Proceedings of the Furniture Flammability and Human Health Summit

Dec. 13-14, 2017 ● Atlanta, GA

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INTRODUCTION

With gratitude, we acknowledge the esteemed members of the Summit Steering Committee for their engaging, passionate and professional commitment to our resources and Summit initiatives on Flammability and Human Health. We also recognize the expert faculty for sharing their knowledge and encouraging discussion on the 2017 issues of furniture flammability, testing and performance measures, policy and regulations, flame retardants, and human health relative to chemical exposure.

We also acknowledge the general participants who contributed their knowledge and interests as key stakeholders in this open and engaging dialogue.

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PREFACE

The following proceedings provide a summary of technical information exchange as recorded by third party sources during the Furniture Flammability and Human Health Summit held in Atlanta, Georgia, December 13 – 14, 2017. The summary is not intended to provide an accurate or complete transcription of each speaker's presentation or participant specific comments. Speakers may be contacted directly for details of their presentations and subject expertise.

These proceedings are provided to share summaries of the presentations and technical discussions among all stakeholders. We hope this exchange of information will enable more collaborative discussions, research, innovation, informed policy advancement, and science-based initiatives leading to fire and chemical safe products.

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Day 1

Welcome

Speaker

Marilyn Black, PhD, VP & Senior Technical Advisor, Underwriters Laboratories Inc.

On behalf of Underwriters Laboratories, and our co-convener, a warm welcome was extended to everyone gathered in Atlanta on December 13-14, 2017, for the third annual Furniture Flammability and Human Health Leadership Summit.

It was acknowledged that ongoing research, market awareness, communications and policy updates regarding the safety and health impacts of flame retardants in upholstered furniture have elevated the need for managing the intersecting risks of chemical exposure and product flammability. While these issues impact upholstered furniture, they also expand to diverse product categories including electronics, insulations, construction materials, home décor, and children specific products.

With the public's increasing concern of chemicals in our everyday products and the consumer expectation of safe products, this summit platform was critical for bringing sound science, practices and professional expertise. Together we need to advance the initiative of achieving fire and chemical safe products.

To foster this dialogue on the safety convergence of flammability protection while simultaneously preventing hazardous chemical exposures, Underwriters Laboratories was pleased to partner with the Emory University, Rollins School of Public Health to host this third focused Leadership Summit. Our goal was to enable an open, honest, and respectful dialogue and discovery about the issues among interested stakeholders.

Key objectives of this year's summit included:

- Review most current fire statistics of injuries and deaths in the US and EU.
- Establish most current knowledge of acute and chronic health impacts of flame retardants used in furniture and consumer products, as related to child and general consumer exposure.
- Review the latest research on chemical exposure risks to firefighters and potential links to flame retardants, other chemicals, and by-products of combustion.
- Establish most current flammability codes and safety standards for upholstered furniture and review how they are addressing flame retardants, safe chemicals, and fire characteristics.
- Review fire characteristics of products and their impact on building fires, and emerging needs for performance verifications.

- Review the latest research and developments in flame retardant chemistries and the feasibility of alternative technologies and safer chemicals with consideration of applications to components, finished products, and manufacturing.
- Identify next steps in research, product development, manufacturing, and verification processes for converging the fire and chemical safe requirements of furniture for today's market.

Dr. Black acknowledged the importance of leadership and knowledge attending this year's Summit, as we look forward to examining the intersection of fire prevention, furniture flammability, and human health. Most importantly, together we look forward to discussing the evolving paradigm of human safety in seeking safe living and working environments for all.

Current Fire and Flammability Statistics

Speaker

Marty Ahrens, MSW, National Fire Protection Association

Marty Ahrens presented the latest national estimates of fires involving upholstered furniture and associated losses. These estimates were annual averages from 2011 to 2015 calculated by combining data collected by the U.S. Fire Administration's (USFA) online National Fire Incident Reporting System (NFIRS) with data from the National Fire Protection Association's (NFPA) annual national survey.

While local fire stations around the country use NFIRS to document in detail the fires they respond to, reporting at the national level is voluntary. Therefore, researchers cannot rely entirely on NFIRS date or they would underestimate. To compensate for fires that are reported to fire departments but not to NFIRS, every January the NFPA sends out its survey to every fire department protecting more than 5,000 citizens and to a random sample of smaller populations, to develop big picture estimates regarding fires and losses. Scaling ratios are calculated by dividing the survey estimates by NFIRS totals. The detailed data in NFIRS are multiplied by these ratios. NFPA's estimates also "include proportional shares of fires in NFIRS with unknown circumstances or causal factors."

Ahrens reviewed two key NFIRS definitions:

- A "home" is defined as a one- or two-family dwelling, including manufactured homes, and apartments or other multi-family housing.
- "Upholstered furniture" includes items such as sofas, love seats, chairs, and car seats.

There is an ongoing problem with such definitions, Ahrens said. "The firefighters who collect these data are generalists." They may not code an incident the way a scientist or regulator would. Upholstered furniture intended for outside use has not traditionally been covered by regulations. Ahrens also noted that a couch in her family room has a non-fitted cover over the upholstery and typically has several throw pillows and a throw-blanket. It is also a sleep-sofa with a mattress. A firefighter might consider the whole unit of couch, covering, pillows and throw to be upholstered furniture. Are futons upholstered furniture? If used as a couch, many would say "yes. "Analysts need to "think like a firefighter when interpreting the data," she said.

Ahrens reviewed some findings from the NFPA's most recent (unpublished) analysis:

Upholstered furniture was the item first ignited in an annual average of 5,500 home structure fires, resulting in 460 deaths and 720 injured.

Although only 2% of all reported fires started on upholstered furniture, such fires caused 18% of civilian deaths, and one in 12 such fires resulted in a fatality.

The fire trend line has been declining smoothly, with fire estimates in 2015 coming in 86% lower than in 1980, and civilian deaths dropping by 64% since 1980, with the lowest point in 2011.

