**Linking exposure pathways to biomarkers of flame retardants**

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Flame retardants (FRs) are chemicals to prevent or reduce the flammability of many consumer goods and household products, such as electric and electronic equipment, upholsteries and textiles. Recent bans and restrictions on the use of several brominated FRs, such as the PBDEs, has led to an increased focus on alternative FRs such as different halogenated (emerging HFRs) and organophosphate chemicals (PFRs). As most of these substitutes are used as additives rather than reactive FRs, they may easily leach out from the products and contaminate both the indoor and outdoor environment.

This study was performed to elucidate the exposure of the general population, including children, to a broad range of halogenated and organophosphate FRs through indoor environments and diet. To do so, we recruited 48 households through two primary schools in the greater Oslo area (Norway) and established a mother-child cohort of 48 mothers and 56 children. In the beginning of 2012, the following samples were collected from the living rooms of the respective homes and additionally from 6 of the class rooms: air/particles using glass fiber filters/PUFs in front of a pump (about 17 m3); dust from all of the available floor area using a forensic filter attached to a vacuum cleaner. Urine and blood was collected from the mothers, while children provided only urine samples. Information on food habits of the participants was obtained through detailed food frequency questionnaires. Further, information was obtained on various characteristics of the homes, such as size, age, and putative sources. After extraction and clean-up, HFRs and PFRs were determined in air, floor dust, as well as HFRs in serum by GC-LRMS using a range of isotopically labeled internal standards. Dialkyl and diaryl phosphate metabolites (DAPs) of the PFRs were determined in urine by UPLC-TOFMS using direct injection.

In air and dust, a wide range of halogenated FRs other than PBDEs have been found at total concentrations about half the sum of PBDEs indicating that the use of PBDE substitutes is quite widespread. In air, tetrabromoethylcyclohexane (TBECH) was observed at the highest concentration ever reported for indoor environments (78 and 47 pg/m3 in hoseholds and schools, respectively). Dust was dominated by tris(2-butoxyethyl phosphate and decaBDE, and one of the substitutes of decaBDE, decabromodiphenyl ethane (DBDPE), reached already half the concentration of decaBDE. Frequent vacuum cleaning appeared to reduce the concentrations of FRs in floor dust probably by removing aged, more contaminated dust.

In mothers blood, the sum emerging HFRs were at similar levels than the sum of PBDEs, and dechloranes, a group of polychlorinated norbornanes, were for the first time reported in a European population. While there were no significant correlations between the biomonitoring data and measured concentrations in indoor air and dust, PBDEs were associated with specific food items. In contrast, for PFRs, several DAPs in urine correlated significantly with the corresponding parent TAPs in air and dust from the household suggesting that the indoor environment is an important source of PFR exposure by dermal absorption and/or dust ingestion. Children had systematically higher urinary concentrations of DAPs than their mothers suggesting a higher exposure of children.

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