RESIDENTIAL WOOD COMBUSTION: TIME-RESOLVED PARTICLE SIZE DISTRIBUTION AND MORPHOLOGICAL FEATURES

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INTRODUCTION

Residential wood combustion is of increasing concern as it has been identified as a major source of atmospheric pollution, mainly in winter, either in rural or urban areas. Analysis of time-resolved measurements can help understanding how the emissions evolve during the combustion process and how the different parameters are inter-related. Furthermore, it can be a useful tool to identify critical stages/intervals in the emission of particles, to contribute to the development of low emission combustion processes/technologies and, consequently, to reduce their impacts. This study aims to characterise aerosol size distributions, number emission factors (EF) and morphological characteristics of particles emitted during the combustion of logs of three common Southern and mid-European woods in two different combustion devices. This study complements a paper already published on the time-resolved study of the evolution of EF gases and particle chemical composition throughout the combustion cycle [1].

FUEL CHARACTERISTICS

The wood was cut into logs of 0.3 to 0.4 m in length with a total biomass burned during each combustion cycle of around 1.7 to 2.0 kg (4 logs in each cycle). The combustion of a batch of fuel lasted between 50 and 90 minutes.

Table 1. Chemical characteristics of the biomass fuel.

		Q. pyrenaica	*P. nigra*	*F. sylvatica*
Proximate analysis (% wt, as received)	Moisture Stove	9.7	6.6	7.9
	Moisture Fireplace	7.5	5.6	11.0
Ultimate analysis (% wt, dry basis)	Ash	2.94	0.53	0.42
	C	47.22	48.86	47.97
	H	5.94	6.26	6.26
	N	0.20	0.07	0.04
	S	bdl	bdl	bdl
	O (by difference)	43.70	44.28	45.31

bdl: below detection limit

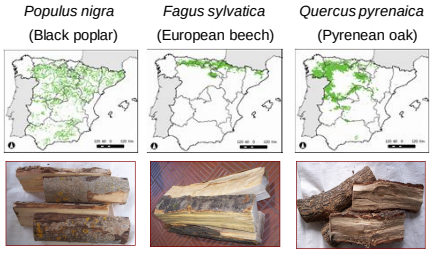
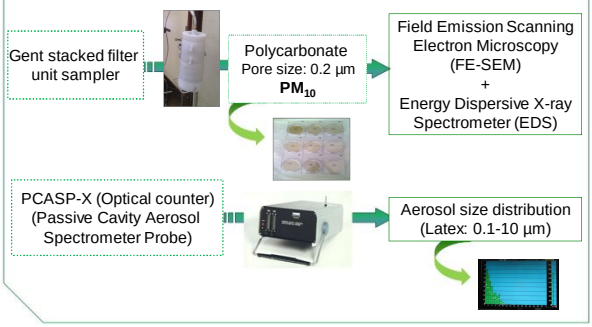


Fig. 1. Distribution in Spain of the tree species combusted and logs used for a fuel batch.

MEASUREMENT EQUIPMENTS



EXPERIMENTAL INFRASTRUCTURE

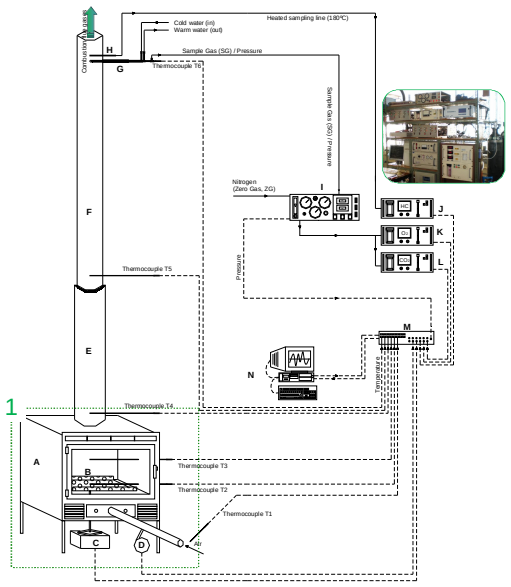


Figure 2. Schematic representation of the experimental installation.

