Particle size distributions of combustion aerosol of various local fuel mixtures

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Introduction

Biomass is increasingly popular fuel for individual and district heating boilers in Lithuania. Consumption of this type of fuel grows constantly due to rising prices of fossil fuels. Use of biomass as a local and "clean fuel" in individual heating boiler and in municipal central heating system boilers is supported by the state.

Despite of its near-zero carbon balance, the combustion of biomass can be significant source of fine aerosol particles, VOC, PAH and other products of incomplete combustion that has negative effect on human health.

Aim of this study was to investigate emissions of aerosol particles and gaseous pollutants generated during combustion of local biomass fuels and their mixtures, including wood pellets, sunflower shell pellets, straw pellets, municipal waste water treatment sludge and others in small scale heating boilers.

Methods

The laboratory fuel combustion experiments were conducted in a small scale (13 kW) grate-type heating boiler. During experiment the following types of fuel were used: wood pallets (humidity content - 7.1 %, ash content - 0.42 %, calorific value – 16907 kJ/kg), straw pellets (12.3 %, 6.1 %, 14133 kJ/kg), rapeseed and other grain waste, sunflower shell pellets, dried wastewater sludge, as well as mixtures of these fuels. The laboratory heating boiler was equipped with controlled fuel supply, removal of ash, air supply, and water circulation. The supply of fuels was kept in a range of 2.5-3.5 kg/h. Flue gas temperature and velocity was measured using temperature and velocity probes. Samples of aerosol and gaseous pollutants were taken through sampling ports in the exhaust tube.

Aerosol PSDs were measured using ELPI+ with double injector dilution system (Dekati Ltd., Finland) with dilution ratio of ~50. Gaseous pollutants were measured using flue-gas analyzer IMR2000 (Environmental Equipment Inc., USA). Measurements of pollutant emissions were conducted during stable and optimal regime of combustion process.

Results

As expected, various fuels exhibited different emission patterns based on their chemical composition. Figures 1 and 2 present PSDs of aerosols obtained the combustion of wood pallets (Fig. 1) and a mixture of wood pellets and wastewater sludge (humidity content - 5 %, ash content - 38 %, calorific value – 11107 kJ/kg, Fig. 2). According to number concentration, PSD obtained from wood pallets a clear mode was observed at 0.154 μm, ($1.59 \cdot 10^8$ #/cm^3). In case of the calculated volume concentration, the PSD was bimodal (0.26 μm, $1.05 \cdot 10^4$ μm^3/cm^3; 9.88 μm, $6.8 \cdot 10^4$μm^3/cm^3). Number concentration PSD obtained from mixture fuel burning was clearly bimodal (0.0272 μm, $428 \cdot 10^5$ #/cm^3; 0.154 μm, $960 \cdot 10^5$ #/cm^3), as well as volume PSD (0.0545 μm, $6.38 \cdot 10^2$ μm^3/cm^3; 9.88 μm, $5.0 \cdot 10^6$ μm^3/cm^3).

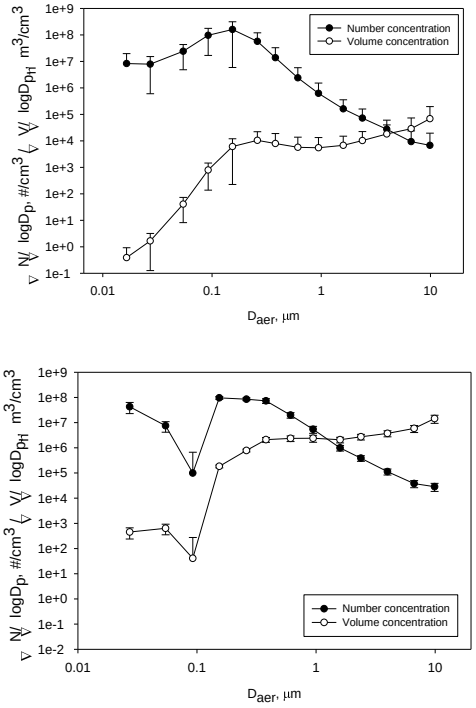

Figure 1. Number and volume concentration PSDs of aerosol particles emitted during combustion of a) wood pellet, b) mixture of 50% wood pellets and 50% wastewater sludge

The following concentrations of gaseous compounds were registered for the above cases: wood pellets: O_2 – 11.4±1.1%, CO – 121±22 mg/m^3, CO_2 – 9.3±2.5 %, NO - 171±24.3 mg/m^3, NO_x - 38±4.6mg/m^3, SO_2 - 270±26.4 mg/m^3; wood pallets and wastewater sludge mixture: O_2 – 12.5±1.3%, CO – 994±92 mg/m^3, CO_2 – 8.2±2.7 %, NO - 521±44.7 mg/m^3, NO_x - 832±37.9 mg/m^3, SO_2 - 1477±166.1 mg/m^3.

The results provide valuable information on the evaluation of environmental impact of the combustion of the researched fuels as well as data on optimization of combustion processes.

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