Elemental, organic carbon and PM from wood combustion

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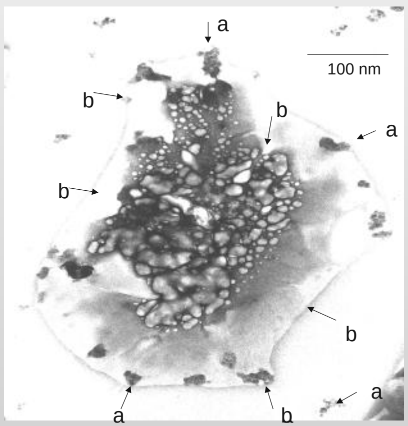
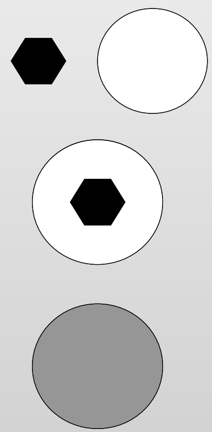
Universität Duisburg Essen





External Mixing

Black Carbon Core

Internal Mixing

London Air Quality Network Seminar
1st July 2011, London, UK

Content

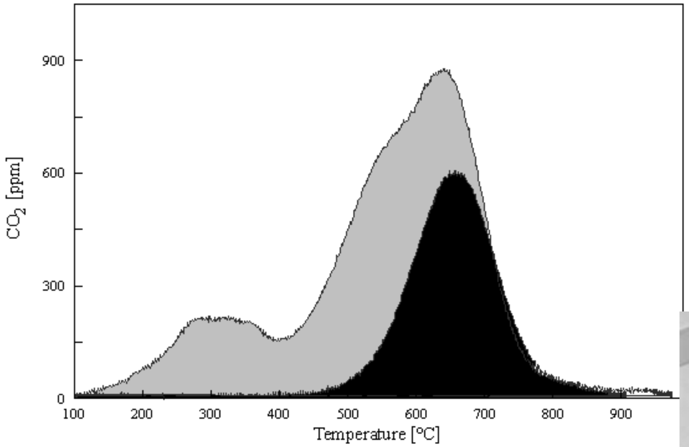
Elemental and Organic Carbon (EC + OC)

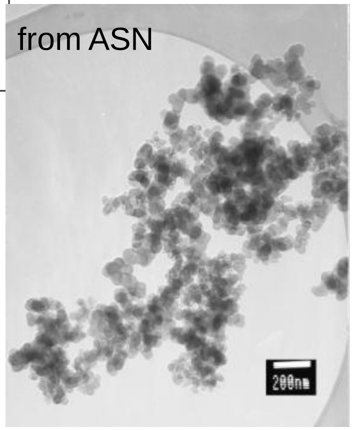
- What is EC and OC? Where does it come from?
- Why do we want to measure EC and OC?
- How can it be measured?

PM from wood combustion

- German emission inventory and model results
- A case study

What is EC and OC?





Defined by
- **its thermal stability?**
- **its chemical nature?**
- **its optical property?**

EC and BC tracer for incomplete combustion.

Often accompanied with inorganics, especially biomass burning.

Where does it come from?

EC:
Combustion processes (anthropogenic & natural)

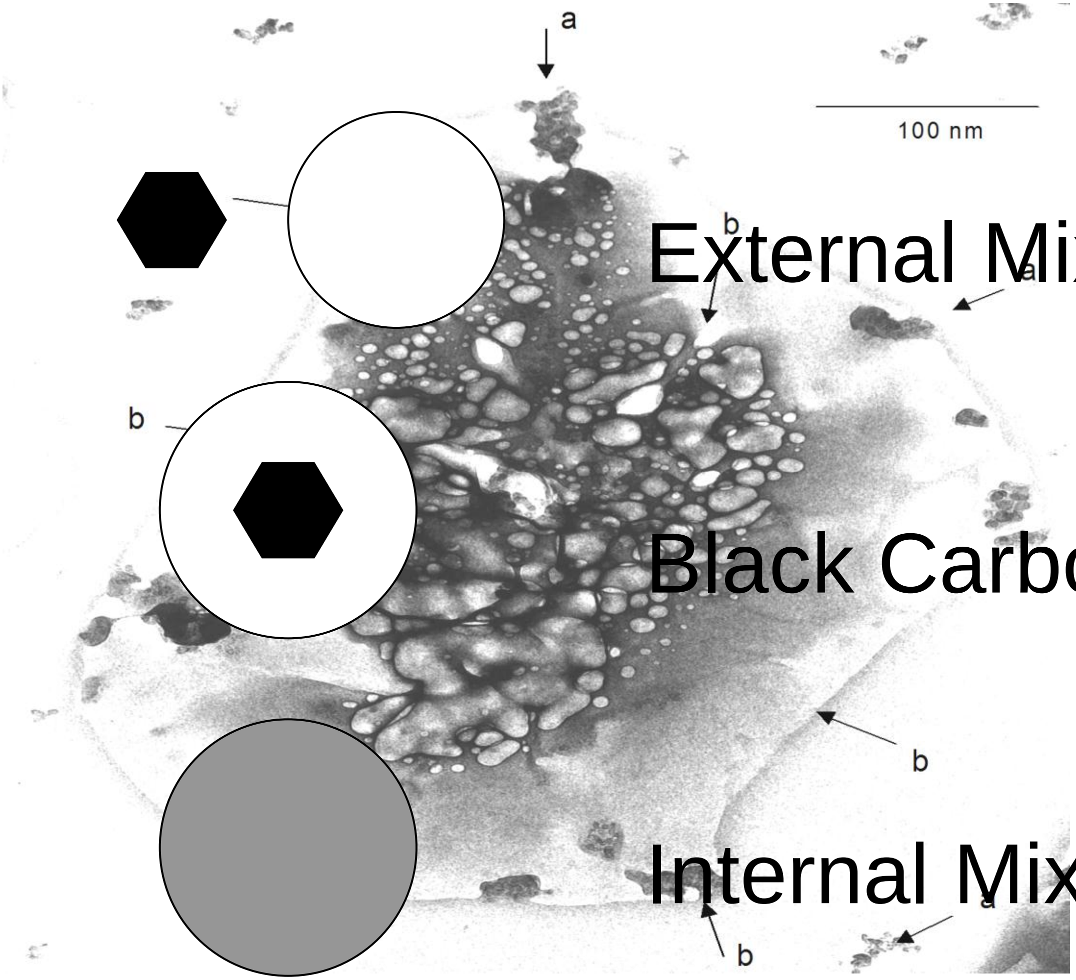
BC: (incl. optically dense material)
Also degradation processes and fire residues

OC:
Industry (dry cleaner…)
Biogenic (isoprene, terpines…)
Biological (wax, pieces of plants….)
Combustion processes (biomass burning)

Content

Why do we want to measure EC and OC?

