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# A Study of Flame Retardants in Residential Furniture and Impact on Human Exposure and Flammability


Marilyn Black[1], Aika Davis[1], Debra Harris[2,3]

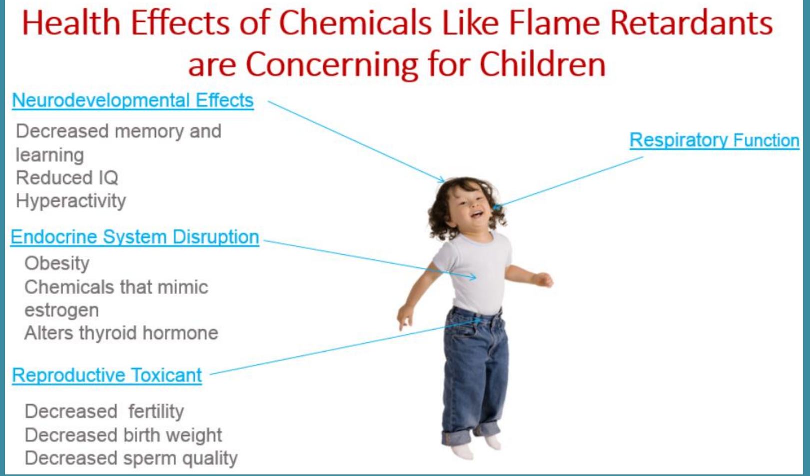
1: Chemical Safety, Underwriters Laboratories Inc.

2: College of Health and Human Sciences, Baylor University

3: RAD Consultants, Inc.


## 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 are 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 fire deaths.





## Objective

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

We conducted a 3 year project on upholstered furniture and various flame retardant technologies to evaluate:
1. VOCs and FR exposure from daily use
2. Effect on flammability performance

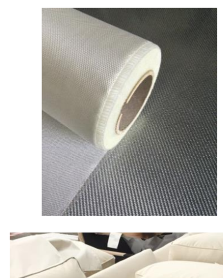
## Test Products

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



## 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.

Environmental Chamber

Heat Release Calorimeter

ISO 9705 Fire Test Room

## Results

### Content Analysis

Conducted by independent labs
1. Non-FR Foam – 70% PUF, 30% Soy-based – No FR detected
2. Non-FR Foam + Fire Barrier, 100% fiberglass – No FR detected
3. Organophosphate FR Foam – Tris-isobutylated triphenyl phosphate (TBPP) mixture
   (high potential for aquatic toxicity, limited information on health effects)
4. Reactive FR Foam – Proprietary – No identification of FRs
   (chemically bound in foam, not likely to "leach" from products)

