

Micro and nanoparticles released from the thermal cutting of polystyrene foams and the associated isomerization of hexabromocyclododecane (HBCD) diastereomers

Y.-Y. Kuo^{1,2}, H. Zhang³, A.C. Gerecke^{1*} and J. Wang^{1,2*}

¹Empa, Swiss Federal Laboratories for Materials Science and Technology, Dübendorf CH-8600, Switzerland

²Institute of Environmental Engineering, ETH Zurich, Zurich CH-8093, Switzerland

³Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian 116023, China

Keywords: Emission Characterization, Indoor Air Pollution, Thermal Treatment, HBCD

Presenting author email: Yu-Ying.Kuo@empa.ch

Polystyrene foam is widely used as building insulation material, architectural model and packing material. Due to its tendency to depolymerize when exposed to fire temperatures, and to generate volatile products of high fuel values, flame retardant is required to meet fire safety regulation. Hexabromocyclododecane (HBCD) is currently the most important flame retardant to protect polystyrene against ignition. However, HBCD has been listed on the 2010 Environmental Protection Agency action plans due to the fulfilment of regulatory thresholds for a persistent organic pollutant (POP). Therefore, workplace exposure and environmental emission of HBCD should be avoided.

In this study, we investigated the co-release of aerosol particles and HBCD during the thermal cutting of expanded polystyrene foam (EPS) and extruded polystyrene foam (XPS). The generated particles were simultaneously measured by a fast mobility particle sizer (FMPS) and collected by a cascade impactor (NanoMoudi). Further chemical analysis was done by a LC-MS/MS after necessary concentration and purification. In the breathing zone of a cutting worker, the number concentration of aerosol particles was above 1×10^{12} particles m^{-3} in the surrounding of operating location in both of EPS and XPS tests. The air concentration of HBCD was more than $50 \mu g m^{-3}$. Most of the released HBCD was partitioned into particles with an aerodynamic diameter at the nano-meter scale. The average concentrations of HBCD in these submicron particles generated from the thermal cutting of EPS and XPS were 13 times and 15 times higher than the concentrations in raw foams, respectively. (Zhang *et al.*, 2012)

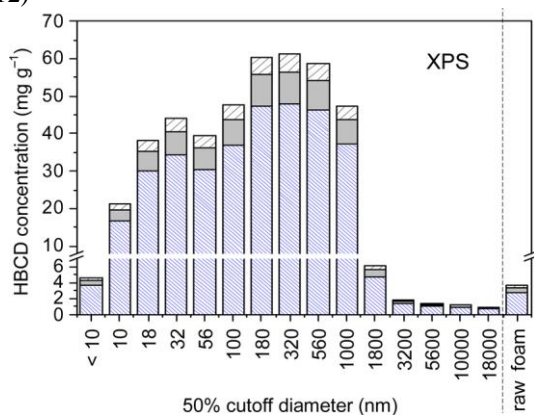


Figure 1. HBCD concentration in raw foams and in size separated particles from thermal cutting of XPS

In the meantime, HBCD underwent isomerization during this process, especially in tests of EPS form. The fraction of the more bio-accumulative α -HBCD increased remarkably, while the fraction of γ -HBCD decreased. The composition of HBCD diastereomers tended to resemble the ratio of thermal equilibrium reported by Peled *et al.* (1995) from the typical technical component. The fraction of HBCD diastereomers is independent from particle size but hugely influenced by the compartment.

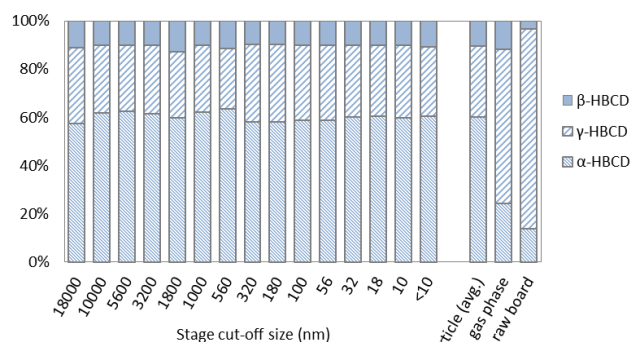


Figure 2. HBCD diastereomer fractions in different compartment and particle sizes in thermal cutting tests of EPS foam.

An occupational exposure assessment indicated that 7×10^7 particles and totally $20 \mu g$ of HBCD can deposit into the lung of the operating worker in 1 hour of working time. More than 70% of particles and 60% of HBCD of those would allocate in the alveolar region. This amount of HBCD is equivalent to the total intake of HBCD by an adult during 1–3 months in daily exposure. (Marvin *et al.*, 2011)

Zhang, H., Kuo, Y.-Y., Gerecke, A. C. and Wang J. (2012) *Environ. Sci. Technol.* **46**, 10990-10996.

Peled, M., Scharia, R., and Sondock, D. (1995) *Advances in Organobromine Chemistry II* Elsevier Science, 92–99.

Marvin, C. H., Tomy, G. T., Armitage, J. M., Arnot, J. A., McCarty, L., Covaci, A. and Palace, V. (2011) *Environ. Sci. Technol.* **45**, 8613–8623.