As for the causes of first ignition, smoking material fires have fallen 94% since 1980, with a corresponding 70% drop in civilian deaths from smoking-related fires.

Open flame fires have dropped 86%, with deaths dropping 90% between 1980 and 2015.

While fires caused by operating equipment have dropped by 73%, deaths from such fires increased by 75% between 1980 and 2015.

Smoking materials started 26% of upholstered furniture fires in 2011-2015. Half (52%) of the upholstered furniture deaths were caused by fires started by smoking material.

Also significant, electrical distribution or lighting equipment caused 17% of upholstered furniture fires and 14% of deaths. Wiring or related equipment caused 6% of fires and 3% of deaths; lamps, bulbs, or lighting, 4% of fires and 4% of deaths; and cords or plugs (mostly extension cords) caused 5% of fires and 7% of deaths.

NFIRS data involving intentionally set fires include children below the age of legal responsibility. Some may be set by children under five. (Intentional is not quite the same as arson).

Space heaters were involved in 11% of the upholstered furniture fires and 12% of the deaths.

Medical oxygen, most frequently associated with fires caused by smoking materials, can make a fire burn hotter and faster.

Ahrens said further research is needed on upholstered furniture as a composite threat.

Discussion

A participant asked whether NFIRS asks detailed questions about upholstered furniture, such as material and provenance. Ahrens replied that because NFIRS is designed to document all types of fires, it does not have the capacity to ask specifics. She added that "with more funding, it would theoretically be possible," especially if fire departments were able to partner with organizations like the Consumer Product Safety Commission, which might then be able to send someone to the fire scene to ask detailed questions, take samples, and collect data. Currently, however, "additional testing is beyond the scope of what most fire departments could be asked for."

A participant asked whether statistics on civilian deaths reflect contributing factors like the absence of smoke alarms, and especially the role that vulnerability or disability might have played. Ahrens said a full third of all people who now die in fires are aged 65 or older. More alarms. She also noted that roughly two out of every five (42%) victims of fatal home fires died as a result of fires in homes with working smoke alarms.

Ahrens said there is a clear correlation between a decline in fire deaths and the increase in the use of smoke alarms. Preventing fires prevents fire deaths. Working smoke alarms alert people to fires in the earliest stages. According to the Consumer Product Safety Commission's study of unreported residential fires, 97% of home ignitions are handled without the fire department. In many cases, people are alerted to a situation before it develops into a fire.

Non-responses in the National Fire Incident Reporting System

SPEAKER

Robert Luedeka, Fire Prevention Alliance and Polyurethane Foam Association

Robert Luedeka presented a report prepared by Dr. Charles Gibbons of the Brattle Group for the Fire Prevention Alliance (FPA). Gibbons' focus was on the twofold problem of non-responses in the NFIRS that "lead to uncertainty in actual numbers," and the concern that "estimates of uncertainty are not traditionally supplied by NFIRS-based analyses."

The Brattle Group study sought to evaluate how non-responses in NFIRS, particularly regarding fires purportedly ignited or spread by upholstered furniture, affect its usefulness for policymaking, and "to calculate degrees of uncertainty in estimates of fires and deaths." The consultants were particularly interested in John Hall's 2014 "White Paper on Upholstered Furniture Flammability," an analysis of the annual average of home structure fires from 2006 to 2010, based on NFIRS data. The Hall "White Paper" reported that an average of 1,500 fires per year involved upholstered furniture as the item of first ignition by a small open flame source (leading to 60 deaths). However, the report estimated that there was an average of 2,200 fires additional fires per year involving upholstered furniture as the primary contributor to fire or flame spread but NOT the first item ignited (in which an average of 130 people died).

The Brattle Group focused on potential uncertainty in the analysis and in the NFIRS database. The problem is that many agencies do not report measures of uncertainty in estimates, and "uncertainty due to data issues is rarely mentioned and almost never evaluated," which can "lead users of the data to perceive uncertainty as inconsequential."

Luedeka described two types of gaps in the NFIRS data: fire department unit non-response, where a fire department never reports, and the frequency of missing or ambiguous data in particular sections.

An earlier study by the National Association of State Fire Marshals identified personnel fatigue and departmental fear of litigation as two reasons firefighters do not fill out the NFIRS form. Luedeka suggested the questions on the NFIRS form may be part of the problem because it tends to ask for a defined and absolute answer. Demands for such certainty may scare firefighters away from answering, he said. Form completion rates might improve if people were encouraged to supply adjectives like "probable" or "likely."

"Without further information about the missing departments or incomplete answers, non-response leads to bias, rather than variance in estimates," Luedeka said. According to the U.S. Census Bureau's 2013 Statistical Quality Standards, "non-response bias analyses must be conducted when unit, item, or total quantity response rates for the total sample or important subpopulations fall below" 80% and 70%, respectively. NFIRS responses have been consistently, and significantly, far below these thresholds, Luedeka said.

Luedeka talked about the imputation of non-responses, noting that these can range from "maximally credible" to "strongly informative." The former is vastly preferable because it is free of assumption and therefore provides a (potentially wide) range of values consistent with the data. Such imputation also "provides a domain of consensus" and "illustrates the role of assumptions in narrowing the range." Strongly informative imputation, by contrast, "typically assumes reported values are representative of unreported ones." Such imputation is achieved either by the "hot deck approach," where it is "assumed that units within a statistical base would have information that would be typical of units that do not report," or by multiple imputation, which involves data sifting through multiple screens, "a very advanced process that takes a lot of resources and money."

Gibbons' report compared how the NFPA and the Brattle Group, both using hot deck imputation, approached the NFIRS data. Whereas NFPA used the national estimates approach, the Brattle Group, conscious that "firefighters aren't forensic analysts" and that "the source of fire spread can be especially difficult to determine," conducted its analysis by regions defined by state and metropolitan area combinations. A key question flagged by Luedeka was "what defines an incomplete record? In particular, is a "response missing because it is unknown? Or just unrecorded?"