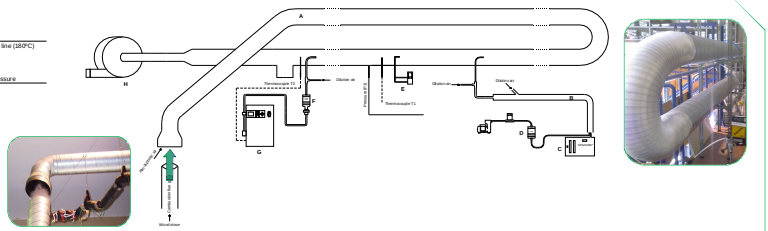


Figure 3. Schematic representation of the dilution tunnel and the sampling instrument. A - dilution tunnel; B – Second dilution tunnel; C– PCASP-X; D– Gent; E– Pitot tube; F - PM2.5 sampling head (TECORA); G - TECORA control and data acquisition system; H - blower.

Dashed line - Electric circuit,
Continuous line - Pneumatic circuit.

- **A** – Stove
- **B** – Grate of the stove
- **C** – Load cell (weight sensor)
- **D** – Air flow meter
- **E** – Thermal insulation of the exhaust duct
- **F** – Exhaust duct (Chimney)
- **G** –Water-cooled gas sampling probe
- **H** – Heated sampling line
- **I** – gas sampling and conditioning unit
- **J, K, L** – Automatic on-line gas analyzers
- **M** – Electronic command unit (UCE1)
- **N** – Computer data acquisition and control system

RESULTS

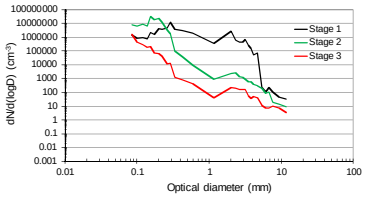


Figure 4. Typical evolution of the distribution of the aerosol from the heating up combustion stage (stage 1) until the flameless combustion stage (stage 3) during the combustion of poplar .

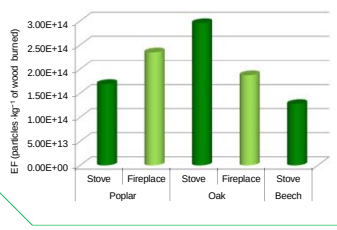


Figure 5. Number emission factors for the three woods burned in both appliances.

Table 2. Summary of the count median diameter (CMD), standard deviation (SD) and geometric standard deviation (σ_g) of the combustion experiments in this study and previously published.

	Monomer's diameter (nm)			
Fuel	**CMD**	**SD**	**Sigma (σ_g)**	**Reference**
Beech wood	**38**	**11**	**1.2**	**This study**
Oak wood	**41**	**9**	**1**	**This study**
Poplar wood	**35**	**7**	**1.1**	**This study**
Cherry/oak mixture	42	12	1.4	Unpublished
White oak wood	33	9.9		[2]
Rice straw	29	5.1		[2]
Dambo grass	39		1.6	[3]
White pine needles	45		1.4	[3]
Poplar wood	41		1.6	[3]
Ponderosa pine wood	35		1.6	[3]
Ponderosa pine needles	42		1.5	[3]
Sagebrush	47		1.7	[3]

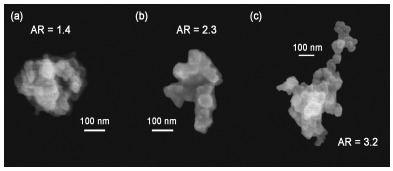


Figure 6. Examples of aggregates with different aspect ratios (AR) from the samples in the experiments.

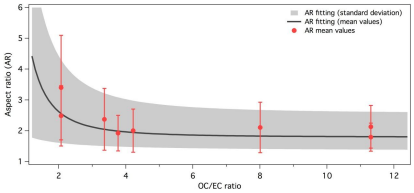


Figure 7 . Mean and standard deviation values of the aspect ratio from the aggregates in the different analysed samples. The dark line and grey shadow correspond to the power law fitting of the mean and standard deviation values.

CONCLUSIONS

- The combustion cycles were characterised by three main stages, namely ignition, flaming and smouldering, with different aerosol size distribution and aerosol morphology associated.
- Important differences were observed in the emission factors registered during the combustion process for the three studied wood species.
- The size of the primary particles comprising the aggregates emitted during the experiments ranged from 10 to 100 nm, with count median diameters of 35±7 nm, 38±11 nm, and 41±9 nm for poplar, beech and oak wood, respectively.
- Very variable mean aspect ratios were obtained for the aggregates in the analyzed samples, which values were closely related to the OC/EC ratios and optical properties, such as their light absorption wavelength dependency.

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