EMISSIONS FROM THE COMBUSTION OF COAL AND MIXTURE OF COAL AND WOOD PELLETS - INDIVIDUAL PARTICLE ANALYSIS BY TEM/EDX ELECTRON MICROSCOPY

J.V. Niemi (1), A. Frey (2), K. Saarnio (3), L. Pirjola (4) A. Häyrinen (5), F. Mylläri (6), T. Rönkkö (6) and R. Hillamo (3)

(1) Helsinki Region Environmental Services Authority (HSY), P.O. Box 100, FI-00066 HSY, Finland; (2) Observation Services, Finnish Meteorological Institute, P.O. Box 503, FI-00560 Helsinki, Finland; (3) Air Quality, Finnish Meteorological Institute, P.O. Box 503, FI-00560 Helsinki, Finland; (4) Department of Technology, Metropolia University of Applied Sciences, P.O. Box 4021, FI-00180 Helsinki, Finland; (5) Helsingin Energia Plc., FI-00090 HELEN, Finland; (6) Aerosol Physics Laboratory, Tampere University of Technology, P.O. Box 692, FI-33101 Tampere, Finland
Presenting author email: jarkko.niemi@hsy.fi

Summary
The study aims to characterise particle emissions from a large coal-fired energy plant operated with pure coal or mixture of coal and wood pellets. Particles were sampled from the smokestack, after the cleaning of flue gases with an electrostatic precipitator (ESP) or with a combination of electrostatic precipitator and desulphurisation plant (DSP) including fabric filters. Individual particle elemental and morphological analysis was performed using transmission electron microscopy coupled with energy dispersive X-ray microanalyses (TEM/EDX). When only ESP was used, the emissions from the both fuel types were mainly composed of mineral impurities of coal. Furthermore, soot particles were observed and their proportions were clearly higher in the combustion of mixed coal and wood pellets than in the combustion of pure coal. When both ESP and DSP were used, the particle concentrations were low and chemical compositions (Ca, S, Na and Cl) indicated that their main sources were the reagents used in the DSP processes as well as gaseous components removed from the flue gases.

Introduction
The co-firing of coal with different biofuels is an option to mitigate greenhouse gas emissions in energy production. The biofuel type and proportion (%) are factors that may significantly alter the particulate and gaseous emissions in co-firing combustion process. Furthermore, the final emissions from a smokestack are highly dependent on both combustion and emission cleaning technique used (Xu et al. 2011). There is a clear need to test and optimise combustion conditions for new fuel mixtures in different energy plants to ensure low emissions and high energy efficiency.

Methodology and Results
We investigated particle emissions from a pulverised coal boiler of a large combined heating and power plant. The boiler was fuelled either with pure coal or mixture of coal and wood pellets (pellets 4.5 ±1.4% of the total fuel volume). The emissions were investigated at the height of 35 meter of the smokestack. Four different combustion cases were studied; 1) pure coal with ESP or 2) with ESP+DSP cleaning as well as 3) mixture of coal and pellet with ESP or 4) with ESP+DSP cleaning. The size-segregated (8 size fractions from 56 to 5600 nm) particle samples were investigated with TEM/EDX. The individual particles (# ~ 1500) analysed were classified into different particle clusters (=groups) based on their elemental compositions (excluding O, N and H) using hierarchical cluster analysis.

When only ESP was used, the emissions from the both fuel types were mainly composed of mineral impurities of coal (typical elements in various particle clusters Si, Al, Ca, Fe, P, S, K, Mg, Na and Ti) and they were formed by spherical nanoparticle chain aggregates in the smallest size ranges (~ smaller than 200-300 nm) and individual spherical fly ash particles in the larger size ranges (Fig. 1). Furthermore, C-rich soot particles were observed in the smallest size ranges and their proportions were clearly higher in the combustion of mixed coal with wood pellets than in the combustion of pure coal.

When both ESP and DSP was used, the main elements of the particles were Ca, S, Na and Cl indicating that their main sources were the reagents used in the DSP processes ($Ca(OH)_2$ and NaCl) as well as gaseous components removed from the flue gases (e.g. SO_2). The proportions of mineral material and soot were very low for both fuel types, showing efficient cleaning of flue gases and low primary particle emission into the atmosphere.

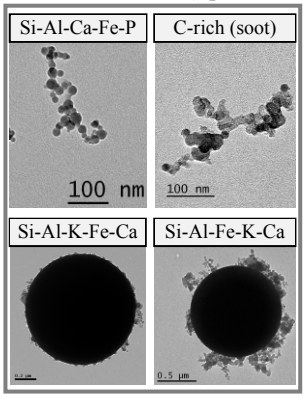

Fig.1 Typical particles after ESP from pure coal (left) and mixed coal and pellet (right).The large spherical fly ash particles (bottom line) were often partially covered by nanoparticle chain aggregates.

Conclusions
The combined cleaning method (ESP and DPS including fabric filters) of the power plant removed efficiently primary particles from the emissions of the both fuel types. The mixed combustion of coal and wood pellets increased the proportion of soot particles in the submicron particles collected after ESP, which emphasises need to further optimize combustion conditions for mixed fuels.

Acknowledgement
This work was partly funded by Measurement, Monitoring and Environmental Assessment (MMEA) research programme, which is supported by Tekes and coordinated by the Finnish Energy and Environment Cluster - CLEEN Ltd.

References
Xu, M., Yu, D., Yao, H., Liu, X., Qiao, Y., 2011. Coal combustion-generated aerosols: Formation and properties. Proceedings of the Combustion Institute 33, 1681-1697.