The national estimates approach used by the NFPA "performs a supplementary survey to estimate total U.S. fires, then calculates the ratio of total U.S. fires to total fires in NFIRS, and finally scales each fire observed in NFIRS by this ratio." The Brattle Group approach, on the other hand, identifies the number of departments in each region in the USFA census of fire departments, calculates the number of departments reporting to NFIRS by region, and scales each fire in a region by the ratio of these values.

While there is value in the Brattle Group's alternative strategy for imputation using NFIRS' non-reporting departments, implementing the approach would result in radically altered trend lines, which would make it hard to go forward and hard to look back, Luedeka said.

The complete Brattle Group report, "A Review of the National Fire Incident Reporting System and the National Fire Protection Association's Upholstered Furniture Fire Statistics," is available at http://www.firepreventionalliance.org/nfirs.pdf

Discussion

In response to a participant's question regarding how to improve data quality and increase the number of reporting departments, Luedeka said there is value in personnel training to improve data collection, and, especially, in having a "data champion" in each department.

A participant said UL is working to "remove some of the human element, and allow data to be used at local level, rather than pitching it up to the federal level and losing track of it."

Current US Fire Codes and Standards

SPEAKER

Dwayne Sloan, UL LLC

This presentation covered the relationship between current US fire codes and test standards, looking at the actual provisions in these codes and the specific requirements and limitations contained within them. A key objective of this presentation was to provide a foundational understanding of codes and tests that would serve the remaining discussions of the summit.

There was a review of the comprehensive fire protection approach" that covers a range of elements, including: education and prevention, flammability of room contents, alarms and detectors, suppression, fire walls, ceilings, and doors, and the fire service. With regards to furnishings, once a fire starts, the goal is to keep it localized and prevent flashover—the point at which a room is fully engulfed in fire and not survivable. Generally, a 1,000-kilowatt heat release rate, the amount of heat released from burning item(s) in a room, will push a room to flashover state.

Sloan discussed some of the key safety codes, such as:

- California's Home Furnishings and Thermal Insulation Act
- International Code Council (ICC) International Fire Code
- NFPA 1 - Fire Code, and NFPA 101 - Life Safety Code

And some of the key test standards for upholstered furniture, such as:

- Upholstered Furniture Action Council (UFAC) tests
- California Technical Bulletins TB 117 and TB 133
- ASTM E1352, E1353, E1537, and E2280
- NFPA 260, 261, and 277 (which is under development)

There was a detailed explanation on which of these methods were material and component level evaluations, which were based on mock-ups, and which were based on fully assembled furniture samples. To adequately assess the contribution of a burning item such as furniture, it is important to understand the scale of tests. In other words, material (or component) results should be indicative of mock-up results, mock-up results should represent full furniture performance, and this should in turn scale to full room flashover, tenability and survival.

The UFAC component test, which has been in place since the late 1970s and is the industry's voluntary standard, governs how the flammability of the different components of a chair, for example cover fabric, wadding, barrier, and foam, must interact to achieve a passing result. He described the different permutations of the smoldering cigarette test, as well as the ramifications of the shift to the self-extinguishing cigarettes now on the market. He also talked about the differences between the UFAC, NFPA, ASTM, and TB 117 component tests.

Prior to 2013, TB 117 required both a smoldering cigarette ignition test and an open flame test in that standard. The 2103 version of TB117 removed the open flame test.

Referring to full furniture or end product test standards, Sloan highlighted TB 133, which involves applying a gas burner to the product for 80 seconds, with an acceptance criteria of total heat release of 25 megajoules or less during the first 10 minutes, and peak heat release of less than 80 kilowatts, far below the flashover temperature of 1,000 kilowatts.

Sloan said occupancy type is a core determinant of how codes address furniture flammability requirements. The Fire Hazard Assessment of the Effect of Upholstered Seating Furniture within Patient Rooms of Health Care Facilities (ASTM E2280), along with the various other codes and regulations, specify both requirements and exceptions. For instance, there are sprinkler and smoke alarm exceptions in nursing homes and hospitals, but not in detention and correctional facilities.

With regards to new Standards activities, NFPA 277, which was under development at the time of the meeting would seek to implement a new open flame test method. The Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (BEARHFTI) has also proposed a test for barriers that would expose the barrier and a standard polyurethane foam to a butane burner flame for one minute, with a pass being no ignition. Also, ASTM is developing a standard test method for observing the transition from smoldering to ignition on flexible foam.

Discussion

A participant asked whether there are any data that shows that the application of standards actually reduces fire deaths. It was discussed during the overall summit that fire death statistics involving upholstered furniture, especially in the US, have been steadily on the decline for a number of years. This could result from several factors, such as change in human behavior, the proliferation of fire standard compliant (FSC) cigarettes, test Standards such as those discussed, increased use of sprinklers, and tighter legislation. It is believed that the application of test standards is one of the factors that contributes to this overall reduction.

Another participant commented that fire "doesn't kill a statistical sample of the population" but rather a disproportionate number of "the young, the old, the drunk, and the very poor"— that is, the vulnerable. Standards must be developed to recognize this reality.

A participant asked whether any of the materials tests include a health risk assessment. Sloan said they do not, but there was considerable support for such measures when the NFPA solicited comment on its 277-furniture component test. Another participant said California is looking at health effects.

Furniture Testing Experiences with TB 117-2013

SPEAKER

Said Nurbakhsh, PhD, CA Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation

Dr. Nurbakhsh reviewed the history, content, and significance of California Technical Bulletin 117-2013, focusing on whether the revised test is sufficient, and of California Business and Professional Code Section 19094 (formerly SB 1019), which regulates the use of fire retardant chemicals.

Enforced in California since October 1975, and "the de facto standard for many large national manufacturers," the original TB 117 required that to pass the open flame test, component materials, especially polyurethane foams, had to be fire retardant. That is, they had to be able to withstand a small open flame for at least 12 seconds without exceeding the failing criteria. To comply with this standard, manufacturers treated their component materials, especially PU foams, with flame retardants.

