Poster Summary – 11th ETH-Conference on Combustion Generated Nanoparticles

Quantification of Wood Burning versus Traffic Contributions to Particulate Matter During Winter Periods in an Alpine Valley

Jisca Sandradewi, Rami Alfarra, Nolwenn Perron, André Prévôt, Ernest Weingartner, Soenke Szidat*, Rahel Schmidhauser, Urs Baltensperger

Laboratory of Atmospheric Chemistry, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland
**Department of Chemistry and Biochemistry, University of Bern, Bern, Switzerland*

In many regions of the world, wood combustion is a common source of heating energy during the cold season. Studies have shown that gaseous and particulate emissions from wood burning activities have adverse health effects.

The AEROWOOD (Aerosols from wood burning) project is a project supported by the Swiss Federal Office for the Environment (BAFU) and the cantons Graubünden and Ticino to study the contribution of wood burning relative to other sources, e.g. traffic, to particulate matter (PM10).

The field measurements took place in Roveredo (46°14'18''N, 9°07'45''E, 298 m a.s.l.), a village with ~2200 inhabitants located in an Alpine valley. More than 70% of the household in this village use wood stove for heating in winter. Strong and persistent temperature inversion prevails in winter because the village lies most of the time in the shadow of the surrounding steep hills and mountains. A two-lane highway passes through the village which is separated from the residential area and the measurement container by a 3-m high concrete wall. The campaigns took place in January, March and November–December 2005.

The Magee AE31 Aethalometer (7 wavelengths, λ=370-950nm) measures the aerosol light absorptions and the black carbon concentration online. The Aerodyne quadrupole Aerosol Mass Spectrometer (Q-AMS) provides online data of the chemical composition and mass size distribution of the nonrefractory fraction of submicrometer aerosols. The high volume (HIVOL) samplers collected the aerosol for the offline ^{14}C analysis. For details on the campaign dates and data availability please refer to Table 1 in the poster.

A novel model for determination of particulate matter from traffic and wood burning ($PM_{traffic}$, $PM_{woodburning}$) using the Aethalometer light absorptions parameters and the AMS total organic mass is introduced. The $PM_{traffic}$, $PM_{woodburning}$ obtained with the model were compared to the ^{14}C-analysis (in terms of total carbon material: $TCM_{nonfossil}$, TCM_{fossil}) and the results summarized in Figure 1-left in the poster (slope=1.03, r^2=0.75). The traffic contribution to the light absorption at 950-nm wavelength ($b_{abs}(950nm)_{traffic}$) corresponds to its black carbon mass. This was compared with the elemental carbon from non-fossil source ($EC_{nonfossil}$) determined by the ^{14}C-analysis as shown in Figure 1-right (slope=1.03, r^2=0.59).

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LABOR FÜR ATMOSPHÄREN-CHEMIE

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Laboratory of Atmospheric Chemistry, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland
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1. Introduction

In many regions of the world, wood combustion is a common source of heating energy during the cold season. Studies have shown that gaseous and particulate emissions from wood burning activities have adverse health effects.

The AEROWOOD (Aerosols from wood burning) project is a project supported by the Swiss Federal Office for the Environment (BAFU) and the cantons Graubünden and Ticino to study the contribution of wood burning relative to other sources, e.g. traffic, to particulate matter (PM10).

2. Field Measurements

Roveredo (46°14'18''N, 9°07'45''E, 298 m a.s.l.) is a village with ~2200 inhabitants located in an Alpine valley. More than 70% of the household in this village use wood stove for heating in winter. Strong and persistent temperature inversion prevails in winter because the village lies most of the time in the shadow of the surrounding steep hills and mountains. A two-lane highway passes through the village which is separated from the residential area and the measurement container by a 3-m high concrete wall. The campaign dates are summarized in Table 1.

3. Instrumentation

The Aethalometer (7 wavelengths, λ=370-950nm) measures the aerosol light absorptions and the black carbon concentration online. The Aerosol Mass Spectrometer (AMS) provides online data of the chemical composition and mass size distribution of the nonrefractory fraction of submicrometer aerosols. The high volume (HIVOL) sampler collects the aerosol for the offline ^{14}C analysis (Table 1).

