The effect of wood fuel species on particulate and gaseous emissions from a wood stove

K. Dahal, R. Tamminen, H. Rinta-Kiikka, J. Tissari
Department of Environmental and Biological Sciences, FINE Particle and Aerosol Technology Laboratory, University of Eastern Finland, Kuopio, Finland

Introduction

- Combustion of biomass in the residential sector contributes significantly to the pollution of ambient air, in terms of fine particle emissions.
- In Europe, about 65% of total energy used by households is utilized for heating which is mostly covered by solid biomass combustion (1).
- Residential wood combustion (RWC) aerosol includes several particulate and gaseous compounds which are important particularly in terms of climate and health perspectives.
- The most relevant aerosol compounds from RWC are particulate matter (PM), black carbon (BC), particulate organic matter (POM), carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NO_X) and polycyclic aromatic hydrocarbons (PAHs).
- Each year, about 464 000 people die prematurely from illness attributed to ambient $PM_{2.5}$ emissions in Europe and the estimated life expectancy has been reduced 9 months on average due to ambient particles (2,3).
- Some compounds such as black carbon (BC) and methane (CH_4) are climate-warming elements of particulate matter (PM), but net warming effect of PM depends on the concurrent emissions of cooling aerosols (e.g., organic carbon) (2).

Objectives

- Various types of wood species (e.g., pine, willow, oak, poplar, birch, and beech are combusted in the residential combustion systems in different parts of Europe.
- Combustion of different biomass species produces dissimilar concentrations of PM emissions in European countries which impacts on emission inventories.
- The aim of this study is to observe the extent of particulate and gaseous emission concentrations from the combustion of different wood species: Pine, Birch, Alder, and Spruce.
- The idea is also to identify the better wood species options for RWC.

Method

- Six batches (10.5 kg each) of different wood species (birch, pine, spruce and alder) with birch for the first batch were combusted in a wood stove.
- To a feasible extent, same protocol for each experiment was applied and tests were repeated two times.
- The experiments were conducted in the small-scale combustion simulator (SIMO) at the University of Eastern Finland https://sites.uef.fi/fine/front-page/simo/
- For particle measurement, a two-phase [ED+PRD] dilution system was used.
- The dilution ratio was controlled and was set to a constant value of 90.
- Concentrations from particle measurements were performed with several on and off-line instruments as described in Figure 1.
- OC and EC analyses were performed in a Thermal/Optical Carbon Analyzer.
- Data from the last four batches were analyzed for the determination of chemical compositions in flue gases (e.g., PM2.5, BC, OC, EC etc.).

