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Controlled Human Chamber Exposure Studies of Biomass Combustion Aerosols

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INTRODUCTION

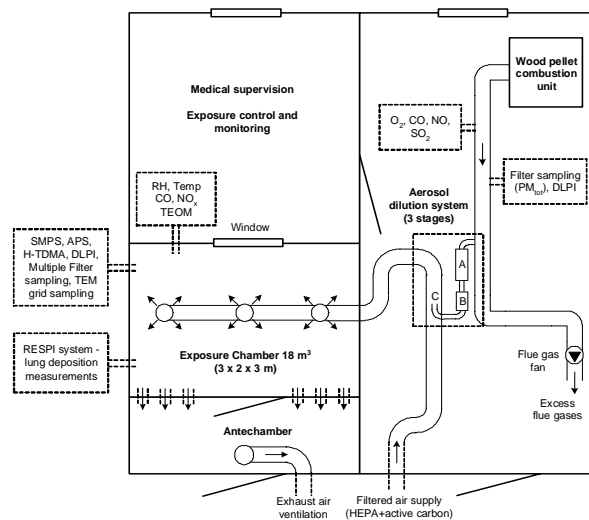
Combustion processes are major sources of air pollution with an increasing focus on airborne particles and their implications for the global climate and human health. Extensive evidence confirms the associations between ambient PM and increased cardiopulmonary mortality and morbidity (Brunekreef *et al.*, 2002). Indoor air pollution from cooking and heating in developing countries causes over 1.6 million premature deaths annually by e.g. COPD, tuberculosis, respiratory infections and cancer (Ezzati *et al.*, 2003). Residential wood combustion can deteriorate the urban air also in developed countries, and "wood smoke" is a complex mixture of gases and particles that most certainly possess a risk factor for human health (Boman *et al.*, 2006). To better understand the exposure-dose-effect relationships as well as to elucidate the underlying biological mechanisms, it is prudent to complement the epidemiological and toxicological work with controlled human exposure studies. This is today a well established methodology for diesel exhaust (Sandström *et al.*, 2004), but similar exposure studies dealing with wood combustion aerosols are, however, still missing.

In this work, a newly developed human exposure chamber set-up used for biomass combustion aerosols is described regarding system design and evaluation and aerosol generation/measurements. Also, the performance of the first exposure campaign is described. The chamber set-up has been used in an interdisciplinary project for studies of health effects of "wood smoke" emissions, respiratory deposition of biomass combustion aerosol particles (Löndahl *et al.*, 2006) and detailed physical and chemical characterisation of different biomass combustion aerosols (Pagels *et al.*, 2006).

METHODS

A human exposure chamber set-up for biomass combustion aerosols was designed and constructed (Figure 1). The system comprises a chamber with the size of a small room (3 × 2 × 3 m) for 1-2 persons. The diluted aerosol is introduced at the ceiling by air distributors and is driven by a slight overpressure through openings at floor level to an antechamber. A fan creates constant mixing in the chamber. The system was designed to achieve; i) controlled generation of

different biomass combustion aerosols, ii) dynamic dilution system with relevant conditions for residential "wood smoke" and iii) easily changeable, stable and well characterized chamber exposure conditions.



A: "Mini-tunnel condensation" dilutor (~1:3) (dilution air at appr. -15 °C)
B: Ejector type dilutor (~1:5) at room conditions (~20 °C)
C: Final dilution (1:10-40) -> concentration and chamber flow control

Figure 1. Schematic illustration of the exposure chamber and biomass combustion aerosol generation set-up.

A residential wood pellet boiler fired with softwood pellets was used. The combustion performance of the system can be adjusted so that different combustion conditions and aerosol generation can be studied. In the present human exposure study, low-temperature incomplete residential wood log combustion (i.e. "wood smoke") was simulated by adding moist sawdust to the pellet fuel (~18 % total fuel moisture) and adjusted (reduced) air/fuel mixing.

A minor part (5-10 L/min) of the flue gases is extracted to the first mini-tunnel dilution stage (A), where water saturation can be achieved to simulate ambient smoke plume conditions. The exhaust flow rate from the first stage is set by the ejector pump used for the second dilution stage (B). The dilution ratio of the first stage is altered by adjusting the particle free dilution air supply (A). In the final dilution step (C) the total dilution ratio and air exchanged ratio for the

chamber is defined. The total flow of diluted aerosols through the chamber can be set to 100-350 m³/h which corresponds to air-exchanged rates of 5 to 20/h.

The undiluted flue gas composition (O₂, CO, NO and SO₂) and combustion temperatures are monitored together with CO and NO concentrations in the chamber. NO is used to determine the total dilution ratio. The particle mass concentration (PM_{2.5}) in the chamber is monitored with a Tapered Element Oscillating Microbalance (TEOM 1400). The TEOM, equipped with a PM_{2.5} impactor and a 48'' Nafion dryer, was operated at 30°C to decrease losses of semi-volatile material. The extensive characterization of the aerosol particles included on-line techniques (e.g. SMPS, H-TDMA and V-TDMA) as well as low-pressure impactors, multiple filters for chemical analysis and TEM-grid sampling.

