

Characterisation of the mass spectra of fine particulate matter from wood burning emissions

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Wood burning emissions contributes to elevated levels of particulate matter especially in Alpine Valleys [Alfarra et al. 2007]. In Switzerland the use of wood as a fuel increased from 1967 to 2005 [BAFU, 2006]. For source apportionment studies the identification of mass spectral signatures of organic aerosol from traffic and wood burning is of great importance.

Therefore a study was carried out at Empa (Swiss Federal Laboratories for Materials Testing and Research) to characterise the chemical and physical composition of aerosol particles emitted from wood burning.

The composition of aerosol particles emitted from the burning of beech, larch, fir, oak and chestnut wood in a small stove were investigated. Measurements of characteristic chemical components of the wood combustion aerosol were performed using an Aerodyne Aerosol Mass Spectrometer (Q-AMS). In addition, the aerosol total mass was measured by a TEOM (Tapered Element Oscillating Microbalance) and the soot concentration was measured using a Micro Soot Sensor from AVL.

The goal of this study was to identify and compare the mass spectral signatures of aerosol particles emitted from wood burning, and also to investigate the change in the mass spectral signature as a function of the burning cycle time and kind of wood. These signatures would then be used to distinguish wood burning emissions from traffic emissions in ambient air.

The five burning experiments were separated into a starting/flaming phase (phase I) and an end/smoldering phase (phase II). For phase I increased wood burning markers (Alfarra et al. 2007) m/z 60, m/z 73 as well as m/z 29 as an indicator for wood burning were observed compared to phase II. These markers related to levoglucosan were produced by all of the studied wood types but with different intensity dependent on the phase.

In February 2007 mobile measurements in the Rhine Valley were performed (see also poster of Chirico et al.) to identify the chemical composition of the non-refractory particle mass. As expected, the results showed that driving inside a plume of wood burning exhibited wood burning markers whereas car exhaust showed no signal of m/z 60 and m/z 73 in the mass spectra.

References:

Alfarra, M.R., A.S.H. Prevot, S. Szidat, J. Sandradewi, S. Weimer, V. Lanz, D. Schreiber, M. Mohr, and U. Baltensperger (2007): Identification of the mass spectral signature of organic aerosols from wood burning emissions. *Environ. Sci. & Technol.*, 44, 5770-5777.

Swiss Federal Agency for Environment (BAFU) (2006): Wald und Holz, Jahrbuch 2006. *Umwelt-Wissen* Nr. 0632, Bern, Switzerland, <http://www.umwelt-schweiz.ch/uw-0632-d>.

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Introduction

During winter time wood burning for domestic heating is very common in many parts of the world.

In Switzerland it was found that wood burning (WB) emissions during periods of atmospheric temperature inversions contribute to elevated levels of particulate matter in Alpine Valleys (Alfara *et al.* 2007). Those elevated levels do quite often exceed the daily Swiss air quality PM₁₀ standard of 50 µg m⁻³.

To characterise the chemical and physical composition of aerosol particles emitted from WB, a study was carried out at Empa. The composition of aerosol particles emitted from burning of beech, larch, fir, oak and chestnut wood in a small stove were investigated. Measurements of characteristic chemical components of the wood combustion aerosol were performed using an Aerodyne quadrupole aerosol mass spectrometer (Q-AMS).

The goal of this study was to identify and compare the mass spectral signatures of aerosol particles emitted from WB, and also to investigate the change in the mass spectral signature as a function of the burning cycle time and kind of wood.

Set up

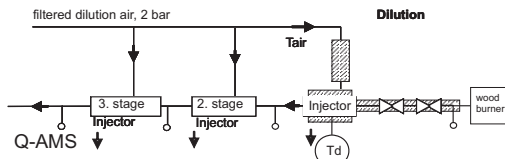


Fig 1. Sampling lines were connected for the exhaust tube of the stove to three dilution stages. The first stage was heated up to a dilution temperature of $T_d = 70$ °C.



Pic 1: Picture of the wood stove used for the experiment. The wood stove has a small combustion chamber (volume: 0.06 m³) lined with fireclay and no "after burning chamber".

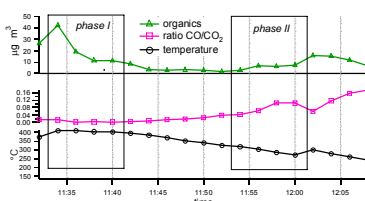
Wood burning marker

Five burning experiments were separated into a starting/flaming phase (Phase I) and an end/smoldering phase (Phase II). For both phases an average of 8 minutes were calculated.