In 2010–11, a sharp escalation in awareness that flame retardant chemicals could be hazardous to human health — being linked to cancer, endocrine disruption, and low birth weights — led to the adoption of TB 117-2013, developed by BEARHFTI. Fully implemented in January 2015, TB 117-2013 is mandatory for all indoor upholstered seating furniture (except items exempted entirely from fire safety regulations, most notably a much broader range children's furniture and equipment than the earlier standard allowed).

Nurbakhsh said the researchers who developed the test for the revised regulation recognized that the outcome had to be the production of upholstered furniture that was "safer from the hazard of smoldering," even in the absence of flame retardants. He said TB 117- 2013 does appear to meet that high standard. TB 117-2013 is based on ASTM E 1353-08a, Standard Test Methods for Cigarette Ignition of Components of Upholstered Furniture. It is also similar to UFAC and NFPA 260 standards. The test method consists of 4 sections covering cover fabric, barrier materials, filling components, and decking materials. Pass/Fail criteria are applied to all sections. Failure of a material is based on: the specimen continues to smolder after the 45-minute test period; a specified char length (per specimen type) is exceeded; or the mock-up test specimen transitions to open flame combustion.

The Business and Professional Code SB 19094, which came into effect January 1, 2015, requires "that furniture be labeled as to whether or not a product contains added flame retardant chemicals." It applies to all covered products subject to TB 117-2013.

Nurbakhsh described a detailed process designed to enforce compliance, requiring manufacturers to retain all documentation and companies that declare their products to be free of flame retardants to provide written proof. Both manufacturers of covered products and suppliers of components will be held liable for failure to comply with the documentation requirements. BEARHFTI must provide the Department of Toxic Substances Control (DTSC) with a selection of samples from covered products that they claim contain no added flame retardant chemicals; these samples will be tested for the presence of those substances.

Nurbakhsh said the great majority of manufacturers are passing the standard. From 2015 to 2017, out of 448 samples, 305 had SB 1019 labels. Of those, 217 checked the "no flame retardant chemicals" box, 77 checked the "yes" box, and 11 did not check either box. BEARHFTI then sent out 25 flame retardant documentation requests and forwarded samples to DTSC for 9% of the "no flame retardant chemicals" respondents. (Nurbakhsh said the low sample rate is due to the expense, as these DTSC tests cost more than $1,500 each.)

Discussion

Asked about the status of TB 133 in California, Nurbakhsh said some stakeholders are pressuring for repeal, and BEARHFTI continues to work with the governor on the subject.

A polymer chemist in the audience said the definition of "flame retardant" in SB 1019 is broad and asked whether there has been any pushback from industry. Nurbakhsh agreed the definition is broad and said regulators continue to "work hard with DTSC."

In response to a question about labeling, Nurbakhsh said SB 1019 does not prohibit the use of flame retardants and requires only that their use be acknowledged.

EU Fire Standards and Research

SPEAKER

Karolina Storesund, MS, Research Institute of Sweden (RISE) Fire Research

European legislation covers both the European Union and the European Economic Area, which includes Norway, Liechtenstein, and Iceland. A fairly basic, pan-European directive on general product safety covers issues of furniture flammability, while other national regulations, recommendations, and requirements address flammability and flame retardant use. However, European norms for ignitability of upholstered furniture and mattresses are not mandatory.

The regulations vary by country, but all EU nations regulate furnishings in terms of health, safety, and environment. Companies are required to register chemicals in use. Unlike the U.S., the EU regulates construction products more heavily than furniture; there are rules governing burning droplets, ignitability, heat release, and smoke production. The United Kingdom and Ireland have the strictest standards for domestic use.

Reduced ignition propensity (RIP) cigarettes have been mandatory in the EU since 2011. A 2014 Swedish study found in standard testing that while RIP cigarettes are generally compliant with the harmonized standard, their efficacy varies according to the material to which they were applied. This uncertainty suggests a "poor correlation between standard and reality"—which is unsettling, as the new cigarettes are "normally used as an argument that we don't need to test because the cigarettes are safe in themselves."

It is difficult to pull together general statistics on fires in the EU. Definitions of key terms differ from country to country. For example, in Sweden, a "fatal fire" is a fire in which victims died within one month of the blaze; in Norway, the time elapsed between a fire and the deaths of victims can be as long as three months.

In Scandinavia, most fatal fires start in either the living room or the bedroom; beds or other furniture are the most common sites of first ignition; sources of ignition are either cigarettes or open flames; and vulnerable groups, especially the elderly, are at higher risk.

UK fire standards are much stricter than those of the EU and, like the original TB 117 standard, tend to require the use of flame retardants. Concern that stricter fire regulations in the EU would cause an increase in the use of fire retardants has at least twice led to putting such legislation on hold. It has also pushed the furniture industry—led by the European Furniture Industries Confederation—to suggest "a mandatory harmonized testing method for upholstered furniture at a level where flame retardants are not needed."

Stricter fire regulations would also have an impact on the EU's larger focus on a circular economy and efforts to close the loop on production, consumption, waste, and recycling. In particular, the addition of chemical additives would make recycling more difficult. Such concerns have led fire researchers from the Research Institutes of Sweden to explore non-chemical means to make fire-safe furniture, from using glass or Kevlar fibers for the barrier, to using fire-resistant wool in exterior fabrics, to deploying 3-D woven fabrics in combinations that might replace polyurethane foam.

Storesund concluded that there is a "desperate need to harmonize EU standards and fire safety levels," and to more fully take into consideration fire safety for the vulnerable.

http://risefr.no/media/publikasjoner/upload/2015/rapport-spfr-a15-20124-2.pdf

Scientific and Regulatory Status of Flame Retardants and Similar Chemicals

Speaker

Christopher P. Weis, PhD, DABT, National Institute of Environmental Health Sciences

All of us are exposed to toxic chemicals every day beyond flame retardants. Highly toxic perfluoroalkyl Substances (PFAS) are found everywhere—from Gore-Tex to dental floss to pizza box liners—and have left airport runways and military training sites all over the United States permanently and catastrophically contaminated. And they are the primary active ingredient in aqueous firefighting foam used for flame retardants in a variety of settings.