Mixing of Black Carbon



	Forcing (W m^{-2}, Jacobson, 2000)
External Mixing	+0.27
Black Carbon Core	+0.54
Internal Mixing	+0.78

The high uncertainty of both, the amount of absorbing carbon and the efficiency of absorption, lead to high uncertainties in climate simulations!

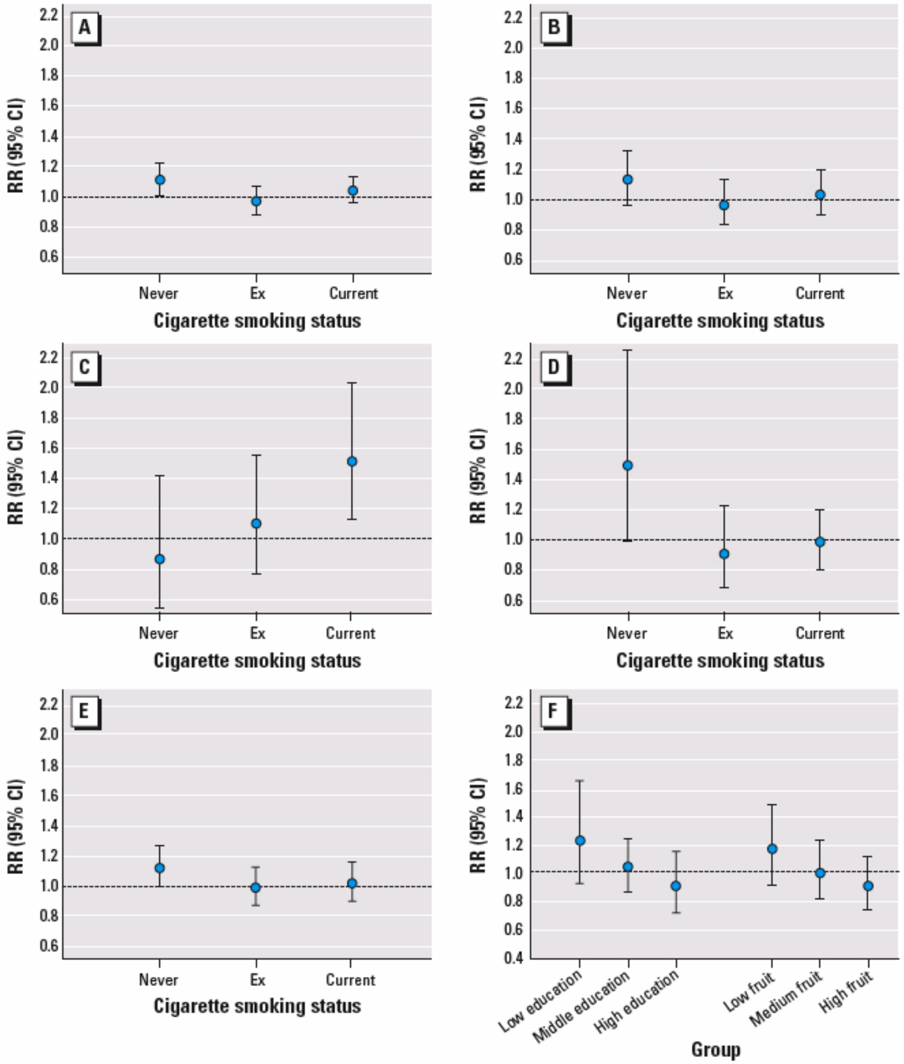


Figure 3. Association between black smoke overall concentration (1987–1996) and cause-specific mortality in subgroups for cigarette smoking status in the full cohort data set (*A*–*E*), and (*F*) by education and fruit consumption in the case–cohort data set. (*A*) Natural-cause ($p = 0.15$), (*B*) cardiovascular ($p > 0.2$), (*C*) respiratory ($p = 0.11$), (*D*) lung cancer ($p = 0.14$), and (*E*) other mortality ($p > 0.2$). (*F*) Education of the household coded as low = only primary school; middle = lower vocational education; and high = junior high school, senior high school, higher vocational education, and university ($p > 0.2$). Fruit consumption divided in tertiles: low, 0–96.8 g/day; medium, 96.8–191.8 g/day; and high, > 191.8 g/day. Adjusted for age, sex, smoking status, and area-level indicators of socioeconomic status ($p > 0.2$). *p*-Value, Cochran's Q test for heterogeneity.

Relative risks (95% confidence intervals) for a 10-µg/m3 increase in BS concentrations were 1.05 (1.00–1.11) for natural cause, 1.04 (0.95–1.13) for cardiovascular, 1.22 (0.99–1.50) for respiratory, 1.03 (0.88–1.20) for lung cancer, and 1.04 (0.97–1.12) for mortality other than cardiovascular, respiratory, or lung cancer. Results were similar for NO2 and PM2.5, but no associations were found for SO2.

Long-Term Effects of Traffic-Related Air Pollution on Mortality in a Dutch Cohort
Beelen et al., Env. Health Persp. 116, Number 2, February 2008

EC

- Optical methods
- Photoacoustic method

} MAAPS, PSAP, Aethalometer, IS etc.

- Thermal methods

} TOD, TOR, Cachier VDI 2465

OC

- Thermal methods
- GC – MS (3D MS) for speciation

EC versus BC

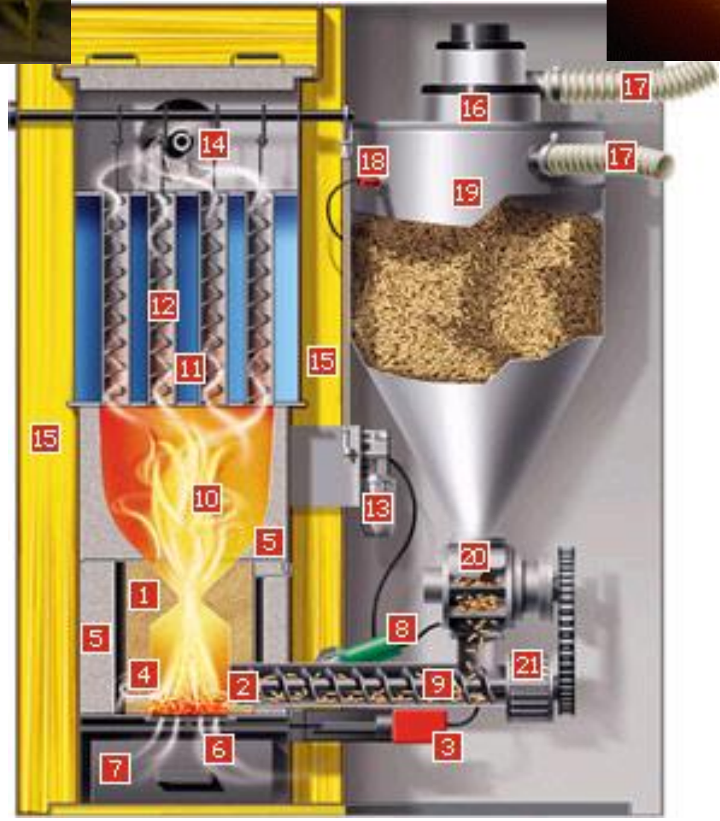
- Thermal methods (EC)

