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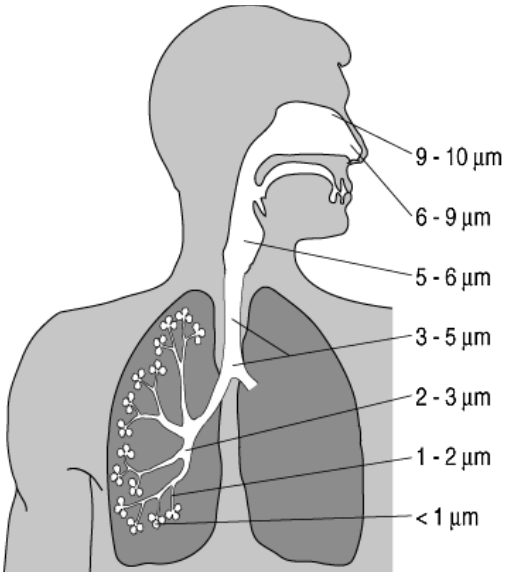
Characterisation of fire generated particles

Assessment of Fire Protection Measures

The particle size is essential

Whether a chemical substance is found in the gas phase or in the condensed phase associated with particles, may be important in different ways. First, a toxic molecule behaves chemically differently depending on whether the molecule is bound to a particle or not, but above all gives the particle-association other forms of transport than a gas phase. Species in the gas phase have a high diffusion rate and reactive molecules are rapidly absorbed in the respiratory tract mucosa, which thereby protects the deeper parts of the respiratory tract. However, a particle-bound molecular substance can be transported much longer before contact with the respiratory tract occurs. The deposition of particles in the respiratory system and its dependency on the size of the particle is shown in the figure. Small particles have a large relative surface and due to the often high content of small particles in fire effluents, compounds may be enriched through adsorption on particles.



The present project has examined the question of distribution patterns of important chemical compounds between gas phase and particle phase. It has also, in some cases, addressed the question of the distribution of individual particle-associated species between the different size-ranges of particles produced in a fire. The chemical compounds studied were hydrogen chloride (HCl), polycyclic aromatic hydrocarbons (PAHs), and isocyanates.

The fire model

The steady-state tube furnace, ISO/TS 19700, was chosen as the physical fire model in order to study the production of particles from different types of fire exposure. Three different fire types were investigated: oxidative pyrolysis, well-ventilated flaming fires and vitiated post flashover. Two materials were chosen for investigation, PVC-carpet and wood board, based on their prevalence fire exposure scenarios and their chemical composition.

Particle production

The particle production from the two materials was investigated both concerning the amounts produced and the particle size distributions. The production of particles on a mass basis was generally significantly lower from the wood board compared with the PVC-carpet. The tests with the PVC-carpet showed that relatively large particles are produced from all combustion conditions examined. The tests made with the wood board show preferably predisposition towards the production of small-sized particles during flaming combustion.

Particle associated chemical compounds

The analysis of PAHs in the tests with the PVC-carpet showed that volatile PAHs were dominating during all types of combustion. However, when the toxicity of the individual species was taken into account, the relative importance between volatile and particle associated PAHs changed. From the tests with the wood board material (OSB) it was noted that the highest yields of total PAHs were found from under-ventilated conditions, and the volatile part of the total PAH dominated for this material as well. The yields found from the well-ventilated tests were very low. Toxicity weighted data showed, however, that the particle associated part dominated the toxicity both for under-ventilated

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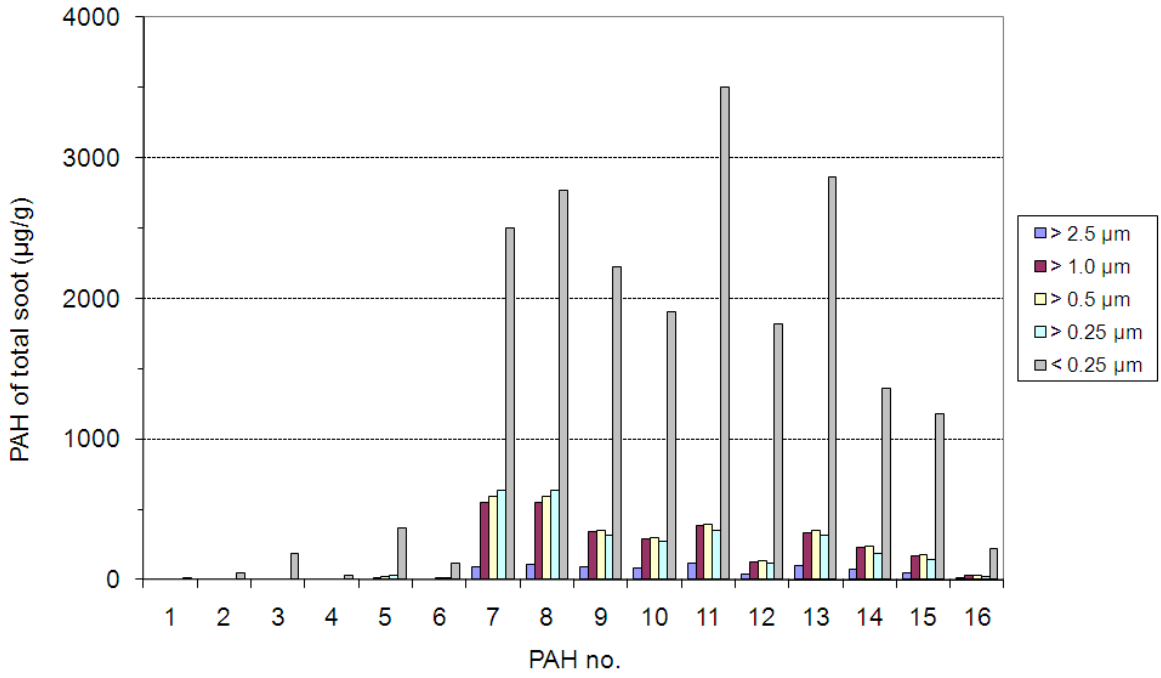
and well-ventilated conditions. The distribution of particle associated PAHs in a under-ventilated test with wood board is shown in the figure below.



Distribution of particle associated PAHs in the soot from under-ventilated combustion of wood board. The greatest part of the PAHs is associated with small respirable particles. PAH species are here numbered after increasing molecular weight, from naphthalene (1) to dibenz(ah)anthracene (16).

The study made of the presence of chlorine on particles showed that it is clear that the major part of the HCl produced during combustion of the PVC-carpet is present in the gas phase. Chlorine was found associated with particulates but these results were, however, inconclusive due to the difficulty in determining the source of the chlorine found in the soot fractions studied.

Isocyanates are emitted from the thermal degradation of polyurethane (PUR). However, the low PUR content of the materials investigated and the substantial degradation of the PUR in the tests resulted in no or very small amounts of quantifiable diisocyanates (i.e. high molecular species that can be associated to particles). Monoisocyanates such as ICA and MIC dominated in the emitted degradation products. These kinds of monoisocyanates are volatile compounds and almost exclusively present in the gas phase.

Report

The project is reported in: Characterisation of fire generated particles. SP Report 2010:01. The report can be downloaded from www.sp.se and from www.brandforsk.se, project number 700-061.

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