Characterization of indoor and outdoor aerosol during extreme pollution events from winter heating in single-family home districts

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Introduction

Heating systems based on solid fuel are the most popular in single family home districts of Nordic countries. Wood-based biomass is mostly used fuel. At the same time in countries of lower income, other types of fuels such as coal, or even uncontrolled fuels such as calorific fraction of household waste are being incinerated. Combustion of the above mentioned fuels in small scale devices result in broad spectra of pollutants emitted, including particulate matter, VOCs, PAHs and other products of incomplete combustion. High density of this type point sources cause extreme concentrations of pollutants in ambient air, especially in the events of unfavorable meteorological conditions. Indoor air is also affected to a higher extent, although there is little data on I/O levels of aerosol concentration during such events.

The aim of this research was to characterize aerosol particles during peak pollution events in residential area of single family houses.

Methods

Concentration of outdoor and indoor air aerosol particles was measured in residential area of Kaunas city, Lithuania. Measurements were performed in January, 2013. The sampling site was located in the centre of city, which in turn is situated in the river valley. Entire district was occupied with private houses (years built 1950-1970) that have individual heating systems based centralized natural gas, biomass or fossil fuel burning.

Measurements of outdoor aerosol PSD were performed using ELPI+ (Dekati Ltd., Finland). Gravimetric $PM_{2.5}$ mass concentration was determined by PEM 10 lpm (MSP Corp., USA) samplers and $PM_{2.5}$ 16.7 lpm cyclones (BGI Inc., USA) on 25 and 37 mm Tissuquartz filters (Pall, USA), respectively. Subsequently, these filters were analyzed for stable carbon isotopes and anhydrous sugars. TSP (25 mm GF/A filters) samplers and XAD-2 (SKC Inc., USA) sorbent tubes were used for particulate and vapour phase PAH sampling. Measurement devices were placed on the second floor balcony, at 6 meters height.

Indoor samplers were placed in the second floor uninhabited room. Pumps of samplers were placed separately in another room. Measurement of indoor aerosol PSD was performed by MOUDI 110 30 lpm (MSP Corp. USA). Particles were collected on raw aluminum foil. Real time particle distribution and trend was obtained with OPC Handheld 3016IAQ (Lighthouse Inc., USA). Similar PM sampling techniques were used for indoor PM sampling for subsequent analyses of stable carbon isotopes, anhydrous sugars as well as gaseous and particle-bound PAHs.

Ambient temperature, relative humidity, CO and CO_2 concentrations were measured by IAQ-Calc meters (TSI Inc, USA). Average temperature during sampling period: outdoors -12 °C, indoors - +16 °C.

Results

During the sampling campaign, several extreme pollution events were registered, with PM2,5 concentrations reaching above 200 μm/m^3. Out of these periods, size distribution data of one hour was extracted to plot PSD presented in Figure 1. It represents evening pollution episode at 10 pm, when the emissions were the strongest. Based on number concentration, particle size distribution was bimodal with modes at 0.0165 μm ($121 \cdot 10^4$, #/cm^3) and 0.154 μm ($6.51 \cdot 10^4$, #/cm^3). The measured PSD is very similar to reported in literature in urban areas highly influenced by biomass combustion emissions. At the same time, the nucleation mode was present, indicating freshly-emitted combustion aerosol. According volume concentration particle size distribution was unimodal with mode at 0.944 μm (2580 μm^3/ cm^3), with an increase in nano particle range.

Substantial relationship between outdoor and indoor particle concentrations was observed, showing significant contribution of combustion particles to indoor air. Tracer chemical analyses revealed that a possible mix of fuels contributing to aerosol concentrations, possibly including biomass, coal, calorific fraction of waste.

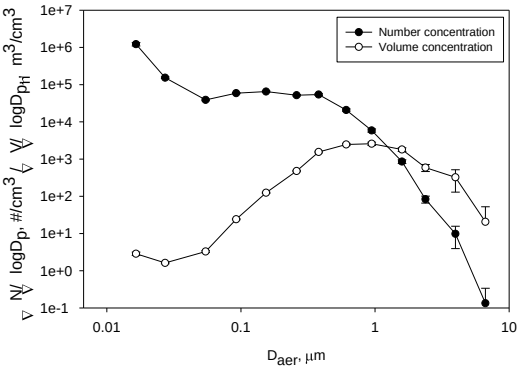

Figure 1. PSD of outdoor air aerosol during peak pollution event.

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