U.S. production of PFAS continues in the form of a wide variety of fluoronated congeners such as those that have polluted water systems in North Carolina, New York, and New Jersey, but these man made, synthetic chemicals are highly persistent and have long half-lives in the environment and in biological systems.

Animal studies using rats in the late 1990s showed unusual and often lethal toxicity of this class of chemicals, and PFAS are now known to cause a range of cancers, including prostate, ovarian, and kidney; liver malfunction; hormonal disruption; and immunotoxicity, including interference with child vaccine response.

Weis described the ongoing contamination of the Cape Fear River and watershed by DuPont and its subsidiaries. He said the Cape Fear River system is "contaminated throughout" with PFAS. Potential exposure routes include drinking water, exposure through skin, ingestion of vegetables and animal products contaminated with PFAS, and exposure through inhalation from showering, bathing, washing clothing and dishes.

Efforts by the United States Environmental Protection Agency (EPA) and others to reduce exposure have led to a decline in levels of certain PFAS such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) in human blood. However, "it is critical to remember that PFOA and PFOS are not the only members of this class," and in the rush to find replacement chemicals, we have further flooded our water systems with chemicals whose toxicology has not been worked out." For example, when DuPont was ordered to cease production of PFOA and PFOS in 2004, the company turned to alternative chemicals of poorly defined toxicity. Based on the structure of these newer forms of PFAS, we would expect the toxicology to be similar to PFOA and PFOS, but we don't yet have the data.

The National Institute of Environmental Health Sciences (NIEHS), the EPA, and the CDC are working to understand this new-generation per- and polyfluoroalkyl substances (PFAS), often doing untargeted analysis (the measurement of all chemicals in a given sample) to get a sense of which chemicals are out there. In response to a question about the number of chemicals with available toxicity information, Weis said "there are 85,000 chemicals in our marketplace only a handful have been adequately characterized for toxicity."

While some consumer safety organizations are fighting hard to hold companies accountable for water, air, and soil contamination, others are lobbying to change chemical regulations to encompass chemical classes, rather than single chemicals.

Weis encouraged participants to apply for NIEHS's competitive funding sources. Currently, grants are being used to fund research on the impact of PFAS on multiple cohorts, including the following studies:

- The Health Outcomes and Measures of the Environment (HOME) birth cohort study in Cincinnati with more than 400 mother and infant pairs
- The Markers of Autism Risk in Babies—Learning Early Signs (MARBLES) longitudinal cohort of women with a child with autism
- The Faroe Islands Birth Cohorts study, focused on postnatal development, neurobehavioral functions, metabolic outcomes, and immune system responses

In response to a question, Weis said that, among the federal, State, and local agencies assisting with the PFAS problems, the Department of Defense remains vitally concerned about toxicity and is anxious to be part of the solution.

Relationships Between Flame Retardant Uses in Furniture and Residential Exposure

Speaker

Heather Stapleton, PhD, Nicholas School for the Environment, Duke University

Dr. Stapleton and her fellow researchers have been studying flame retardant exposure in homes for the past 15 years. Since February 2014 they have been working to provide a unique flame retardant testing service to the public. The free online service guides the public through the process of submitting polyurethane foam samples, which are then assessed, using mass spectrometry, for the presence of flame retardants. The service communicates the findings to the original requester, but the researchers also use the data collected to build a knowledge base that will help others "to decide how to focus efforts on biomonitoring and risk assessment." Also of interest is how changes to CA TB 117 labels will affect the use of fire retardants in baby products and residential furniture.

In the past three years, the program has received more than 2,000 samples for screening. Stapleton summarized the results through to June 2016:

- Out of 1,141 samples, 598 showed traces of added flame retardant chemicals.
- Ninety samples contained more than one flame retardant.
- Two-hundred seventy four samples showed traces of TCPP.
- Over 200 samples showed traces of either Firemaster 550 (FM 550) or Firemaster 600, two flame retardant mixtures.
- Car seats and other child products showed particularly high incidence of the chlorinated organophosphates TDCPP and TCPP.

The data reflect the phasing out of pentaBDE in 2005, while TCPP (its replacement) was not observed before 2005.

Data also showed that changes to TB 117 are having a positive impact. In a sample of 117 products purchased in 2015, 70% contained no detectable flame retardants, and in a sample of 62 products purchased in 2016, 80% contained no detectable flame retardants. In contrast, in samples purchased in 2010, 80% contained flame retardant in the polyurethane foam.

Dr. Stapleton described her work on a study of young children investigating residential exposure to semi-volatile organic compounds. The study included 203 North Carolina families with children aged 3 to 6 to determine exposure to organophosphate flame retardants such as FM 550 and TDCPP in the home environment. A key finding was that while house dust had been a good predictor of the presence of polybrominated diphenyl ethers (PBDEs) in blood in earlier studies, hand wipes, which contain residues directly from the skin, were more highly correlated with urinary metabolites of organophosphate flame retardants, which are more volatile and degrade faster than PBDEs. Organophosphates are used widely beyond flame retardants, especially as plasticizers. Dermal absorption is therefore likely a critical element to consider when reviewing the health impacts of the newer flame retardants on the market. The bottom line, Stapleton said, is that "whatever is in your sofa is in your child's body."

Critical liver functions are inhibited by TBPP and FM 550. Specifically, these chemicals inhibit the activity of carboxylesterase enzymes, which play a critical role in the body's defense against toxic insult and in normal physiologic function. As well, these chemicals may interfere with the biological activity of some pharmaceuticals like Tamiflu.

