8/DR)

Mean and standard deviation of particle concentrations ($PM_{2.5}$, OC and EC) by DR. Particle concentrations are normalized to 20 °C, 1 atm and 13 % O_2.

DR	$PM_{2.5}$ (mg/Nm³)	OC (mg/Nm³)	EC (mg/Nm³)
9,3±2,0	41,0±11,3	**8,9**±5,4	25,1±13,4
20,1±0,1	45,3±10,7	7,2±2,7	36,1±10,4
40,0±0,1	31,2±1,5	6,3±2,3	20,0±3,7
89,8±0,0	32,2±10,5	6,7±3,7	22,0±8,7
512,4±48,4	46,3±13,3	7,4±2,0	25,7±3,5

$PM_{2.5}$ concentration in each batch



Summary

Dilution

- No clear correlation between DR and $PM_{2.5}$
  - Most of the differences are due to combustion conditions
- DR is not such an important factor for the modern appliances (when the EC dominate particulate mass)

Wood species

- Different fuel species produced different emissions
- Even same specie (e.g. BirchA and BirchB) differ
- Making combustion the same with different fuels is complicated → difficult to compare
- Also, the literature results of different fuels conflict from study to study
- **What kind of strategy with wood species would be the best in official testing of appliances?**

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Thank you!

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