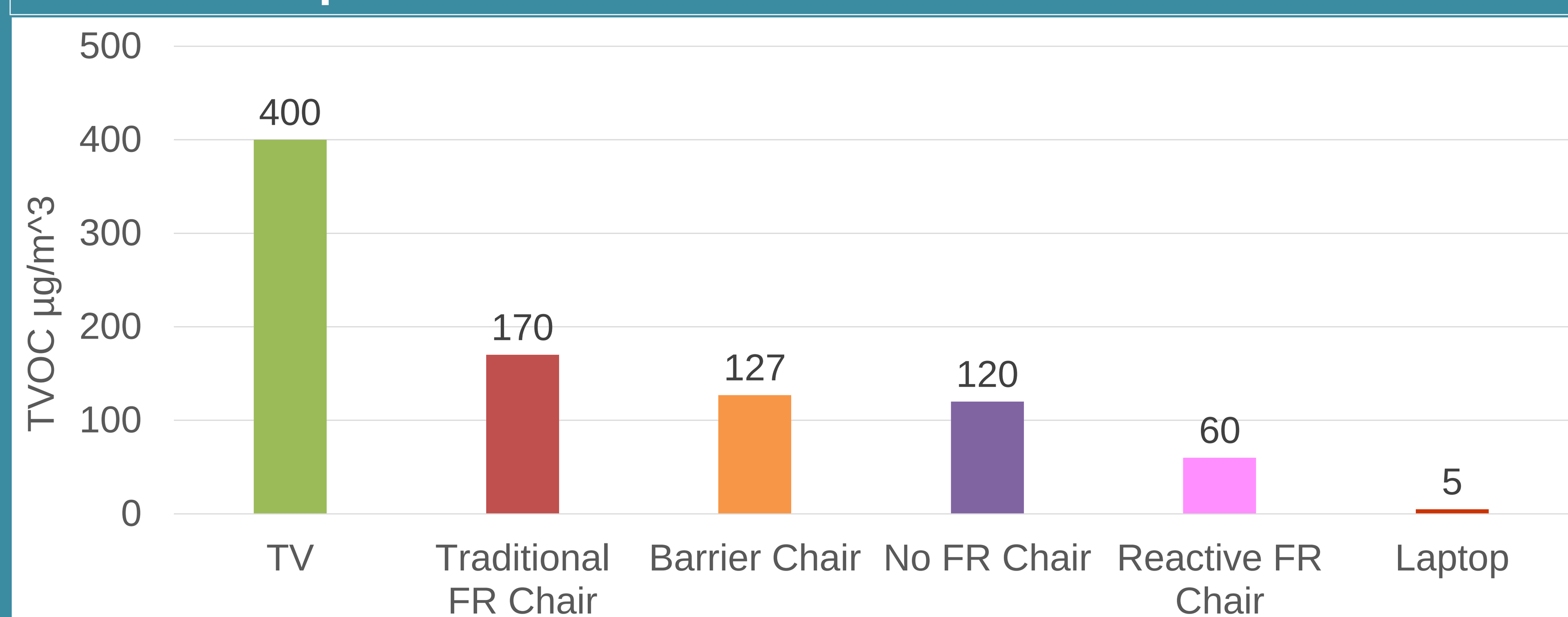
### VOCs

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

### Top 5 common VOCs among Chairs (μg/m³)

| Analyte | No FR (65) | Barrier FR (75) | Reactive FR (80) | OPFR (125) |
|---|---|---|---|---|
| Hexanal | 63 | 75 | 18 | 99 |
| Butanol | 34 | 42 | - | 13 |
| Propanoic Acid | 16 | 34 | 30 | 33 |
| 2-butoxyethanol | 9 | 12 | 5 | 8 |
| Formaldehyde | 4 | 6 | 5 | 4 |

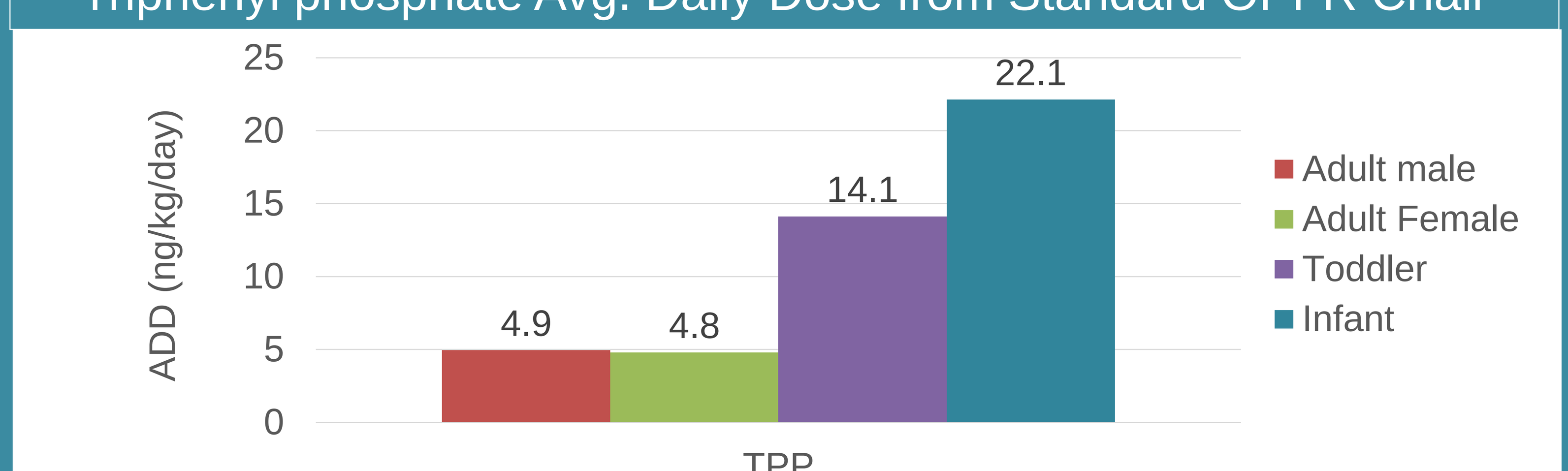
### Comparison of TVOC Emissions Across Products




### Flame Retardant

- Only measurable FR was from chairs with OPFR added to the foam (TBPP isomers and Triphenyl phosphate)
- 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