In summary, the use of FRs in residential furniture has changed significantly in the last two decades with increasing use of organophosphate flame retardants (OPFRs) and indications of reduction of overall use of FRs in furniture. Exposure to OPFRs is ubiquitous and levels on hand wipes correlate to internal dose.

Organophosphate Flame Retardants and Fertility

SPEAKER

Courtney Carignan, PhD, Michigan State University

We are in an infertility epidemic. Infertility, defined as taking a year or more to conceive, now affects 10-15% of the population. A recent study found a 50% decline in sperm counts over the last 50 years. Infertility affects men and women equally. While age is certainly an important factor in fertility the increasing global trend in infertility is not explained by delayed childrearing alone.

There is significant research and indication that environmental factors impact reproductive health and fertility. Animal studies have reported impacts of organophosphate fire retardants (OPFRs) on fertility. Most people are exposed to OPFRs due to their use in products as ubiquitous as office furniture, foam training equipment (i.e., landing mats and foam pits), home electronics, and nail polish.

Few studies have looked at the impact of OPFRs on humans.

Dr. Carignan examined the hypothesis that preconception exposure to the OPFRs impacts fertility using couples undergoing in vitro fertilization as a model to investigate human reproduction and pregnancy outcomes. The study included infertile couples and looked at embryo quality, live births, and urinary OPFR metabolites. The study of maternal exposure is complete, and the paper on paternal exposure is in progress.

Because the study population was recruited from an infertility clinic in Boston participants were primarily college-educated white non-smokers in their thirties.

The study found decreased measures of fertility across increasing quartiles of both summed and individual OPFR metabolites. Women with the highest levels of urinary OPFR metabolites had a lower proportion of cycles resulting in successful fertilization (10% decrease), implantation (31%), clinical pregnancy (41%), and live birth (38%) compared to those with the lowest levels. Male partners with urinary TDCIPP metabolite had a lower proportion of cycles resulting in successful fertilization (8% decrease) compared to those with the lowest levels. Findings were similar with consideration of variables closely associated with successful conception including age, ethnicity, body mass index, year of sample collection, and infertility diagnosis.

The results suggest that paternal exposure to TDCIPP and maternal exposure to mono-ITP may inhibit fertilization. They also suggest that maternal exposure to TDCIPP, TPHP, and mono-ITP may inhibit implantation, clinical pregnancy, and live birth.

The study group showed lower exposure rates than the general population. Older subjects tended to have lower levels of OPFR metabolites in their urine. White males exhibited lower levels of the TDCIPP metabolite, and those levels rose with body mass index. Urinary concentrations of the TDCIPP metabolite were higher in the summer and lower in the winter; concentrations increased overall across the past decade.

An important strength of the study is its ability to assess the contribution of preconception exposure as this is the period of oocyte and sperm maturation that can be sensitive to environmental exposures. This was the first human study to explore OPFR exposure and fertility. Results are consistent with toxicological studies of OPFRs and fertility, which have reported negative effects on fertility.

[1] Carignan, Courtney et al. *Urinary Concentrations of Organophosphate Flame Retardant Metabolites and Pregnancy Outcomes among Women Undergoing in Vitro Fertilization.* Environmental Health Perspectives. 087018-8. https://doi.org/10.1289/EHP1021.

[2] Carignan, Courtney et al. *Erratum: "Urinary Concentrations Of Organophosphate Flame Retardant Metabolites And Pregnancy Outcomes Among Women Undergoing In Vitro Fertilization"* Environmental Health Perspectives. 119001-1. https://doi.org/10.1289/EHP2784.

[3] Carignan, Courtney et al. *"Paternal Urinary Concentrations of Organophosphate Flame Retardant Metabolites, Fertility Measures, and Pregnancy Outcomes among Couples Undergoing In Vitro Fertilization."* Environment International 111 (2018) 232–238. https://doi.org/10.1016/j.envint.2017.12.005

Hazardous Exposures and Cancer Risks Concerning Firefighters

SPEAKER

Patrick Morrison, International Association of Firefighters

For the International Association of Firefighters (IAFF), one of the biggest health concern for firefighters is cancer. As a result, many states now have firefighter cancer presumptive laws which allows fire fighters to prove they developed occupational cancer from their occupation.

In 2017, 68% of firefighters placed on our IAFF Fallen Fire Fighter Memorial walls were work-related firefighter deaths from cancer. Fire fighters are routinely exposed to a variety of chemical substances, considering many home products are now made of synthetic materials instead of wood, and they are coated in flame retardants. The shift has changed the ways fires burn and has made the combustion products highly toxic.

It is also known that firefighters are twice as likely as the general population to get mesothelioma. "There is a direct link between Asbestos exposure and mesothelioma. The concern is that exposure to asbestos is part of the job on a daily basis," Patrick Morrison said.

The high cancer rates have made us evaluate our methods and practices. Firefighters now know that smoke and soot carry carcinogens. The days when "a dirty face would be a badge of courage" are over, but a 2007 UL study found that 97% of particulates are invisible. Firefighters' gear protects them from heat, but it does not protect their lungs and sometimes their skin. The question is how much and how quickly firefighters absorb these toxins through their skin. The only way to reduce cancer is to reduce exposure at every stage.

To evaluate the exposures to flame retardants, the IAFF partook in a study to evaluate dust samples from five fire stations in five different states. The levels of carcinogens found were astonishing: firefighters were bringing flame retardants back from fires. Fire services and new generations of firefighters are beginning to understand that contaminants are tiny, and that exposure does not stop once they leave the scene of a fire.

Another study conducted by the University of Ottawa looked at exposure rates for polycyclic aromatic hydrocarbons and other organic mutagens. We are finding that not cleaning our gloves is another major concern because when, our members take them off, they are getting these contaminants on their hands, and potentially ingesting these toxic chemicals if they do not wash their hands.

