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INTRODUCTION

In the strive for renewable and CO_2-neutral energy sources the biomass burning is predicted to increase in the following years. As part of a coordinated Swedish effort aiming at determining the possible effects of increased biomass combustion for power and heat production on the environment and human health, the emissions from a 1 MW biomass combustion unit was studied. During wintertime, the studied moving grate combustion unit burns moist forest residues (water content 30-55% by mass) for production of 1 MW of heat, distributed locally to some hundred houses in the small community of Ingelstad, located outside Växjö in southern Sweden.

In February 2001, the hygroscopic properties of the fine mode (<300 nm) aerosol particles emitted from this burner were studied using a Hygroscopic Tandem Differential Mobility Analyser (H-TDMA). To our knowledge, this is the first time that the hygroscopic properties of aerosol particles emitted from a biomass combustion unit have been studied with the H-TDMA technique. The instrument measured the hygroscopic diameter growth for individual particles with dry sizes between 20 and 265 nm when taken from a dehydrated state to an elevated humidity close to 90% relative humidity (RH). The H-TDMA measurements were performed mainly to characterize the biomass combustion particle emissions in order to enable an apportionment between various sources when studying ambient aerosols and to predict the negative effects on health and environment of the emitted particles. The measurements were also done to study the particle formation and transformation mechanisms during biomass combustion.

EXPERIMENTAL

The aerosol particles were sampled at 150 °C after a multi-cyclone and a flue gas fan, immediately before the stack. The flue gases were diluted (ten- to twentyfold) and cooled to room temperature using particle-free dry compressed air. The cooled gas stream was diluted further (1:10) before entering the H-TDMA and a DMA (TSI SMPS 3934) used for concurrent measurements of aerosol particle number size distributions. Additional measurements include super-micrometer particle size distributions (TSI APS 3320), a Dekati low pressure impactor collecting samples for elemental analysis, and filter sampling for analysis of major ions. When the boiler operated at full capacity, the total particle stack emissions were ~150 mg/Nm^3.

RESULTS

The H-TDMA data showed that the particles emitted from the biomass combustion unit had a unimodal hygroscopic behaviour (Figure 1). The growth factors were quite high (1.5-1.8), decreasing with increasing size, and would have been classified as more hygroscopic if observed in atmospheric aerosols. Ion chromatography and PIXE, used for chemical analysis showed K_2SO_4 (followed by KCl) to be the main ion content, and K, S, Cl and Zn to be the major elemental components of the sub-micrometer

aerosol particle mass (L Lillieblad et al, 2001). The presence of alkali salts, in this case K_2SO_4 and KCl (pure KCl at 90% RH has growth factor ~2.1), explains the high growth factors of the emitted particles.

The observed growth factors can be used to estimate soluble volume fractions ε of the individual aerosol particles, based on the simple assumption that KCl was the only compound contributing to hygroscopic growth. The soluble volume fractions thus calculated (Tang, 1997) ranged from nearly fully soluble ($\varepsilon \approx 0.8$) for 20 nm particles, to $\varepsilon \approx 0.3$ for the 165 and 265 nm particles. The soluble volume fraction had dropped to $\varepsilon \approx 0.5$ already at 35 nm.

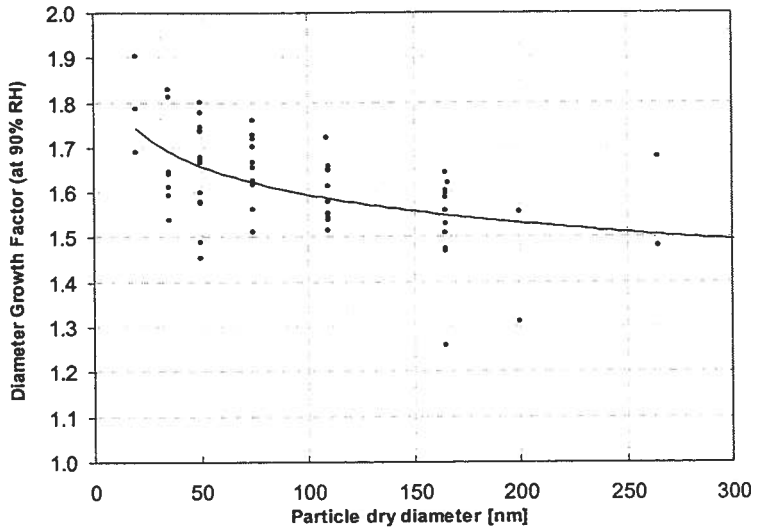

Figure 1. Diameter growth factors of particles emitted from the 1 MW biomass combustion unit operating on moist forest residues. The line was drawn only to guide the eye.

Typical size distributions had CMD at 125 nm, GSD ~1.6, and number concentrations around $2 \cdot 10^7$ cm^{-3}. At the point of sampling, the new particles formed by condensation of low-volatility vapours during cooling of the flue gases had largely coagulated with larger particles, such as primary soot particles. The observed highly soluble 20 nm particles – that were very few in comparison with the particles with sizes around 125 nm – are likely to be the remains of the numerous ultrafine particles formed during cooling. The unimodal behaviour of the hygroscopic properties suggests that the processes of coagulation and condensation shapes the aerosol into an internal mixture, that is all particles of a given size have identical, or at least similar, chemical composition.

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