### Flammability

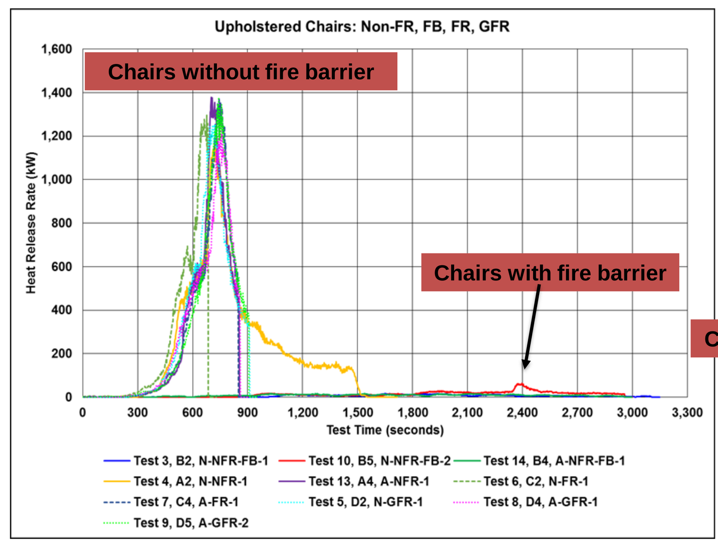
- Significant difference in fire performance for chairs with fire barrier vs. all other chairs with or without FRs
  - Fire barrier reduced the involvement of foam in fire
  - lower values in all measurements for Barrier chairs: HHR, mass loss, effluent gas concentrations, smoke density, temp.
- The chemistries 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

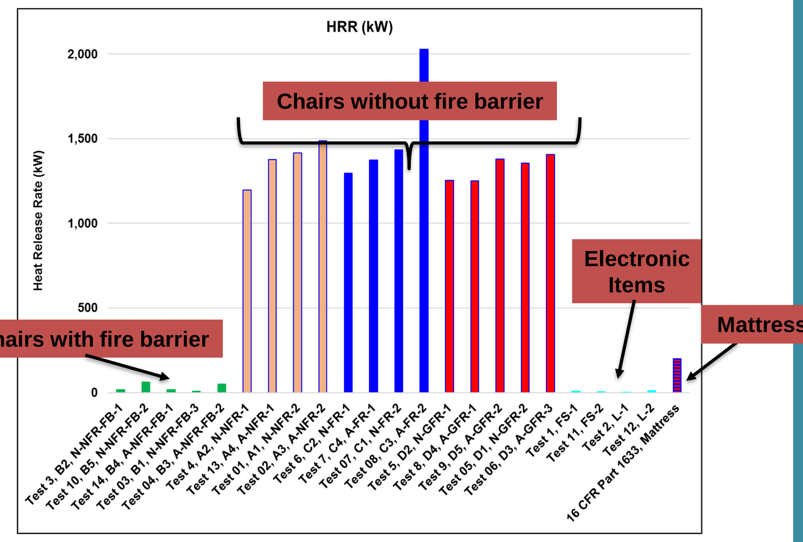
### Still Shots at Peak Ignition for a Chair with Barrier and no FR


Barrier Chair


No FR Chair

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




### Fire Hazard Summary

| Chair Construction | Sample ID | New/ Aged | Weight Loss (lb.) | % Weight Loss | Max. Heat Release Rate (kW) | Max. Doorway Temperature (°C) | Max. CO (PPM) | Max. HCN (PPM) | Max. Smoke Optical Density (1/m) |
|---|---|---|---|---|---|---|---|---|---|
| Non-FR foam | NFR | New | 36 | 53.6% | 1,416 | 530 | 5950 | NA | 0.98 |
| | | Aged | 39.7 | 58.3% | 1,400 | 570 | 3390 | 25 | 0.93 |
| Non-FR foam + Fire Barrier | NFR+FB | New | 3.4 | 4.9% | 8 | 59 | 266 | T | 0.01 |
| | | Aged | 5.8 | 8.3% | 51 | 69 | 821 | T | 0.03 |
| Standard FR foam | FR | New | 40.2 | 60.5% | 1,432 | 594 | 1613 | 43 | 1.00 |
| | | Aged | 38.5 | 58.2% | 2,028 | 601 | 1137 | 47 | 1.10 |
| Reactive FR foam | GFR | New | 41.9 | 61.8% | 1,335 | 538 | 2596 | 51 | 0.80 |
| | | Aged | 40 | 59.4% | 1,406 | 574 | 1485 | 43 | 0.88 |

## 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
- Furniture foam with reactive alternative FR indicates no release from the product
- Furniture with carefully selected materials can be very low in VOC air exposure