Firefighters cannot be completely encapsulated, so the question is how do we deal with contaminants? We must focus on decontamination and ensuring our members are aware of the health concerns associated with not cleaning their gear. The IAFF magazine now discourages manufacturers from using photos of firefighters covered in dirt and soot in their advertisements. This only glorifies behaviors the IAFF is trying to change.

"We used to take our gear home," Morrison said. Now firehouses are being redesigned with hot and cold zones. The new best practice is to bag dirty gear at the fire, and shower once return from a call. "I never thought this would be practiced in the fire service."

The IAFF is committed to tracking cancers over the careers of firefighters. Researchers will now follow a cohort of young firefighters for the next 25 years.

"We're passionate about this," Morrison said. "If we're going to be exposed, we want to know. Are there better ways to protect firefighters? We have to find those ways."

Flame Retardant Exposures in the Fire Service

Speaker

Kenneth Fent, PhD, CIH, US Public Health Service, National Institute for Occupational Safety and Health

Flame retardants such as PBDEs, TBB, and TDCPP are ubiquitous in the environment, and similar chemical compounds are being used especially as plasticizers. Although PBDEs were phased out between 2003 and 2013, these chemicals nonetheless “remain present in nearly all U.S. buildings,” Kenneth Fent said. When fire retardants burn, bromine, chlorine, and phosphorus atoms may react to produce acid gases, PBDEs may oxidize to brominated dioxins and furans, or the parent compounds may be released into the atmosphere. In addition to airborne toxicants, there will also be surface contamination, with consequent dermal absorption.

Firefighters can be exposed to flame retardants through inhalation, dermal absorption, and inadvertent ingestion, from contaminated gear and equipment, and from take-home exposure—in personal vehicles, for example. Agreeing with an earlier speaker, Dr. Fent said, “organophosphate flame retardants (OPFRs) and dioxins may be more readily absorbed through the skin than PBDEs, though more research is needed.”

Studies have found higher levels of certain PBDEs and OPFRs in the blood and urine of firefighters compared with the general population. Higher-than-average levels of flame retardants have been found contaminating turnout (bunker) gear and in fire station dust. Studies have also found fire retardant contamination through the seams of the hood that provides the primary protection for a firefighter’s neck. Firefighters must remove their gloves with care, as these are a major source of fire retardant contamination and spread.

There are a number of major gaps in knowledge, including “the biological uptake and excretion of fire retardants and dioxins and furans during firefighting,” the correlation between firefighters’ position on the fireground and their uptake of fire retardants, and the efficacy of decontamination and laundering. Preliminary results indicate that while laundering did lower OPFR levels, washing did not greatly affect PBDE levels.

Data analysis is ongoing, and there are plans to further compare biological levels of PBDEs, dioxins, and OPFRs, before and after firefighting, between interior and exterior crews, and between firefighters wearing decontaminated gear and those wearing non-decontaminated gear.

Fireground Chemical Exposure and Protection

Speaker

Gavin Horn, PhD, Illinois Fire Service Institute

Gavin Horn spoke about best practices among firefighters to avoid unnecessary exposure to products of combustion, including flame retardants, especially in light of the alarming increase of cancers among workers in this job sector. Firefighters’ bunker gear is regularly contaminated with a full suite of flame retardants among other chemicals. In their study, exposure levels depend upon job assignment, repeated exposure, cleaning efficacy, and the tactics employed on the fireground.

Critical to keeping clean of flame retardants, and clear of their toxic effects on the body, are immediate cleaning of the skin and rapid showers after a firefight and, especially, regular cleaning of gear. Repeated wearing of non-decontaminated bunker gear can increase the risk for cross contamination to the firefighter, fire apparatus or fire house. But financial pressures on fire departments can make this challenging, given that a full set of bunker gear costs around $2,000. And repeated laundering may begin eroding gear quality: after five washings, a bunker suit begins to feel softer, though current research is studying how this impacts protective properties. One alternative to laundering might be decontamination through wet soap process. Research continues, but to date, "a wet soap decontamination with the equivalent of a garden hose seems best practice" with 85% efficacy for removing PAH contamination.

Emphasizing the need to avoid head and neck contamination in the first place, especially to organophosphates, which absorb easily through skin, Horn described the recent changes to hood material and design and the number of new hoods to hit the market in the past two years, as well as hood exchange programs and "wash your hood Sundays." However, some fire departments still do not require the use of hoods. He added that a recent study showed that wiping the neck with wet wipes reduced PAH contamination by 54%.

Horn highlighted the problem of cross-contamination, especially when firefighters are removing their gloves, and he noted the existence of a YouTube video showing firefighters to think about how they remove their gloves—like EMTs do after medical call. Hands are particularly vulnerable to contamination, and in ways and at levels that are only now being measured and understood.

Initial academic papers on the subject of fireground exposure are available, and an online program via UL Fire Safety Research Institute will be up and running in early 2018.

Flame Retardant Technology Advancements

Speaker

Gordon Nelson, PhD, Florida Institute of Technology

Dr. Nelson spoke about the formulation and production of environmentally friendly flexible foams with significantly reduced flammability.

Between 2011 and 2015, 358,500 home structure fires resulted in 2,510 deaths, 12,300 injuries, and damages of $6.7 billion. While only 2% of home structure fires involve upholstered furniture as first ignition sites, such fires are culpable in 18% of deaths.

Polyurethane has been in great demand across industrial, commercial, and domestic sectors, with global demand in 2015 exceeding $50 billion. Such demand reflects polyurethane's versatility, ease of manufacture, and low cost. It is also biodegradable, and extremely flammable.

Past approaches to the problem of flammability have involved the addition of flame retardants to the foam, retardants like PBDE, which were non-binding and often contained volatile compounds. New approaches involve the physical welding of polymeric flame retardants directly into the polyurethane. These new flame retardants are non-halogenic, non-volatile, and non-migrating.

Noting that key applications such as school bus and aircraft seating, as well as prison furniture, continue to legally mandate flammability resistance, Nelson reviewed, in highly technical detail, recent tests of the flame-resisting ability of the new flexible polyurethane foams containing polymeric or bound-in flame retardants. Concluding, he said this new product is non-detrimental to both human health and the environment and is effective at keeping foam from bursting into flames.

