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A Study of Chemical Exposure from Consumer Products Used in Residential Environments

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ABSTRACT

Some flame retardants (FRs) are added to consumer products despite their association with negative health effects. Construction materials contain other chemicals associated with their formulation/manufacture that can impact the indoor environment. This study examined the emissions of electronics and upholstered furniture that have been constructed with and without FRs. During simulated use of the products in a controlled environmental chamber, airborne VOCs, FRs, and settled dust were collected. Air results were modeled for an energy efficient home and settled dust results were evaluated for FR exposure. The product's flammability and emission during burn were investigated for a residential room.

INTRODUCTION

This study examined and compared chemical exposure levels from residential lounge chairs and electronics as well as flammability characteristics of them. The residential products were measured for environmental exposure levels of volatile organic compounds (VOCs) and flame retardants (FRs) via oral, dermal, and inhalation routes. Chemical FRs are often added to furniture and electronic components to meet flammability requirements. Other chemicals are related to material composition or construction processes. The health risks associated with organohalogen FRs include cancer, endocrine disruption, immunotoxicity, and effects on fetal and child development (Shaw 2010). The use of FR is decreasing, however, researchers are continuing to find that people are exposed to FRs in the indoor environment and that metabolites of various FRs are found in our bodies (Hammel et al. 2017). A cone calorimeter with mock-up bedroom was used to investigate the flammability characteristics of the chairs and air emissions that can occur during fire. Basic methodologies developed for this study has been presented previously at ISES/ISEE 2018 (Davis, Harris, and Black 2018). This presentation will focus on the data showing flammability performance and chemical exposure in residential settings. The chemical exposure levels modeled to typical home settings, including energy efficient homes with lower air exchange rate, for both everyday use of the products as well as during a fire will be presented.

METHODS

A series of commercially available chairs were manufactured specifically for this study, all constructed the same except for the four different FR technologies applied: no FR; use of a textile fire barrier; use of PUF with an added organophosphate FR (OPFR); and use of PUF manufactured with a reactive FR. The chair components were tested

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by separate laboratories confirming the identification/quantification of FRs. A 55-inch 4K LED flat screen television (TV) and a 15.6-inch HD laptop were purchased to be tested. Little was known on the product materials and the FRs included from the documents available to the consumers. Therefore, some material testing was conducted of the electronic components including the casings, PCBs, and wire insulation.

VOC and FR emissions were characterized using a 6 m^3 stainless steel chamber that was constructed and evaluated following ASTM D6670 (ASTM 2013). Clean air, free from particles and VOCs, was supplied into the chamber at 1 air exchange rate (ACH). A stainless steel drop device was used to mimic a person using the chair during air sampling. VOC and aldehyde samples were collected onto solid sorbent cartridges and analyzed by gas chromatography-mass spectrometry (GC/MS) and high-performance liquid chromatography respectively, following US EPA Compendium Method TO-11A (US EPA 1999a) and TO-17 (US EPA 1999b). FR samples were collected for inhalation, oral, and dermal exposure routes. Airborne FRs were collected on PUF filters with a quartz filter up front. The settled dust from the floor of the chamber was collected by a gauze saturated with solvent. A filter patch saturated in saline solution was placed between a weight and the seat cushion to analyze for dermal exposure. All FR samples were quantified by GC/MS. The results of all test samples were compared amongst one another, as well as compared against national and international health risk tables. The residential-use human exposure levels of flame retardants and other chemicals of concern through inhalation, oral, and dermal routes were calculated using exposure models. The predicted indoor air concentration for inhalation exposure was modeled to an energy efficient home with the 0.23 ACH as presented in ANSI/CAN/UL 2904 (ANSI and Underwriters Laboratories Inc. 2019). Oral exposure modeling consisted of direct and indirect mouthing activities especially for children, and sweat mediated dermal exposure model with area of skin in contact.

Open-flame flammability characteristics were measured inside an open cone calorimeter for mass loss, heat release rate, smoke optical index, and effluent gas concentrations. All products were ignited by a match equivalent open fire source. An ISO 9705 (ISO 1993) test room was used to create a realistic residential bedroom scenario with limited air supply for the second set of flammability testing. The measured effluent gases were analyzed for smoke toxicity, predicted air quality condition during a fire, and predicting escape times.

RESULTS AND DISCUSSION

The results from the environmental chamber exposure testing showed that similar VOCs including alcohols, ketones, glycols, siloxanes, carboxylic acids, and aldehydes were released from all the chairs. VOCs known to be irritants and have health effects, including formaldehyde acetaldehyde, toluene, naphthalene, and xylenes, were detected from all tested chairs. However, they were detected at low levels that they would meet GREENGUARD certification (UL 2014) and ASHRAE 189.1 (ASHRAE 2017) allowable levels. The emission levels were low enough that they would result in low levels of exposure when used in a typical indoor environment. The TVOC chamber concentration was the highest from the TV (384 $\mu g/m^3$) compared to the chairs (70-210 $\mu g/m^3$) and the laptop (4 $\mu g/m^3$). The TV released complex mixture of numerous VOCs including siloxanes, phenol, and xylenes, alcohols, aromatics, acrylates, benzenes, and phthalates. The laptop, on the other hand, released low levels of hydrocarbons, aldehydes, and alcohols. The chemicals of concern released from the electronics included acetaldehyde, formaldehyde, toluene, naphthalene, ethylbenzene, and styrene.

The OPFRs, such as triphenyl phosphate, were detected in air, dust, and dermal transfer samples from the OPFR chair. FRs were also detected from the operating electronics. The highest FR exposure route for children was via ingestion, followed by dermal, then inhalation. For adults, dermal was the highest FR exposure route, then ingestion and inhalation. The difference in ingestion exposure between children and adults drove the average daily doses

(ADDs) of FRs in the OPFR mix to be about ten times higher for children than for adults. The predicted ADDs were compared to limited FR toxicity data.

All chairs without the barrier textile burned similarly and fully ignited by 13 min after ignition. The ISO room hindered the combustion process due to lack of oxygen availability inside the room, resulting in thick smoke that would hinder one's visibility. The effluent gases released from the chairs without barrier were significant enough to cause adverse health effects within minutes of exposure. Benzene, a Class 1 carcinogen, was the dominant combustion VOC detected. Other hazardous gases released included carbon monoxide, aldehydes, nitriles, isocyanates, acrylates, phthalates, aromatics, carboxylic acids, and hydrogen cyanide. The fire barrier technology had the greatest impact on suppressing open-fire combustion. The barrier chair measured significantly less for weight loss and heat generation, resulting in lower transmitted fire hazards. Neither electronics ignited nor sustained fire, resulting in lower heat release and effluent gas concentrations compared to the chairs.

CONCLUSION

Although health risks from daily exposure to FRs and injury or death resulting from a house fire cannot be equitably compared, this study approached this topic by obtaining data for chemical exposure levels and flammability characteristics of residential chairs and electronics. The study showed the presence of FRs and other chemicals that should be considered in evaluating IAQ and chemical exposure risks. The results provide scientific data to current policy discussion on product safety, chemical exposure, and flammability regulations.

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