Poster Presentation:
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A Study of Flame Retardants in Residential Furniture and Impact on Human Exposure and Flammability

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Background
Flame retardants (FR) and other chemicals are prevalent in upholstered furniture and other consumer products. They can be found in electronics (casing and wiring), chairs, insulation, car seats, and many more. Certain FRs have been phased out due to health, aquatic, and environmental toxicities. They are being replaced by other chemical FRs with limited health risk information. Other times, the FRs being removed from a product which leads to an increase in fire risk. While the number of house fires are reduced since decades ago, upholstered furniture remains the leading item involved in home fires.

Objective
Investigate the potential of fire safety strategies that reduce fire growth potential and reduce chemical exposure.

Methods
Test Sample (Chair) Construction and Preparation
- New chairs and duplicate “aged” chairs
Environmental Chamber Exposure Testing
- 1 chair inside the chamber with “simulated sitting”
- Sampling for VOCs (air) and FRs (air, dust, and chair surface)
- VOCs analyzed by GC/MS, aldehydes by HPLC, FRs by GC/MS (Emory)
Fire Performance Testing
- Open flame, match equivalent ignition
- Sampling for Heat Release Rate, mass loss, smoke density, fire effluent gases (FTIR), temperature, VOCs, and FRs.

Test Products
Commercially available chairs using a FR-free textile with the following conditions:
- No flame retardant
- Barrier fabric, no flame retardant
- Standard Organophosphate (OP) FR added to cushion foam
- Reactive chemistry flame retardant added to cushion foam
- Electronics: Flat Screen TVs, 55” HD - readily available
- Laptop Computers, 15.6” – readily available

Comparison of TVOC Emissions Across Products

<table>
<thead>
<tr>
<th>Analyte</th>
<th>No FR (65)</th>
<th>Barrier FR (75)</th>
<th>Reactive FR (80)</th>
<th>OPFR (125)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexanal</td>
<td>63</td>
<td>75</td>
<td>18</td>
<td>99</td>
</tr>
<tr>
<td>Butanol</td>
<td>34</td>
<td>42</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Propanol Acid</td>
<td>16</td>
<td>34</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>2-butoxyethanol</td>
<td>9</td>
<td>12</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

Comparison of Upholstered Furniture Heat Release Rate: time series (left) and max HHR (right)

<table>
<thead>
<tr>
<th>Chair Construction</th>
<th>Sample ID</th>
<th>Test Material</th>
<th>Weight Loss (lb.)</th>
<th>% Weight Loss</th>
<th>Max. Heat Release (kW)</th>
<th>Max. CO (ppm)</th>
<th>Max. HCN (ppm)</th>
<th>Max. Smoke Optical Density (1/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NFR</td>
<td>New</td>
<td>36</td>
<td>53.6%</td>
<td>416</td>
<td>530</td>
<td>5950</td>
<td>NA</td>
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<tr>
<td></td>
<td>NFR+FB</td>
<td>New</td>
<td>3.4</td>
<td>4.9%</td>
<td>8</td>
<td>59</td>
<td>266</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Standard</td>
<td>FR</td>
<td>New</td>
<td>40.2</td>
<td>60.5%</td>
<td>43</td>
<td>1613</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>GFR</td>
<td>New</td>
<td>41.9</td>
<td>61.8%</td>
<td>2,026</td>
<td>601</td>
<td>1137</td>
<td>8.03</td>
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Flame Retardant
- Only measurable FR was from chairs with OPFR added to the foam (TBPP isomers and Triphenylphosphate)
- Measurable exposure amounts can be found in: airborne vapor, airborne particles, settled dust and dermal transfers
- Primary exposure route is dermal and ingestion (dust)
- Exposure levels are very low, but accumulation may develop with dust accumulation for long term exposure

Triphenyl phosphate Avg. Daily Dose from Standard OPFR Chair

<table>
<thead>
<tr>
<th>ADI (ng/kg/day)</th>
<th>TPP</th>
<th>Adult male</th>
<th>Adult Female</th>
<th>Infant</th>
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<tbody>
<tr>
<td>4.9</td>
<td>4.8</td>
<td>10.7</td>
<td>2.0</td>
<td>0.6</td>
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Flammability
- Significant difference in fire performance for chairs with fire barrier vs. all other chairs with or without chemical FRs
- Fire barrier reduced the involvement of foam in fire
- Lower values in all measurements for Barrier chairs: HHR, mass loss, effluent gas concentrations, smoke density, temp.
- The chemicals of the foam, with and without flame retardants, did not have a significant influence on fire performance
- All isomers of TBPP mix FRs identified in effluent gas

Still Shots at Peak Ignition for a Chair with Barrier and no FR

Comparison of VOCs among Chairs (µg/m³)

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VOCs
- Complex mixture of low level VOCs for all chairs
- All chairs are well below VOC requirements for GREENGUARD/BIFMA/LEED Certifications
- Similar primary VOCs emitted from all chairs
- Major VOCs include alcohols, ketones, glycols, siloxanes, carboxylic acids, and aldehydes
- New chair and aged chairs similar in emissions with aged slightly lower (~10-15%)

Findings
- The use of a fire barrier in place of FR showed reduced fire hazards
- No significant differences in fire performance among chairs with or without chemical FRs
- Chance of escaping the fire increases with chair with barrier material
- Simulated aging of chairs did not influence fire behavior
- Standard OPFRs added to the furniture foam can produce low level human exposure primarily through settled dust and transfer dust