Particle release from open ethanol fireplaces into the indoor environment

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The indoor use of open ethanol burning fireplaces is a common decorative trend. In contrast to wood burning fireplaces that feature enclosure and/or chimneys, all combustion products that ethanol fireplaces generate are released into the indoor environment. Due to the fact that the fuel is burned in liquid or gel form, complete combustion can be expected. Even though the fireplaces show no significant visible smoke they can be assumed to be strong sources for (ultra)fine particles (UFP). The present study reports emission test chamber experiments of ethanol fireplaces with a series of liquid and gel fuels.

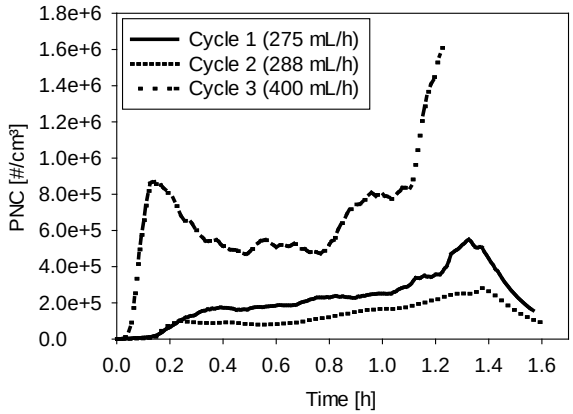

Figure 1. Development of the particle number concentration (PNC, FMPS) during the burning phase of 3 measurement cycles of sample "1/fluid" (500 mL). The observed ethanol consumption is given in brackets.

The open fire places were tested in a ventilated 48 m³ stainless-steel emission test chamber according to the recommendations of the manufacturer and DIN 4734-1. Three liquid and five gel samples were tested. Before each experiment, the heating value of each fuel was measured. The burning phases lasted between 70 - 240 min. The emission was monitored during and until 12 h after the burning phase. The following parameters were continuously measured: particles, NO_x, CO, CO_2 and formaldehyde. In addition volatile organic compounds were measured via a thermal desorption GC/MS method. The particles were continuously measured via Fast Mobility Particle Sizer (FMPS, 5.6 nm – 560 nm) and Grimm Aerosol Spectrometer (0.3 µm – 20 µm). The particle exposure assessment was performed on the basis of the lung deposition model of the International Council on Radiological Protection (ICRP, 1994). The longest burning time observed was 240 min and, thus, the assumed exposure scenario comprised a duration of 4 h for all tested devices without further consideration of the burning time.

Operation of the ethanol fireplaces significantly affected the air quality in the test chamber. During the operation of some devices the German guideline values for CO_2 (2000 ppm) and NO_2 (350 µg/m³) were exceeded. Some systems showed considerable release of formaldehyde. Peak particle concentrations ranged between $6.2 \cdot 10^3$ #/cm³ and $2.3 \cdot 10^6$ #/cm³ for the sum of particles in the size range of the FMPS. The devices were not constant emitters of particles and - in some cases - showed significant differences between different measurement cycles (Fig. 1). The count median diameter (CMD) of the particles during the burning phase ranged between 10 nm and 65 nm. This low particle size allows deep lung penetration down to the alveolar region. For the present aerosols, approx. 60% of the total lung particle deposition is expected to occur in the lower alveoles (AI). The calculated particle surface deposition ranges from 0.1 cm²/4h (AI) to 6.2 cm²/4h (AI) within an estimated exposure time of 4 h for a sitting male. Buonanno et al. (2011) estimated the daily alveolar particle intake for Italian in the range between 22.8 cm²/d (AI) and 25.1 cm²/d (AI) (3.8 cm²/4h – 4.2 cm²/4h) for several indoor activities, such as cooking and cleaning. The operation of an ethanol fireplace induces a particle exposure that adds between 1% and 155% to this common "background" exposure. (Fig. 2) This further illustrates that open ethanol fireplaces are a strong source for ultra-fine particles indoors in some cases.

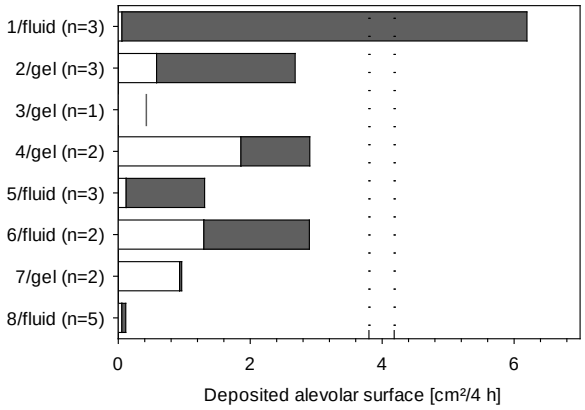

Figure 2. Estimated particle surface deposited in the alveoles of the human lung. The dashed lines mark the range of estimated particle deposition (4 h) by Buonanno et al.

Buonanno, G., Giovinco, G., Morawska, L., et al. (2011) *Atmospheric Environment*, **45**, 6216-6224.
ICRP (1994) *Annals of the ICRP*, **24**, 36-54.