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An Evaluation of Flame Retardant Exposure Routes from Upholstered Furniture

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1 Introduction

Human exposure to specific halogenated and organophosphorus flame retardants (OPFRs) has been associated with a range of health concerns including cancer, thyroid disruption, delayed mental and physical development, precocious puberty, and/or reduced fertility. As a result, regional regulations on flame retardant (FR) use on consumer products have changed and these FRs have been eliminated or replaced with more benign alternatives in residential furniture.

This study of residential upholstered furniture examined FR and other chemical exposure levels and their routes of exposure.

2 Materials/Methods

A commonly available lounge chair was constructed with different flammability construction technologies: 1) polyurethane foam with no added FR; 2) polyurethane foam with added OPFRs; 3) polyurethane foam with a reactive FR integrated in the foam formulation; and 4) no added FR with the use of a barrier material wrapped around the polyurethane foam. These chairs were constructed to evaluate FR exposure opportunities as well as flammability performance of different fire management constructions.

Using a controlled exposure chamber, a pneumatic device with weights simulating a human sitting activity for each individual chair following the BIFMA X5.4 Seating Durability Test (BIFMA 2012). The four types of chairs were also mechanically aged to mimic a residential use of 10 years. Analytical techniques following van der Veen and de Boer (2012) measured inhalation, oral, and dermal exposure amounts of FRs, and volatile organic compounds (VOCs) following US EPA Method TO-01 (1999).

Figure 1: A studied chair inside an environmental exposure chamber with a device to mimic a person sitting.

Human exposure models were used to calculate average daily doses of measured FRs via the various exposure routes. Human parameters were obtained from EPA Exposure Factor Handbook (EPA 2011).

3 Results and Discussion

Total VOC (TVOC) concentrations from the four chair types were similar, regardless of the chairs being new or mechanically aged (Table 1). TVOC concentration levels from these chairs are low and levels were below standard certification or guidance levels recommended for seating (UL 2014; BIFMA 2011).

Table 1. Comparison of TVOC concentrations (μg/m^3) inside the chamber among chair types.

	No FR	OPFR	RFR	BNFR
New	120	206	67.9	160
Aged	116	154	111	141

A a mixture of VOCs at low concentrations was found in emissions from all chairs that included alcohols, ketones, glycols, siloxanes and aldehydes. VOCs commonly found in the highest concentrations were hexanal, butanol, and propanoic acid. Primary chemicals of concern that were released by all four chairs were acetaldehyde, formaldehyde, naphthalene, which are all classified as carcinogens by IARC and US EPA and toluene, identified for developmental and female reproductive toxicity by ATSDR Tox Profile.

Three out of the four OPFRs identified in the OPFR foam chair were detected in air, dust, and dermal exposure samples. The OPFR measurements were used to infer average daily dose via predictive exposure model (Figure 2). Triphenyl phosphate (TPhP) was detected at the largest concentration, therefore predicted to be the FR resulting in highest exposure for both for adults and children.

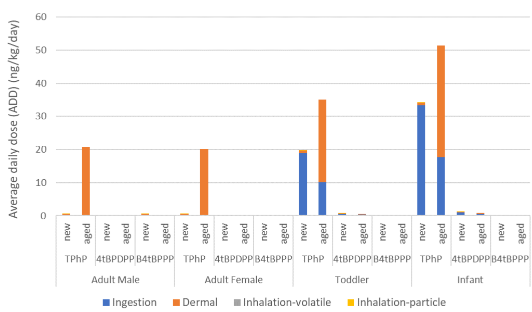

Figure 2: Comparison of adults' and children's average daily dose (ADD) of FRs predicted from emissions data from new and aged OPFR chairs. TPhP; 4tBPDPP: (4-tert-butylphenyl) diphenyl phosphate; B4tBPPP: (2,4-ditert-butylphenyl) diphenyl phosphate.

Children, especially infants, are more susceptible to FR exposure due to their frequent hand to mouth contact and subsequent ingestion. Adults are exposed to FRs primarily via dermal contact. Mechanical aging of the chair was considered, a priori, to affect the increase in TPhP emission from the aged OPFR chair; however, emission rate of other FRs did not change due to mechanical aging.

The measured emissions from the chair with reactive FR suggests a potential reduction in FR exposure since none of the identifiable FRs were detected in the environmental chamber. However, the only FR technology that showed an advantage in suppressing flammability was the chair with the barrier textile.

4 Conclusions

Chemical FRs added to the polyurethane foam of upholstered furniture are released into the surrounding environment, as presented in this study. This study detected OPFRs in ambient air, via simulated dermal contact, and in settled dust surrounding the OPFR chair. Exposure modeling showed that children are the most susceptible to FR exposure due to their frequent hand to mouth contact. The results contribute to the discussion on flammability regulations and product safety.

5 Acknowledgement

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