Phase I: Starts at T_{max} and $CO/CO_{2,max}$

Phase II: Ends right after T_{min} and $CO/CO_{2,max}$

Fig 2. Exhaust temperature, ratio CO/CO₂ and organic mass concentration time series are shown for the defined phases.



Wood burning (WB) marker*
m/z 60, m/z 73
Indicator for WB*
m/z 29

wood type	m29/org / %		m60/org / %		m73/org / %		m44/org / %	
	I	II	I	II	I	II	I	II
beech	5.4	2.6	1.3	0.6	0.7	0.1	5.0	30.1
larch	7.5	3.0	2.1	1.6	1.2	0.8	6.1	8.0
fir	6.6	1.5	1.6	0.7	1.6	0.3	6.0	27.6
oak	9.1	8.3	3.5	2.4	1.3	1.0	5.8	18.0
chestnut	9.2	11.2	6.7	4.1	2.9	2.0	7.6	6.1

Table 1. Ratios of wood burning markers and m/z 44 for phase I and phase II are presented.

Phase I
increased WB markers

Phase II
increased m/z 44 marker fragment for oxygenated organic aerosol (OOA)
- except for WB experiment with chestnut

Wood type

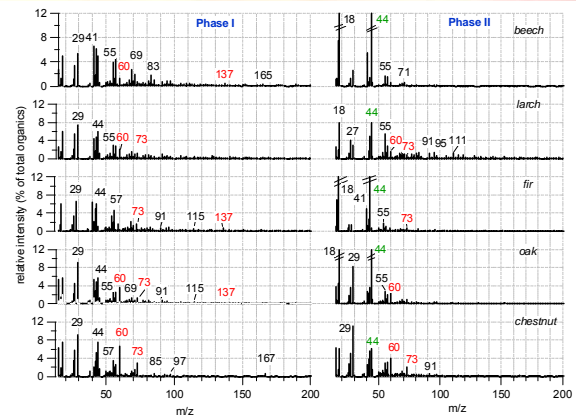


Fig 3. Averaged normalised mass spectra for phase I and phase II of measured particle components from burning different wood types (offscale values for m/z 44 are noted in Table 1).

Ambient measurements

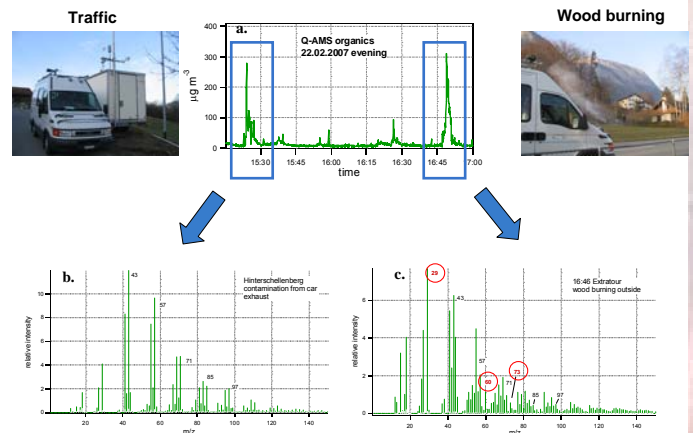


Fig 4. a. Organic mass concentration time series, b. averaged mass spectra of particles derived from diesel engine exhaust and c. from wood combustion. Measurements were performed in Rheintal, February 2007 by using a mobile laboratory (see also poster of Chirico *et al.*).

Conclusion

- Separation into two phases: starting/flaming phase and end/smoldering phase
 - wood burning (WB) markers were enhanced in the flaming phase
 - markers distinct fragments of levoglucosan, which is commonly used as a marker compound for WB
 - m/z 44 (fragment of OOA) increased for smoldering phase
- Mass spectra of the five wood types do not hint to a specific mass spectral signature
- WB markers were observed when driving with a mobile laboratory next to a plume of wood combustion

*References: Alfara, M.R., A.S.H. Prevot, S. Szidat, J. Sandradewi, S. Weimer, V. Lanz, D. Schreiber, M. Mohr, and U. Baltensperger (2007). Identification of the mass spectral signature of organic aerosols from wood burning emissions, *Environ. Sci. & Technol.*, 44, 5770-5777.