  Currently standardisation in progress CEN TC264, WG35, waiting for mandate
  Good for mass closure, hardly possible for online measurements, difficult to differentiate “types” of EC

- Optical methods (BC)

  Currently no standardisation foreseen
  Good for online measurement (and networks), possibility to differentiate “types” of EC, difficult to relate to mass and hence current regulation

EC/OC and PM in wood smoke



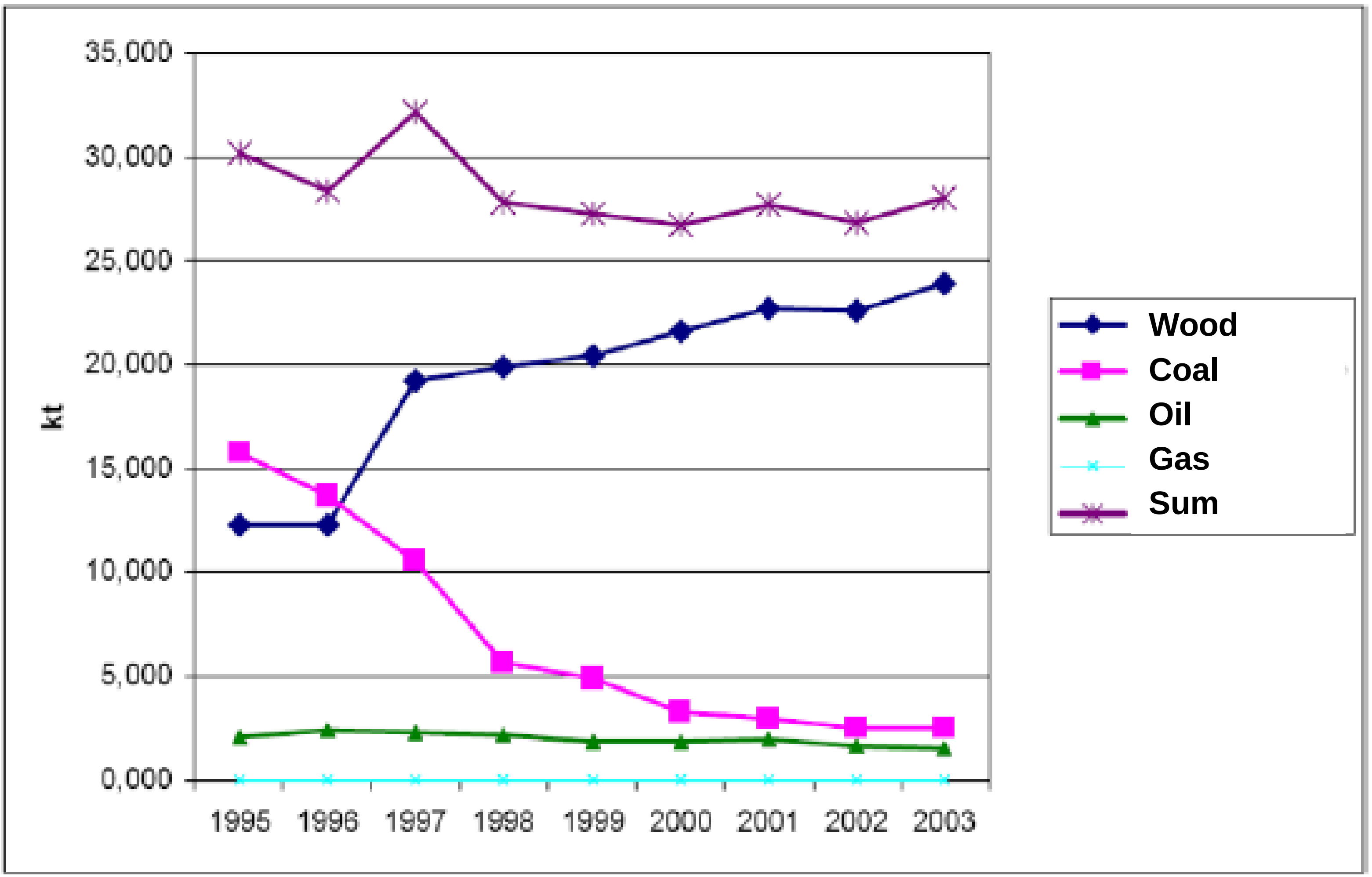
EC/OC and PM in wood smoke

Emission characteristics for the different classes of wood combustion appliances

Type of combustion appliance	Particle class(es) dominating
Open fireplaces	organic carbon/soot
Conventional wood stoves	organic carbon/soot
Masonry heaters	organic carbon/soot
Conventional boilers for wood logs	organic carbon/soot *
Modern wood stoves	inorganic ash/organic carbon/soot *
Modern boilers for wood logs	inorganic ash/organic carbon/soot *
Pellet stoves and boilers	inorganic ash

Kocbach Bølling *et al. Particle and Fibre Toxicology* 2009 **6**:29 doi:10.1186/1743-8977-6-29

Development of PM 10 Emission from small-scale furnaces in Germany (UBA 2006)