19 healthy adults were exposed to "wood smoke" and "clean air" at different occasions. 1-2 subjects were alternating between 15 min rest and 15 min cycling in the chamber for 3 hours at each exposure occasion. The PM_{2.5} concentration in the chamber during the exposures was aimed at 250 µg/m³. The physiological/immunological responses comprise: symptoms (mucosal and airway); lung function; respiratory inflammatory markers; blood samples for inflammatory and coagulation markers; and bronchoscopy including biopsies (e.g. antioxidants) and BW/BAL (e.g. inflammatory markers and antioxidants).

RESULTS AND CONCLUSION

The design of the exposure chamber set-up showed high feasibility regarding flexibility and stability. Present combustion facilities were adjusted and used together with a dynamic aerosol dilution system. The system was designed for studies of fine and ultrafine combustion aerosol particles. Relatively stable aerosol conditions in the chamber were achieved and characterised for three different type of wood combustion (Pagels *et al*, 2006).

Low-temperature, incomplete biomass combustion aerosol ("wood smoke") was used in the exposure campaign which was successfully accomplished for all 19 human test subjects. The incomplete combustion process resulted in undiluted CO concentrations of 1000-8000 ppm and typical PM_{2.5} emissions of 30 mg/MJ. The flue gases were diluted 200-300 times with an average air-exchanged rate of 10/h during the exposures. The PM_{2.5} (TEOM) during the exposures varied in the range 200-300 µg/m³ with average of 220-240 µg/m³ (Figure 2). CO and NO exposure concentrations were 5-15 ppm and 0.2-0.3 ppm, respectively.

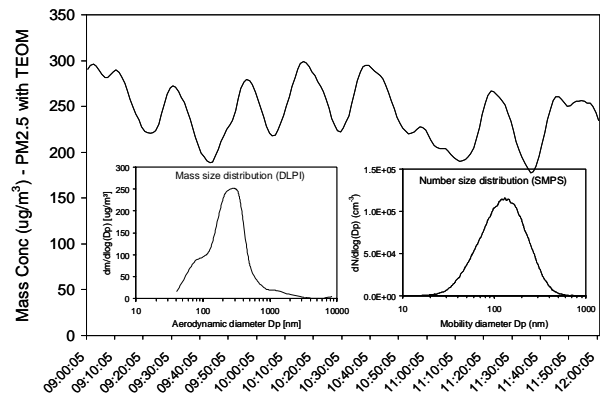


Figure 2. Typical mass concentrations (PM_{2.5}, TEOM) and particle size distributions (DLPI and SMPS) during a 3 h exposure.

This multidisciplinary project has in a novel way combined topics of combustion technology, aerosol science and respiratory medicine. The designed and constructed chamber facility and methodology used have shown to be very useful and gives data that can be related to well controlled and characterised wood combustion aerosol exposure. Presently, the data regarding human effect parameters from the first performed exposure campaign is under evaluation.

Keywords: Biomass Combustion Aerosols, Human Exposure Chamber, Health Effects

REFERENCES

- Boman, C., Forsberg, B. and Sandström, T. (2006) New light on wood smoke - a risk factor for respiratory health (Editorial), *Eur. Respir. J.*, In press.
- Brunekreef, B. and Holgate, S.T. (2002) Air pollution and health, *Lancet*, Oct 19, 360(9341), 1233-42.
- Ezzati, M., Hoorn, S.V., Rodgers, A., Lopez, A.D., Mathers, C.D. and Murray, C.J. (2003) Estimates of global and regional potential health gains from reducing multiple major risk factors, *Lancet*, Jul 26, 362(9380), 271-80.
- Löndahl, J., Pagels, J., Massling, A., Boman, C., Swietlicki, E., Rissler, J., Blomberg, A. and Sandström, T. (2006) Respiratory tract deposition of biomass combustion aerosol particles in 17 human subjects. *7th International Aerosol Conference, IAC 2006*. St.Paul, Minnesota. September 10-15.
- Pagels J., Boman C., Rissler J., Massling A., Löndahl J., Wierzbicka A., Swietlicki E. (2006). Residential biomass combustion aerosols - influence of combustion conditions on physical and chemical particle characteristics. (2006).. *7th International Aerosol Conference, IAC 2006*. St.Paul, Minnesota. September 10-15.
- Sandström, T., Helleday, R., Törnqvist, H., Behndig, A. and Blomberg, A. (2004) *Experimental studies in humans*. WHO-Review on Air Pollution. WHO Bonn.

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