THESIS FOR DEGREE OF DOCTOR OF PHILOSOPHY

Alkali-containing aerosol particles – release during biomass combustion and ambient air concentrations

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Abstract

Air pollution in the form of particles has considerable influence on human health and climate. Atmospheric aerosol particles arise from direct emissions of particles and from the conversion of certain gases to particles in the atmosphere. They are produced by a number of different sources and have a typical lifetime of about a week in the atmosphere. The chemical composition of the atmospheric aerosol is highly variable in time and space, and the different effects of the aerosol can usually not be understood without taking its multi-component nature into account.

The overall aim of this thesis is to contribute to an improved understanding of climate effects and air quality issues related to aerosol particles. The thesis focuses on aerosol particles containing alkali-compounds, and particles produced by biomass combustion are of particular interest. Aerosol mass spectrometer techniques for highly sensitive and selective detection of alkali-containing particles have been further developed and applied in laboratory experiments, in fluidised bed combustion, and in ambient air measurements. The experimental techniques provide the chemical composition of individual aerosol particles with high time resolution and they are well suited for combustion aerosol applications, and for detection of sea salt particles that contain a large fraction of sodium compounds.

Laboratory experiments were performed to study the emission of potassium- and sodium-containing compounds during rapid pyrolysis of birchwood. The alkali emission during the pyrolysis phase and from ash and char formed at high temperatures was characterized. Studies were also carried out during biomass combustion in a 12 MW (thermal) circulating fluidized-bed boiler. The effect of the addition of chlorine and/or sulphur to the fuel on fly ash composition, deposit formation, and superheater corrosion was investigated. Addition of sulphur and chlorine increased the formation of submicron particles and lead to enhanced deposition of potassium sulphate and chloride. The results compared well with results from earlier laboratory-scale experiments concerning the effects of chlorine and sulphur on potassium chemistry. The findings are of importance for actions aimed at minimizing alkali related corrosion and deposition problems during large-scale biomass conversion.

The seasonal variation of the elemental composition of particulate matter in Skopje was studied by chemical analysis of samples collected with impactor technique. Major aerosol components were identified including mineral dust, oil combustion, traffic-related aerosol and secondary sulphate, while a separate biomass burning component could not be identified with the employed methods. Aerosol mass spectrometry was used to study the influence of atmospheric transport patterns and meteorology on alkali concentrations in Gothenburg. The observed potassium and sodium concentrations were concluded to be affected both by emissions from the nearby region and by long-range transport. Sodium-rich sea salt particles were favoured by westerly winds and high wind speeds, and were preferentially observed in air masses originating from the Atlantic. Potassium-rich particles originating from biomass burning were favoured by low temperatures and low wind speeds, and they were most abundant in air masses transported from Eastern and Central Europe.

Keywords: aerosol, alkali metal, sodium, potassium, pyrolysis, combustion, biomass burning, circulating fluidised bed, surface ionisation, aerosol mass