Scenario comparison

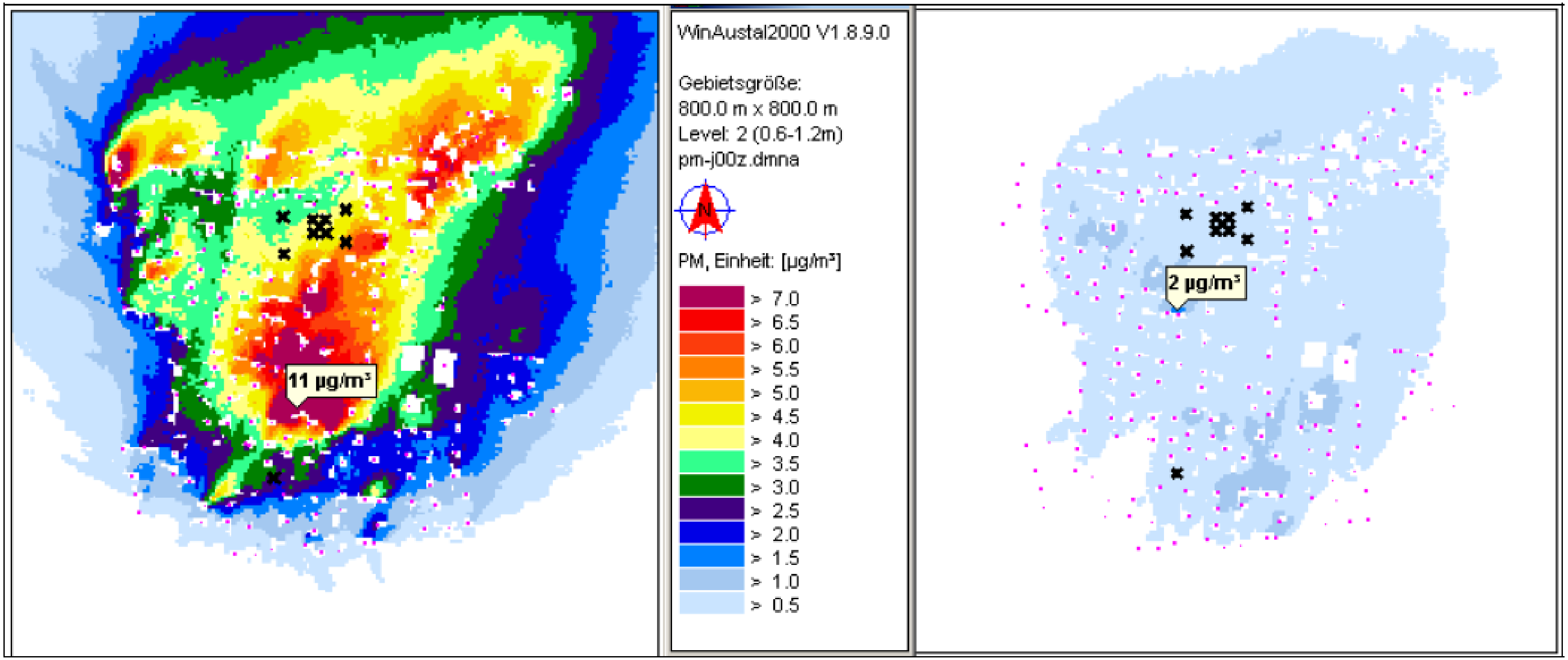
Emission factors and yearly load for private small-scale furnaces (< 50 MW)
Comparison of two scenarios for Germany
(Thiruchittampalam, 2008)

		Stoffe				
		NO_x (als NO_2)	NMVOC	SO_x (als SO_2)	NH_3	PM10
Basic scenario data of 2005	Emissionsfaktor (kg/TJ)	50,9	332,4	6,6	0,5	107,8
	Emissionsfracht absolut (kt/a)	10,4	67,7	1,3	0,1	22,0
	Emissionsfracht relativ	0,7%	4,7%	0,2%	0,0%	10,5%
Oil scenario data of 2005	Emissionsfaktor (kg/TJ)	40,4	1,5	59,3	2,5	1,5
	Emissionsfracht absolut (kt/a)	8,2	0,3	12,1	0,5	0,3
	Emissionsfracht relativ	0,5%	0,0%	2,1%	0,1%	0,2%

Baumbach et al., 2010

Ambient PM10 concentrations in Bechtoldsweiler as modelled with Austal2000 for 28.12.2007 - 30.01.2008:

biogenic fuels **fossil fuels**



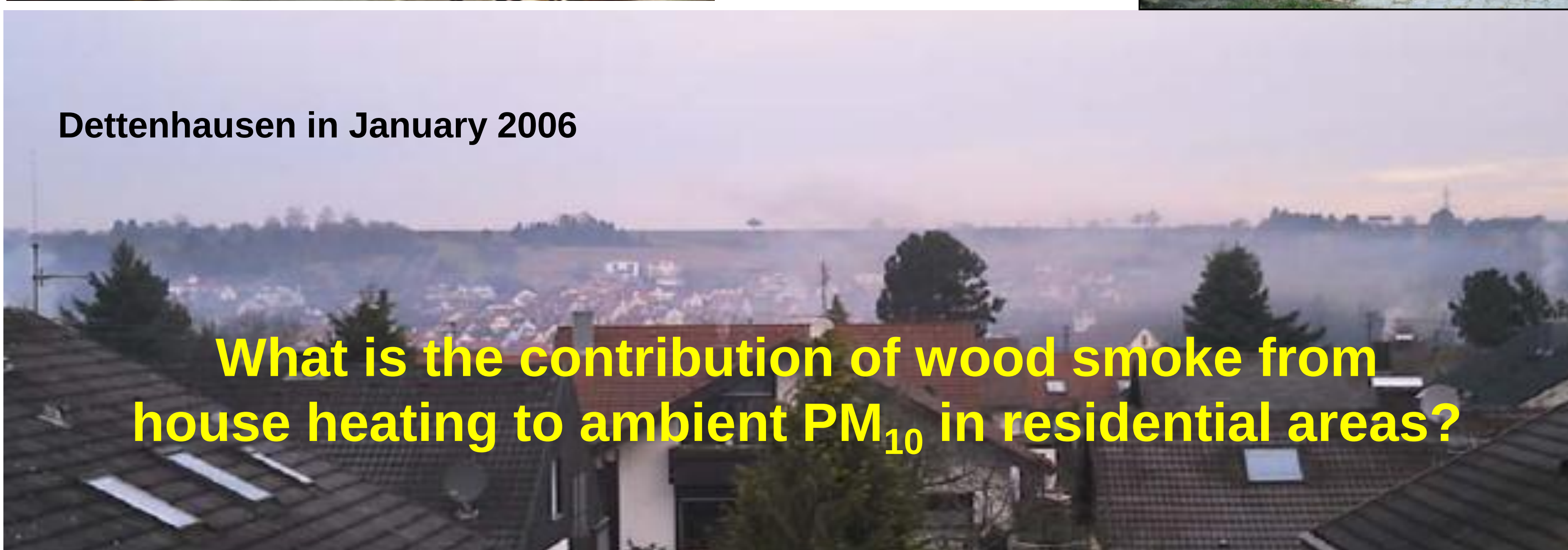
Baumbach et al., 2010

The Problem: Annoyance caused by wood burning smoke from house heating

Universität Stuttgart

Dettenhausen
December 2005

Bechtoldsweiler
January 2007



Methodology

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Characterisation of wood smoke by
PAH fingerprints of wood smoke emissions and ambient air particles

