

**Chemical Composition of PM10 from Small-Scale Combustion Plants – Factors for the Macrotracer Model**

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***Abstract***

Biomass is considered to be a modern, environmentally friendly fuel for small-scale combustion plants. At the same time, the combustion of biomass causes high emissions of fine dust, especially if the technology of the combustion plant is obsolete or the plant is not operated correctly. This can have a massive effect on the local and regional air quality. This problem is particularly pronounced in residential areas that are poorly aired because of the geographical conditions (e.g. a basin location). To assess the effect of biomass combustion on air quality, it is necessary to determine chemical tracers for the combustion processes by using emission measurements. The derived emission factors can then be used in model calculations (e.g. the macrotracer model). In the *PMinter* project, the emission rates of selected anhydrous sugars, organic carbons and soot are used to determine the proportion of fine dust from wood combustion. The data comes from four projects and mainly refers to firewood combustion (beech and spruce) in individual furnaces. Several additional combustion trials with wood pellets show that their fine dust emissions are considerably lower compared to wood billets.

**Introduction**

According to information from Statistics Austria, more than 17% of all households in Austria use wood or other biogenic fuels to generate heat. However, this data only covers the information for main heating. The current market analysis (Biermayer et al., 2012) estimates the stock of already installed individual furnaces in Austria to be approximately 1 million. Around 40,000 individual furnaces were sold in 2011. Many of them were installed as "secondary heating" and are operated mostly in the transition times in the autumn and spring.

The large number of biomass small-scale combustion plants in the regions where wood is used most frequently is reflected in the poor air quality.

The small-scale combustion plants are mainly responsible for the increased values of fine dust (PM10). Around 30% of all PM10 emissions in Austria are attributed to small-scale combustion plants (IIR, 2012, Federal Environmental Agency). This was also confirmed by air pollutants studies to show the fine dust sources (AQUELLA Study, Bauer et al. 2009 as well as the results of the current *PMinter* project). Wood combustion became the most important regional factor that led to several overruns of the PM10 limit value (2008/50/EC).

The air pollutant studies, in which the main objective was to identify sources of fine dust, are based on information that was acquired through source characterisation.

The data for characterisation of wood combustion presented here is based on four different studies to show the fine dust from small-scale combustion plants, which were conducted between 2006 and 20011 at the Vienna University of Technology. It comprises emission factors for individual tracer components and a presentation of the proportions of the tracer components levoglucosan (LG) and mannosan (MN), which provide information on the type of fuel used.

**Methods**

Chemical profiles of emissions from biomass combustion were determined for 12 plants (furnaces and boilers with output of up to a maximum of 50 kW) and around 50 different types of biomass. Besides fine dust, gaseous emissions were investigated as well as odour caused by combustion (Schmidl et al., 2008; Schmidl et al., 2011; Kistler et al., 2012).

Combustion was carried out at a test bench (Institute for Process Technology, Environmental Technology and Technical Bioscience) or alternatively "in the field". Fine dust was collected "cold", i.e. at room temperature, which could be achieved through a dilution system. In each case, sampling took place during the entire combustion (fuel quantities and plant settings according to information from the suppliers). The fine dust was collected on quartz filters and then subjected to the following analytical procedures:

* gravimetric determination of the mass (PM10)
* thermal-optic carbon chemical analysis (soot (EC), organic carbon (OC))
* liquid chromatography (inorganic ions and anhydrous saccharide).

The results presented here cover wood pellets, cuttings, briquettes, spruce and beech firewood, because those fuels are relevant for the Austrian/Slovenian border region studied as part of the *PMinter* project according to the Austrian forest inventory, 2010 or alternatively Cop (2007).

The macrotracer model calculates the wood smoke proportion via the anhydrous sugar levoglucosan, which is created by the pyrolysis of cellulose. This compound is stable to a great extent under atmospheric conditions and can therefore be used as a marker for biomass combustion (Simoneit et al. 1999). The method comprises a comparison of the proportions of LG to the particle mass (PM) as well as to the concentration of organic carbon in order to calculate the fractions of fine dust or alternatively of the fraction of the fine dust that contains carbon. The LG/MS ratio is used to draw a conclusion about the fraction of softwood or alternatively hardwood in the combustion.

**Results**

The emission factors, or alternatively the emission rates (based on the total fine dust mass) of EC, OC and levoglucosan for wood pellets, cuttings, briquettes, spruce, and beech were determined in four categories:

* traditional Austrian tiled stoves
* modern fireplaces
* modern individual pellet furnaces
* modern pellet boilers.

The emission factors for fine dust are in a broad range between 5 mg/MJ up to more than 400 mg/MJ, whereby the majority of the high values came from individual furnaces and wood billets. The average fine dust values for individual pellet furnaces or alternatively boilers were considerably lower than for individual wood billet/briquette furnaces.

The studies did not show any significant differences between PM10 emission factors for spruce and beech firewood, however there was a clear trend regarding the values for levoglucosan and mannosan. The levoglucosan fractions in the fine dust are highly dependent on the type of wood, although the formation of these compounds is also supported by specific combustion conditions. There were very low values for the combustion of wood pellets, both in individual furnaces as well as in boilers. In contrast, there were fractions of LG that were up to 10% of the PM10 mass for billet combustion. Furthermore, significant differences were also discovered for beech and spruce as representatives of hardwoods and softwoods. Hence, for successful emissions modelling using LG, it is crucial to know the composition of the fuel mix that is used.

The LG/MN ratio can be used for this evidence. Thanks to the differences in the chemical composition of the different varieties of wood, these two anhydrous sugars are not formed in the same quantities during combustion. The ratio can be used as a robust tool for the interpretation of the fuel that is used (Schmidl et al., 2008).

Another important aspect for modelling the fine dust sources is the results of the carbon chemical analysis. Through it, further mapping of the fraction of fine dust that contains carbon is possible, which subsequently also permits a comparison to other methods of source mapping (for example the 14C method). The EC fraction was between 20% and 50%. The heating plant with the lowest PM10 emissions usually had higher EC values. The oldest unit, a tiled stove, had the highest OC fraction. These results were confirmed by comparison to studies by Goncalves et al (2012) and subsequently, they were also used as the basis for microtracer modelling in the *PMinter* project.

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