Dilution affects particle properties originating from residential biomass combustion

H. Lamberg[1], T. Kaivosoja[1], J. Leskinen[1], M. Kortelainen[1], A. Viren[1], H. Koponen[1], V. Tiihonen[1], M. Miettinen[1], J. Pyykönen[2], J. Jokiniemi[1,2] and J. Tissari[1]

[1]Department of Environmental Science, University of Eastern Finland, Fine Particle and Aerosol Technology Laboratory, P.O. Box 1627, FI-70211 Kuopio, Finland
[2] VTT, Technical Research Centre of Finland, Fine Particles, P.O. Box 1000, FI-02044 VTT, Espoo, Finland
Keywords: dilution, biomass combustion, sampling.
Presenting author email: heikki.lamberg@uef.fi

Residential biomass combustion is known to be a significant source of particulate matter (PM) in regions where it is in common use. Sampling of fine particles from residential combustion appliances is of great significance because of a need to create standards for particulate emission measurements. Small-scale biomass combustion sources often emit fine particles that contain substantial amounts of organic compounds that condense at relatively low temperatures. Sampling procedures, such as temperature control and dilution ratio (DR), are known to affect sampled particles, especially as concerns their organic constituent (Lipsky et al. 2006). The aim of this study was to identify the effect of DR on fine particles, and to study the use of porous tube diluter in this type of measurements.

Batch combustion appliance with simple combustion technology, a sauna stove, was used in the experiments. Sampling of flue gases was done with a setup of porous tube and ejector diluters (Tissari et al. 2007). Three different DRs, 15, 40 and 115, were used. DRs were controlled with simultaneous CO_2 concentration measurements in the flue gas and in the diluted sample gas. Two similar dilution and sampling systems were operated during each measurement at different DRs. This ensured that the samples were comparable even if the combustion process varied slightly between each individual experiment, which is often present in batch-combustion process.

Overall, only a minor effect of DR on sampled PM mass was observed in the experiments. As expected, the smallest DR seemed to lead to the highest PM mass. While the total PM mass remained rather constant, a large variation as a function of DR was observed in measured particulate form PAH content, in the studied combustion conditions. The total particulate PAH at DR 15 was 1.8-fold to 2.9-fold compared to DRs 40 and 115, respectively (Fig. 1). The PAH/PM_1 ratio decreased from 9.4% to 5.8% and 2.5%, while DR increased from 15 to 40 and 115. The effect of DR was the largest for light PAH compounds. Heavy PAH species have most likely condensed prior to sampling. The fact that their measured concentrations scaled very well with DRs indicated that the porous tube diluter worked in a reliable way.

Computational fluid dynamics (CFD) modelling was used to obtain a better understanding of flows and losses inside the porous tube diluter. The studies identified the tip of the porous tube nozzle as the critical region for condensable organic vapour and fine particle losses. Right at the tip, the porous flow does not provide protection. Overall, only minor sampling losses are predicted for typical small-scale biomass combustion conditions. Model considerations of dynamics involved in gas-to-particle conversions indicate that the residence times in the diluter are sufficient for equilibrium, provided that no chemical reactions are involved. This is the case for PAH compounds that are the same in the gaseous and condensed forms. Indeed, vapour pressures seem to provide sufficient explanation of the observed trends in PAH contents.

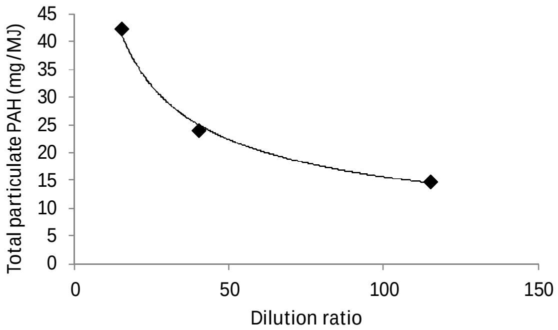

Figure 1. The effect of dilution ratio on total particulate PAH.

The porous tube diluter worked in a consistent and reliable way in the measurements. The experiments indicate that, even in cases where total PM emissions only show weak DR dependence, particulate properties may still be significantly affected by DR. This is especially true of health effect studies. The samples have large variation in their PAH contents, and consequently, possibly in their health effects as well.

This work is part of the ERA-NET joined project EN-PME-TEST. The work at UEF and VTT is funded by the Finnish Funding Agency for Technology and Innovation (TEKES). This work was further supported in part by the strategic funding of the University of Eastern Finland for project Sustainable Bioenergy, Climate change and Health (SUBI).

Lipsky, E.M. and Robinson, A.L. (2006). *Environ. Sci. Technol.* **40**, 155–162.

Tissari, J., Hytönen, K., Lyyränen, J., Jokiniemi, J. (2007). *Atmos. Environ.* **41**, 8330–8344.