↓

Chemical analysis of wood smoke PM emissions

↓

Chemical analysis of ambient PM

↓

Determination of winter ambient levels of PAHs in PM in residential areas

↓

Determination of other wood smoke tracer compounds in emissions and in ambient air and comparison

↓

Identification and quantification (source apportionment) of wood smoke contribution to ambient particulate matter (PM_{10})

Charaterisation of wood burning emissions from residential chimney stove

ifk
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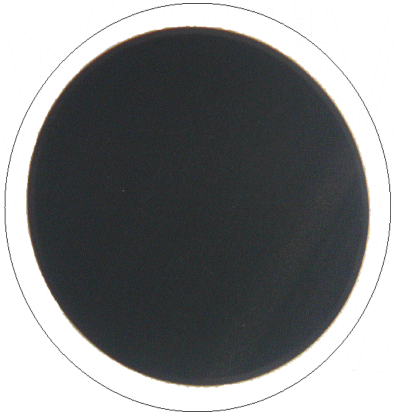
Softwood burning: pine
Hardwood burning: beech

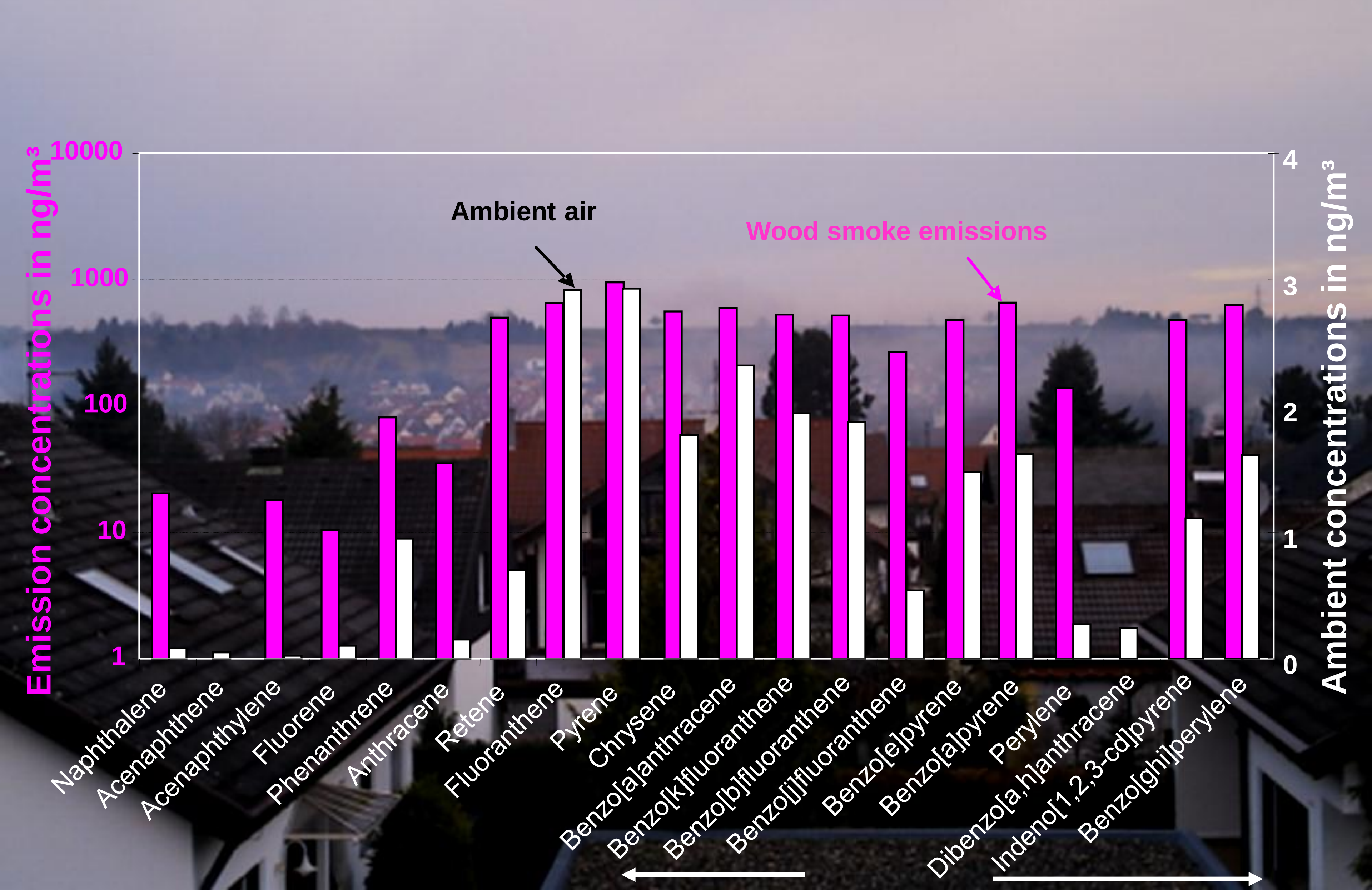
Wood smoke emission

Hardwood (beech) burning
Chimney oven
(conc. 80 mg/m³)



Softwood (pine) burning
Chimney oven
(conc. 192 mg/m³)

PAH Fingerprints (Composition) of Wood Smoke Emissions and Ambient Air Composition (Dettenhausen)