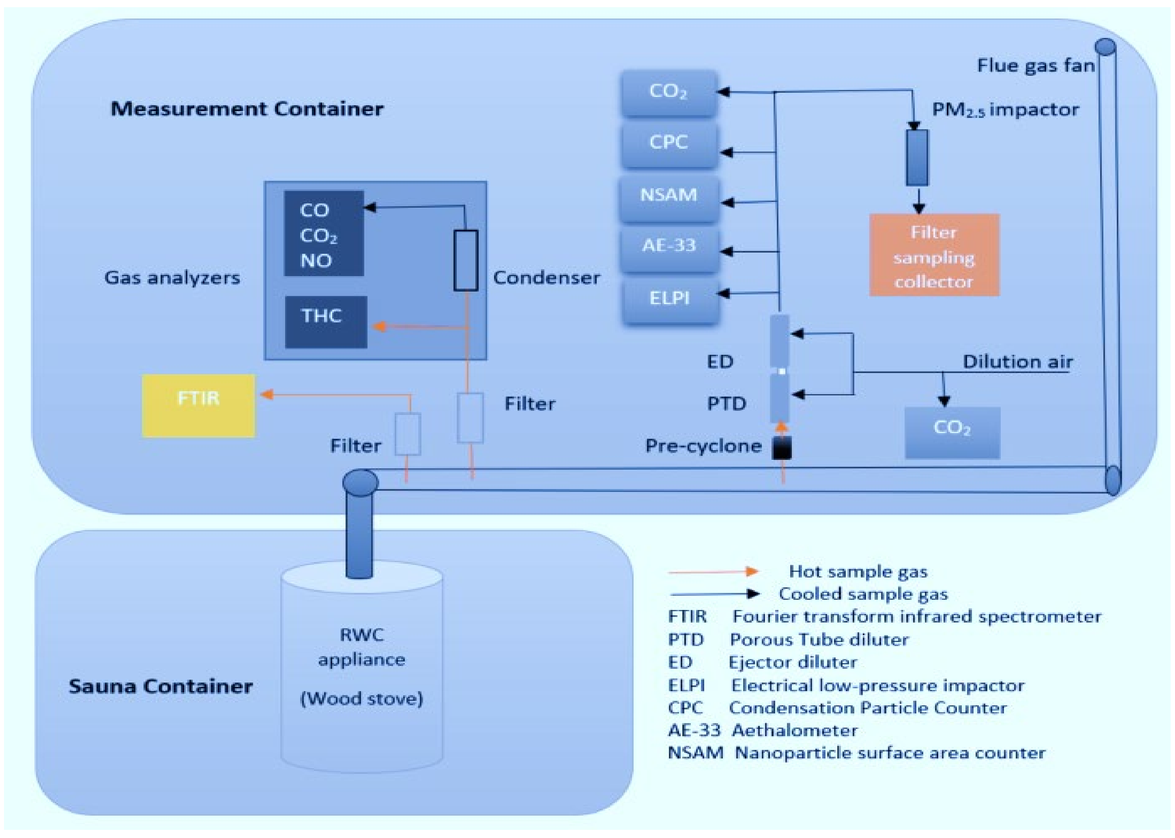

Figure 1: Experimental set-up with sampling system and instrumentations

Results I

- Both the gaseous and particulate mass emissions varied in the combustion of all four fuel species, even if the same fuel, varied concentrations of these emissions in four different batches are clearly observed (Table 1, Figure 2).
- On average, all emissions were the lowest with birch wood (except of nitrogen oxide (NO), that was slightly higher than with pine wood), whereas spruce produced the highest CO, THC, OC and EC concentrations.
- EC portion in PM2.5 is 51-68% i.e., PM2.5 is mainly EC.

Table 1: Concentrations (in mg/nm^3, 13% O_2) of emission components for different fuel species

	NO	CO	THC	$PM_{2.5}$	BC	OC	EC
PINE	77.74	2080.99	50.73	32.18	19.71	5.04	22.01
SPRUCE	94.04	4671.53	163.69	46.46	13.62	13.64	21.05
ALDER	122.76	2821.18	105.13	48.61	19.49	11.69	24.84
BIRCH	88.70	1239.45	20.06	22.28	13.61	3.89	14.75

Results II

- Largest variation of emissions was observed in Alder wood (e.g., $PM_{2.5}$ = 20.1 to 69.3 mg/Nm^3), while the smallest variation of emissions was observed in birch wood; (e.g., $PM_{2.5}$ = 11.6-27.5 mg/nm^3) (Table 1 and Figure 2).

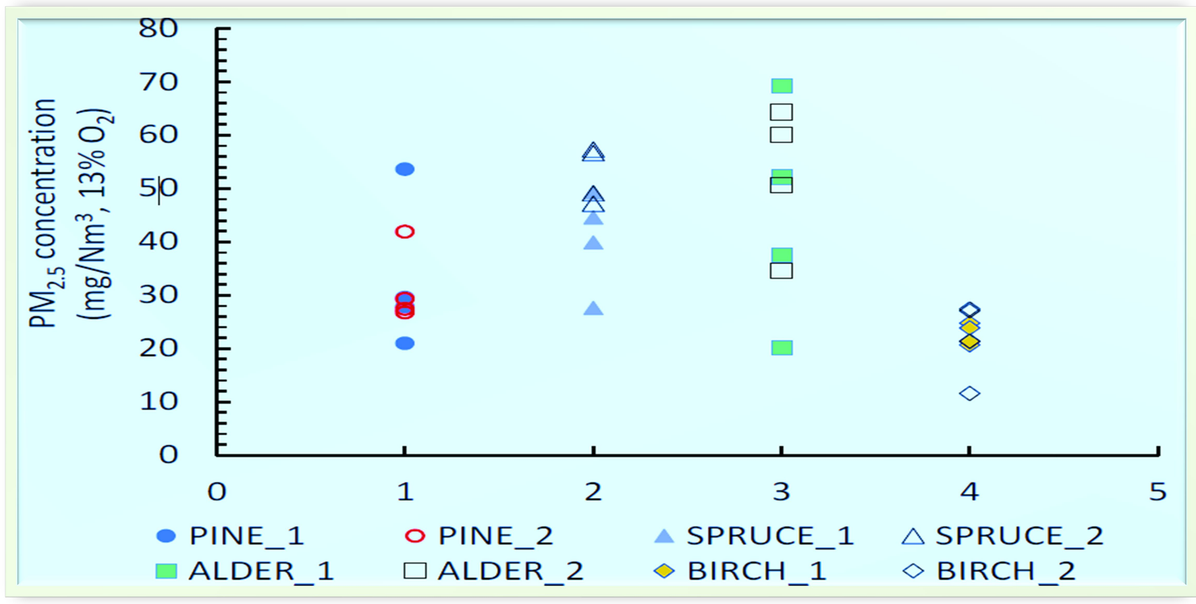

Figure 2: Effect of different fuel species on PM2.5 emission

Conclusions

- The different fuel species produced different concentration of gaseous and particulate emissions, thereby, referring to the chemical content of the wood (e.g., N content) as one determining factor for generating the emissions.
- Among all tested fuel species, birch wood seems to be better option for combustion in this kind of stove.
- Several other parameters such as air to fuel ratio, physical size of the wood logs, and the moisture contents may also have the impact on emission formation.

References

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Real-LIFE Emissions Project Website:
https://sites.uef.fi/real-life-emissions/

Karna Dahal
karna.dahal@uef.fi