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FINE AND ULTRAFINE PARTICLES FROM COMBUSTION SOURCES - INVESTIGATIONS WITH IN-SITU TECHNIQUES

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INTRODUCTION

Primary and secondary aerosol particles from combustion sources affect global climate and are suggested to be important for aerosol related health effects. Combustion particles vary widely in physical and chemical properties within and between sources and are therefore expected to affect climate and health differently. There is a strive towards the use of in-situ techniques to analyse particles while airborne. Hygroscopic Tandem Differential Mobility Analyzer (H-TDMA) measurements of hygroscopic growth provide direct information of particle growth due to water-uptake in the atmosphere and in the human lungs. The growth affects respiratory deposition; H-TDMA data also give information on particle solubility, which affects the uptake kinetics upon deposition. Evaporation rates determined with the Volatility-TDMA is in principle a measure of the vapor pressures of the particle constituents, which can be used to infer evaporation/condensation processes in various settings. Another important application of TDMA-measurements is to separate different particle types from the same source (external mixture). Particle morphology affects measurement techniques, particle optics and may for insoluble particles also be important for adverse health effects. The objective of this work was to compare the properties of particle emissions from some common indoor and outdoor combustion sources.

METHODS

Particles from local district heating of woody biomass were passed through a dilution system (Wierzbicka et al. 2005; Pagels et al. 2003). Emissions from three indoor particles sources; sidestream cigarette smoke, candles and incense were studied in a 22 m^3 stainless steel chamber at EAT (Pagels 2005). Emissions from a 10 kW wood pellets burner were studied in a similar chamber at ETPC (UmU) developed for human wood smoke exposure studies. Particle number concentration and size distributions were determined with an Electrical Mobility Spectrometer (SMPS 3934, TSI Inc.). Hygroscopic growth and particle volatility were studied with TDMA analysers. In a few cases combined SMPS-Electrical Low-Pressure Impactor data were used to assess the particle morphology in-situ. A TEOM was used to determine the mass concentration. Samples for the chemical composition were collected using filter and low-pressure impactor samplers and then analysed off-line for metals (PIXE), major ions (IC) and organic and elemental carbon (OC/EC; thermal-optical analyser). Complementary data on the studied particle types and representative data for diesel emissions and long range transport were collected from the litterature.

RESULTS AND DISCUSSION

The results of the study are shown in table 1. From biomass combustion three extreme particle types have been identified dependent on the combustion conditions, with particles being dominated by potassium salts, elemental carbon and organic carbon, repectively. These particle types are varying strongly in particle size, hygroscopic growth, morphology and emission rates over time. Sidestream cigarette smoke and incense burning are examples of sources of organic aerosols from incomplete

combustion with particle properties similar to those of the low-temperature biomass combustion. The volatility of these particles decrease over time during ageing in the chamber indicating that the chemcial composition changes accordingly, either through evaporation or oxidation of organic compounds. Soot (EC) dominated aerosols are typically strongly agglomerated, therefore relations between number size distributions based on mobility and particle mass concentrations are complex. Mobility sizes of soot-particles from biomass combustion and candles are significantly larger than those from diesel engines. Relatively high particle concentrations may form even when oxidation of carbon in the fuel is complete. For biofuels and candles these particles typically have high hygroscopic growth factors and are emitted with low temporal variations as expected from the stable combustion processes. In biomass combustion the particles form through heterogeneous chemcial reactions in the gasphase involving oxidation of SO_2 and subsequent reactions with K to form K_2SO_4.

The different particle types have been separated with TDMA-techniques. While the particle types from candles and diesel engines are relatively general (however, potentially changed by future engine technologies, particle traps and oxidation catalysts), the mixing status and formation mechanisms of the different particle types in residential biomass combustion are more complex and the present understanding is limited. For example organic compounds may condense onto present EC or salt particles during sampling in a "real-world" combustion cycle.

Table 1. Summary of properties for the studied particle sources and comparissons with particles from diesel engines and long range transport aerosol.

Particle Source	Mobility Diameter (nm)	Main Chemical Components	Hygroscopic Growth at RH=90%	Volatility (°C)*	Morphology	Emissions – Temporal Variations
Biofuels (optimized)[2,4,7]	30-120	K_2SO_4, KCl	1.5-1.7	Non-volatile	Compact	Small
Biofuels (air-starved, >800°C)	100-600	EC	1.0	Non-vol.	Aggl.	Large
Biofuels (cold , ~500°C)	100-300	OC	(1.0-1.2?)	(50-150?)	Compact	Large
Tobacco Smoke[3]	50-200	OC	1.1	50-150	Compact	Medium
Incense[3]	100-300	OC	1.1	50-150	Compact	Small
Candles (nucl. mode)[3]	5-80	(Salts?)	1.5 or 1.8	130-170, 400-450	?	Small-Medium
Candles (soot mode)[3]	80-500	EC[1]	1.0	Non-vol.	Aggl.	Large (Air flow)
Candles (smoulder)[3]	20-150	OC[1]	(1.0?)	50-100	Compact	Large (Wick length)
Diesel (Accumulation)[5,6]	30-120	EC+OC	1.0	EC non-vol. OC 70-100	Aggl.	Large (Load, Fuel)
Diesel (Nucleation)[5,6]	5-30	OC	1.0	60-90	Compact	Large (Load, Fuel)
Long Range Transp. (Accumulation)	100-300	$SO4^{2-}$+OC	1.2-1.7	$SO4^{2-}$ 100-200 OC < 100	Compact	Large (Meteorology)

* The volatility is given as the temperatures between which the majority of the aerosol volume is evaporated in the thermodesorber in the V-TDMA.

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