Levels of levoglucosan and dehydroabietic acid in ambient air

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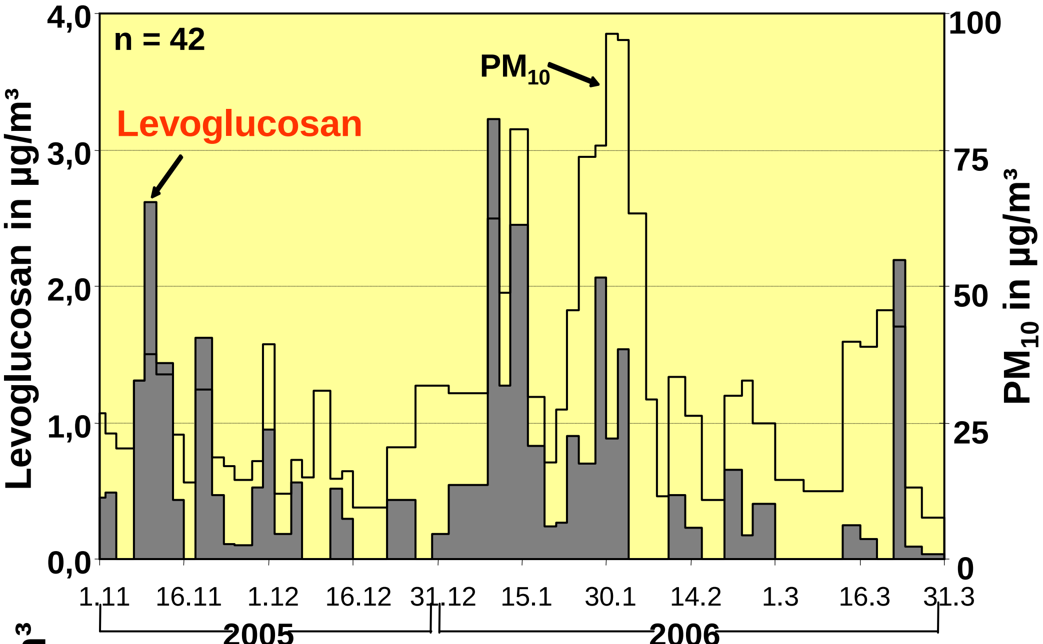
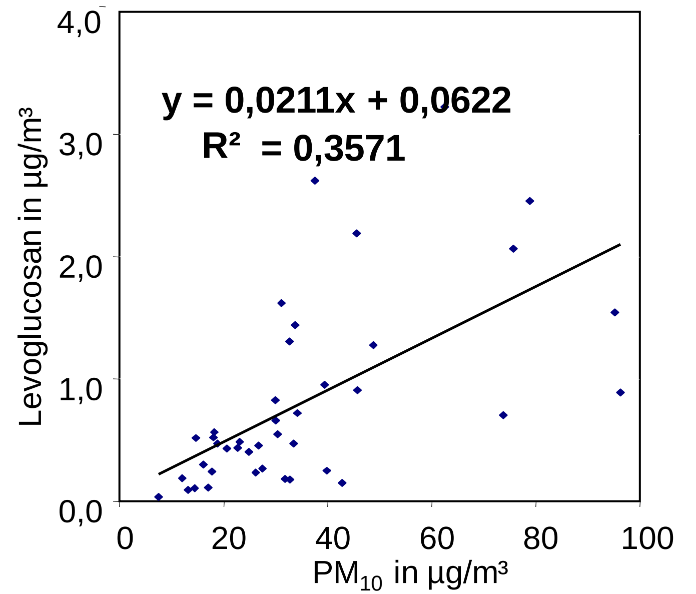
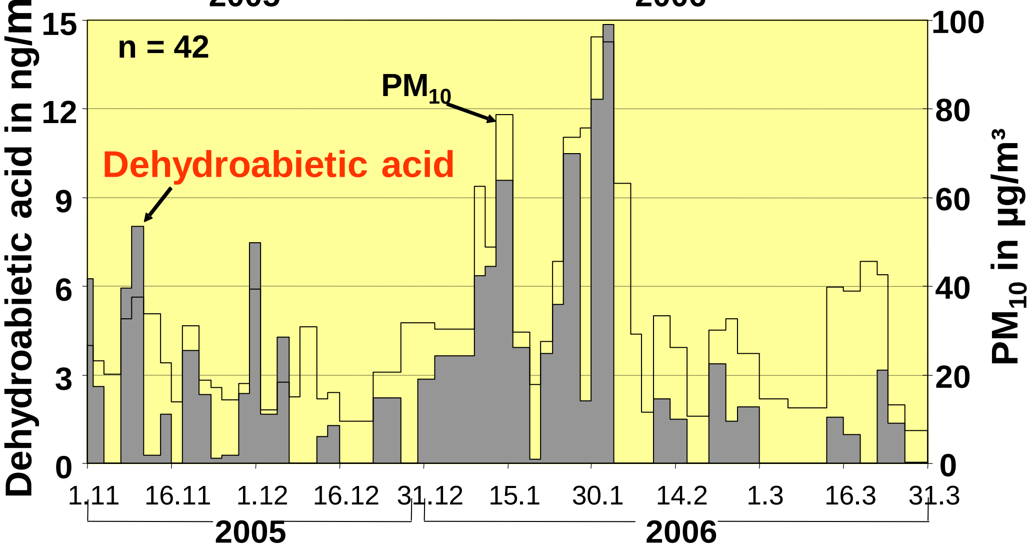
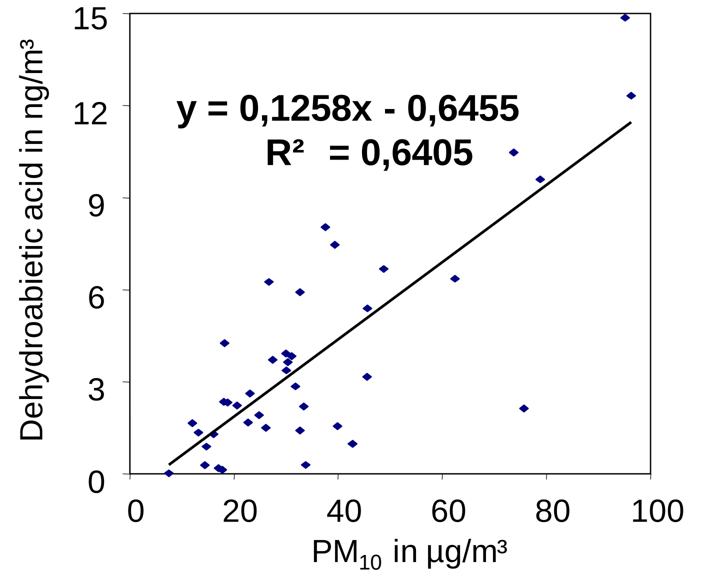