Table 1. Summary of field campaigns and instrumentations

Roveredo Campaigns	Aethalometer	HIVOL for ^{14}C analysis	AMS
13–24 January 2005	2-min time resolution.	Morning and evening filters, 16-hour sampling time per filter. PM10 size-cut. 4 filters analyzed [1]	n/a
1–16 March 2005	Same as above	Morning and evening filters, 16-hour sampling time per filter. PM1 size-cut. 4 filters analyzed [1]	2-min time resolution [2]
24 November–15 December 2005	Same as above	24-hour sampling time per filter. PM1 size-cut. 4 filters analyzed	5-min time resolution [2]

References:

[1] Szidat et al., 2007, Dominant impact of residential wood burning on particulate matter in Alpine valleys during winter. Geophys. Res. Lett. 34, L05820.

[2] Alfarra et al., 2007, Identification of the mass spectral signature of organic aerosols from wood burning emissions. ES&T 41, 5770-5777.

[3] Schnaiter et al., 2003. UV-VIS-NIR spectral optical properties of soot and soot-containing aerosols. J. Aerosol Sci. 34, 1421–1444.

[4] Kirchstetter et al., 2004. Evidence that the spectral dependence of light absorption by aerosols is affected by organic carbon. J. Geophys. Res. 109.

4. The Aethalometer model

Studies have shown that the presence of wood smoke aerosol significantly enhances the light absorption at the UV-range, while diesel soot from traffic mainly absorb light in the near-IR range [3] [4].

$$OM{+}BC = \underbrace{c1 * b_{abs}(950nm)_{traffic}}_{PM_{traffic}} + \underbrace{c2 * b_{abs}(370nm)_{woodburning}}_{PM_{woodburning}}$$

OM: total organic mass measured by the AMS
BC: black carbon conc. measured by the Aethalometer
b_{abs}: aerosol light absorption at the given wavelength
c1, c2: constants determined by linear regression

From the Beer-Lambert's Law we derived the following equations:

$$\frac{b_{abs}(370nm)_{traffic}}{b_{abs}(950nm)_{traffic}} = \left(\frac{370}{950}\right)^{-\alpha_{traffic}} \qquad \frac{b_{abs}(370nm)_{wb}}{b_{abs}(950nm)_{wb}} = \left(\frac{370}{950}\right)^{-\alpha_{woodburning}}$$

For diesel soot or traffic aerosol [3]: $\alpha_{traffic}$ ~1.0 – 1.1

For wood combustion [4]: $\alpha_{woodburning}$ ~1.8 – 2.2

5. Result and Outlook

The Aethalometer model is calibrated with the ^{14}C results for a range of $\alpha_{woodburning}$ between 1.6–2.1 (α calculated with 470 and 950nm wavelengths) while $\alpha_{traffic}$ is held constant at 1.1. We found that an $\alpha_{woodburning}$(470nm, 950nm)=1.8 gives the best correlation with the ^{14}C results as shown in Figure 1 below.

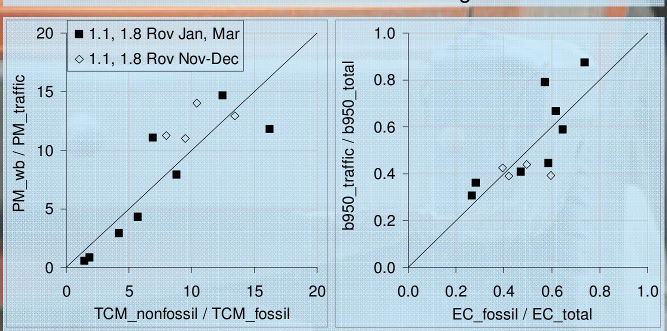

Figure 1. $PM_{woodburning}/PM_{traffic}$ versus $TCM_{nonfossil}/TCM_{fossil}$ (left) and $b_{abs}(950nm)_{traffic}/b_{abs}(950nm)_{total}$ versus EC_{fossil}/EC_{total} for all three campaign periods with $\alpha_{traffic}$=1.1 and $\alpha_{wb(470nm,950nm)}$ =1.8. The 1:1-line is included for comparison.

This model will be applied on similar data sets which are available for the winter campaigns in Zürich (January 2006) and Reiden (February 2006).

Acknowledgement

We thank the Office of Nature and Environment (ANU) of Canton Graubünden for their support, and the Swiss Federal Office for the Environment (FOEN) for funding the AEROWOOD project.