Levels of levoglucosan and dehydroabietic acid in ambient air

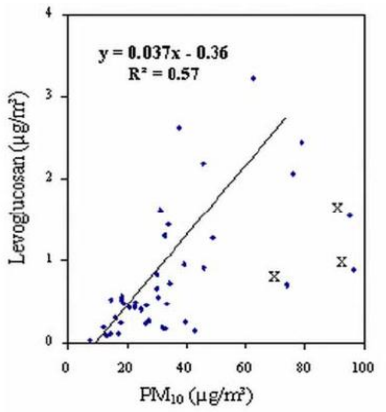


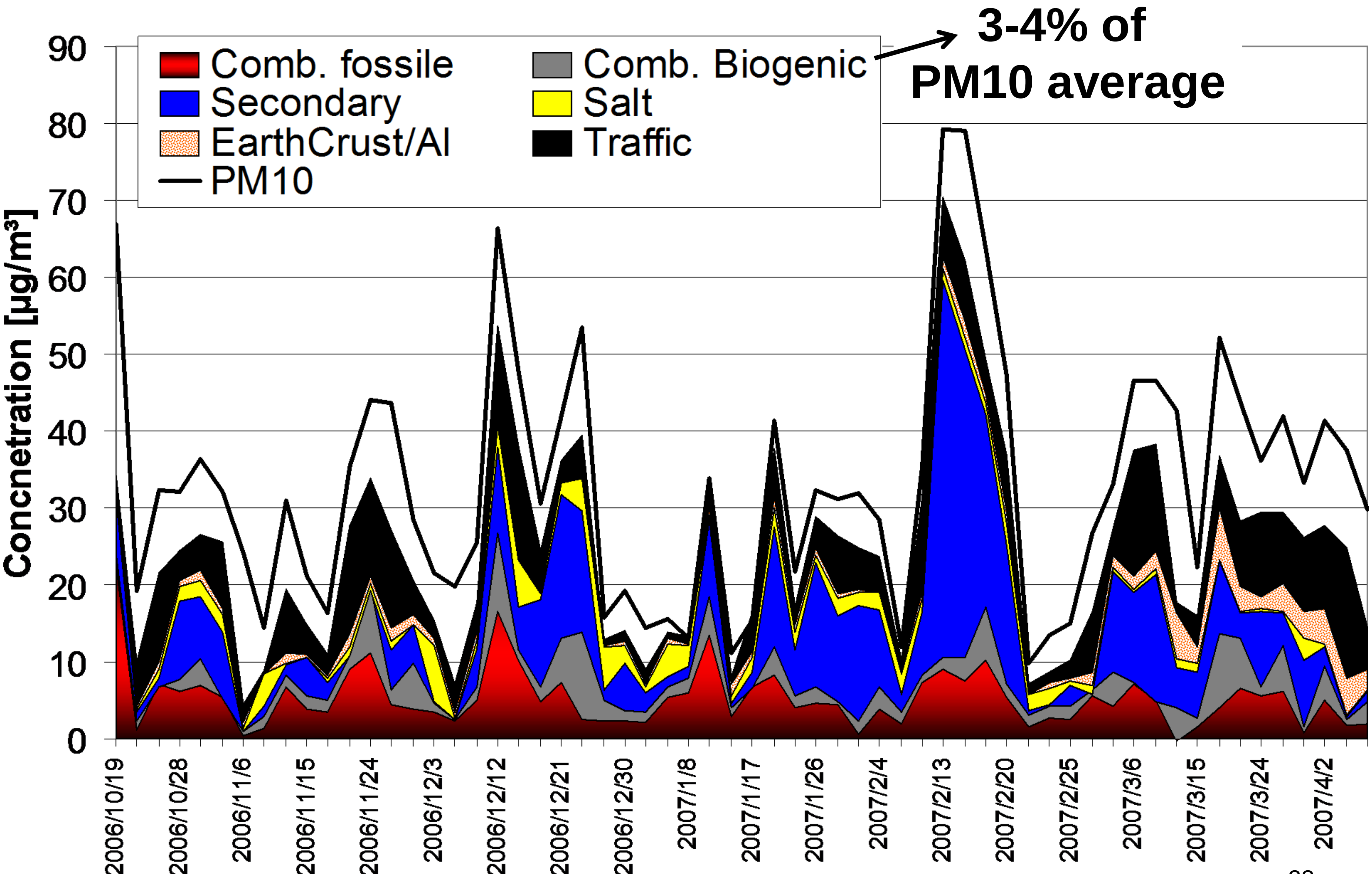
Fig. 3. Correlation between ambient concentrations of levoglucosan and PM_{10} in Dettenhausen. Outliers in cross (x) marks were excluded from the least-squares fit

Table 2. Emission factors and concentrations of monosaccharide anhydrides (MA), dehydroabietic acid and retene in wood smoke emissions and ambient PM_{10} samples in the residential site

Compounds	Emission factor mg/g PM		Emission concentration (µg/m3)		Ambient concentration (ng/m3)			
	beech	pine	beech	pine	mean	median	min	max
Levoglucosan	22.87	10.7	480	1209.8	805.5	517.1	35.45	3223
Mannosan	0.16	0.28	32.5	31.8	70.8	48.5	1.99	277
Galactosan	0.82	0.094	17.3	10.7	24.5	13.6	1.55	79

Contribution of woodfired heating to wintertime ambient PM10 pollution was found to be 59 ± 41% in a small rural town.

PMF factor contributions (traffic site Frankfurt)



Quass et al., 2009

Comparison of average concentrations of wood smoke tracer compounds between wood combustion and in ambient air

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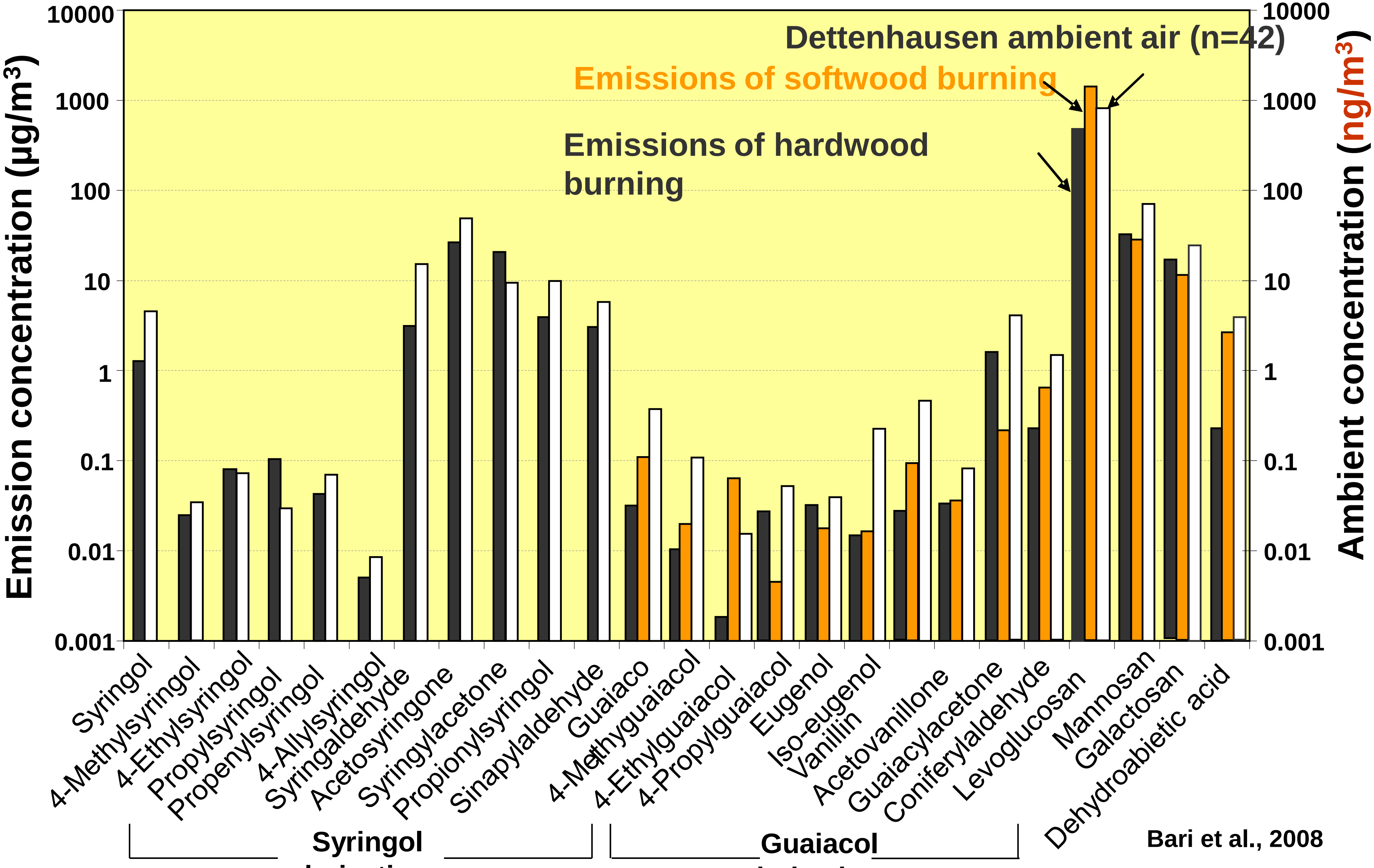

Bari et al., 2008

Atmospheric Environment

Source contribution to mass concentration of measured PM_{10}-bound organic compounds in Dettenhausen

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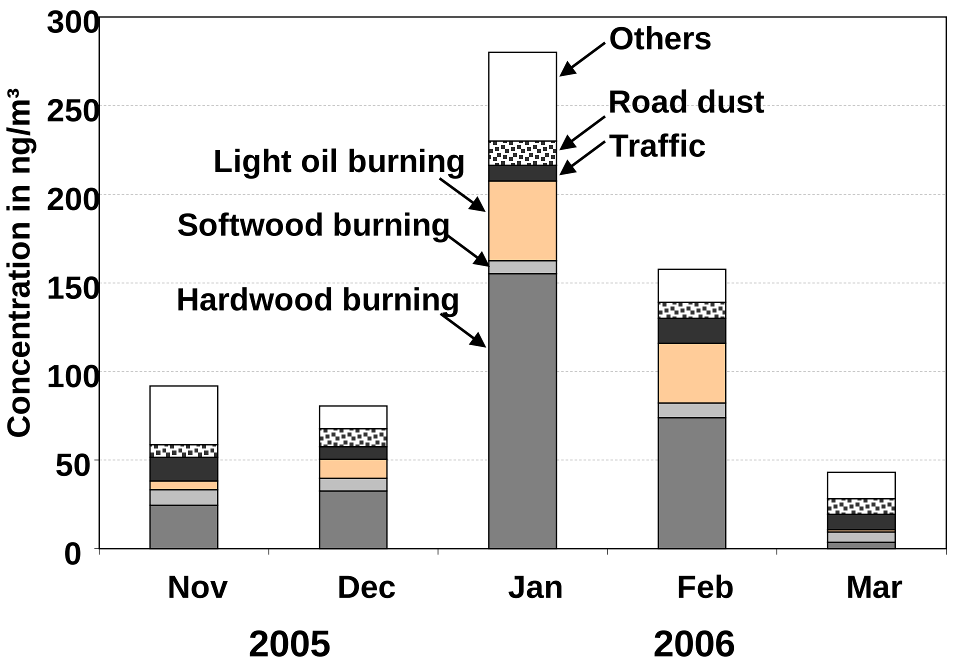
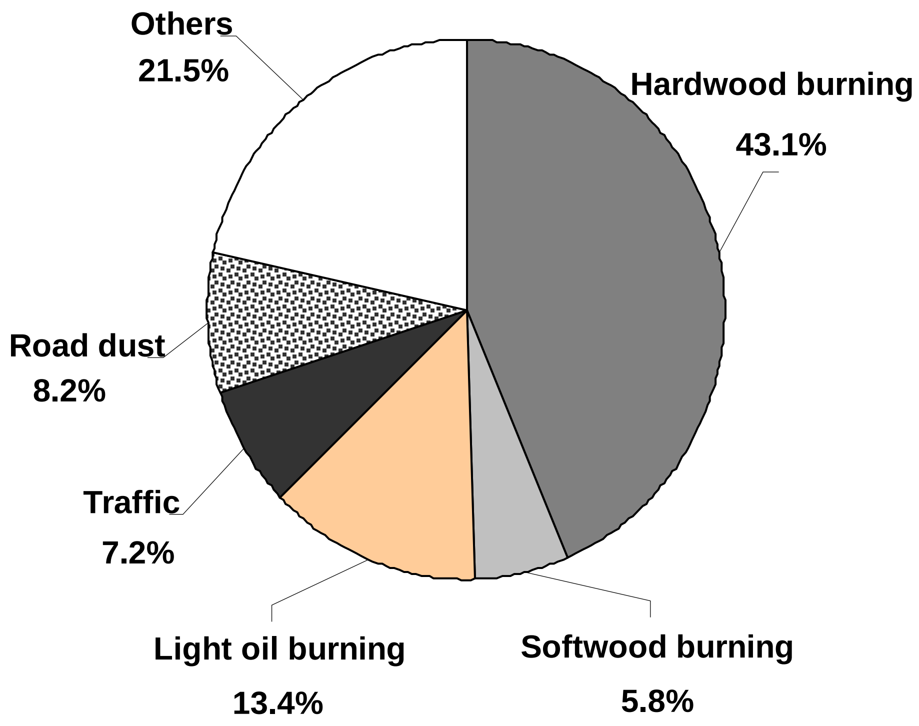
Positive Matrix Factorisation (PMF)





Monthly average contribution

Summary

EC and OC of interest for radiative forcing and human health

EC and BC methods available but have different advantages and disadvantages

EC and OC important in (wood)combustion PM

Combustion of biogenic fuels significantly contribute to ambient PM

Model results were validated in a field study

Biogenic fuel combustion can contributes up to 90% of PM10 in rural settings in winter

Detailed studies of tracer allow differentiation of soft and hard wood emission