Flame Retardant Innovations

SPEAKER

Munjal Patel, MS, Israel Chemicals LTD

ICL is committed to sustainability as a source for innovation and renewal, responsible chemistry, and open for cooperation and transparency with NGOs, governments, and anyone with a legitimate interest in understanding our industry. It is unclear whether banning or imposing severe labeling requirements on all known and unknown chemicals that could be used as flame retardants is good public policy, suggesting instead that "today we know more than ever about routes of chemical exposure and mitigation through chemical choice and design. We can have fire safety and chemical safety."

ICL uses its Systematic Assessment for Flame Retardants (SAFR™) system to ascertain which of its flame retardants are safe for use, and in what applications. The evaluation is based on measuring hazard and exposure potential. Among its research methodologies, ICL also uses zebra fish to assess early any developmental issues. Negative results lead to early rejection of the molecule in question.

ICL has been working on innovations in flame retardants for flexible foam in furniture applications. Patel said key considerations when dealing with foam are that "not all fire retardant mechanisms work in polyurethane foams," that foam density matters, and that fire retardants must maintain their function through a relatively long-lived product. Reviewing the history of ICL flame retardants, he noted the production of halogen-free Fyrol A710 in early 2000, low-emission Fyrol HF10 for automotive application in 2014, and the ongoing research into a reactive (ideally) or polymeric flame retardant for furniture foam.

ICL-IP America's internal extraction analysis method was described. It is a test designed to see whether a reactive flame retardant has successfully chemically bonded to polyurethane foam.

During the test, foam samples are soaked in solvent for 12 hours, and then the solvent extract is analyzed for the presence of the reactive flame retardant.

Based on the application of the SAFR methodology to flexible foams, TDCP is not recommended for seats in transportation settings. ICL is working to create alternative fire retardants that work with fabrics. Such fire retardants are particularly important because many synthetics are highly flammable and must be flame retardant to pass TB 117-2013. Fire retardants for fabrics must be able to withstand multiple launderings. ICL's TexFRon 4002, a "polymeric, non-leaching, insoluble, easily processed, and cost-competitive" flame retardant that shows "no deterioration of flammability performance after 25 laundry cycles" has been approved by Oeko-Tex, an independent testing and certification program headquartered in Zurich that tests fabrics for such things as pesticides, heavy metals, and preservatives.

Flame retardants are needed for achieving robust fire safety in many consumer goods. The SAFR tool "helps designers make better choices," and ICL's polymeric and reactive fire retardants are attractive alternatives to other fire retardants currently in use.

Discussion

A participant asked what percentage of reactive retardant would likely be needed to treat polyurethane foam. Patel suggested four parts, comparing this percentage to the TDCP at 12-part in generic formulation. He said ICL and other research bodies must establish a replicable methodology to test the degradation products of fire retardants as part of an effort to generate data that speak a common language.

Consumer and Residential Furnishings Industry Perspective

SPEAKERS

Nonnie Preuss, Wellness Within Your Walls

Susan Inglis, Sustainable Furnishings Council

Nonnie Preuss gave an overview of Wellness Within Your Walls (WWYW) and the organization's work with consumers on healthy environments. Wellness Within Your Walls (WWYW) promotes healthy, eco-sensitive products that support beautiful, sustainable, non-toxic environments. The organization works with designers and partners, who are very influential, even if they are not involved with every job. WWYW wants to leave a legacy of truly healthy homes, free of toxins.

Our educational program consists of three categories:

- Natural materials, free of harmful chemicals and synthetic options;
- Sustainable, innovative materials that support long-term well-being; and
- Responsible control of toxins.

Manufacturing technologies that detect toxins and check quality are developing at an astonishing pace, but social media gives legs to both success stories and lies.

WWYW works with builders to find ways to cope with off-gassing in new construction. One strategy might be to stagger painting and carpeting and kitchen installation—activities that release toxic gases into our living spaces. With the increased use of synthetic building materials and furnishings, as well as chemically formulated personal care products, pesticides, and household cleaners, the indoor living environment has become more toxic, resulting in "tight box syndrome." A tightly fitted house with poor ventilation may not be as healthy as the leaky house next door.

The problem facing the sector is clear, and WWYW's goal is to make a significant different. "Everyone in this room is moving the needle."

The fires raging in California pose a special problem — thousands of chemicals off-gassing at once. Heavy metals are a particular threat.

Preuss pleaded with regulators, builders, and designers to "go beyond the regulations you know to be a little weak," to educate and self-regulate.

A review of consumer research on environmental safety was presented by Susan Inglis of the Sustainable Furnishings Council (SFC). This survey showed that concern over toxic pollutants related to home furnishings among female respondents grew from 62% in 2012 to 91% in 2017. Shoppers were very interested in buying environmentally safe furnishings and understood that they might have to pay more for them.

Chronic diseases like asthma, brain cancer, and fertility impairment are dramatically rising, and a large majority of buyers are interested in learning more. There is an interest in understanding chemicals used in manufacturing of products and their links to these issues. Consumers were particularly interested in understanding chemicals used in the manufacturing of children's furniture.

There was discussion around a "what's it made of "program promoted by the SFS where manufacturers indicate their commitment to reducing harmful chemicals that pose harm to the environment and human health. They commit to ask their supply chain about the presence of harmful chemicals and take steps to reduce. An emphasis is placed on antimicrobials, PVC or vinyl, flame retardants, fluorinated stain treatments, and VOCS including formaldehyde.

Panel I: Flammability & Chemical Performance

MODERATOR

Stephen Kerber, MS, Underwriters Laboratories Inc.

PANELISTS

Marty Ahrens, MSW, National Fire Protection Association

Christopher Weis, PhD, DABT, National Institute of Environmental Health Sciences

Patrick Morrison, International Association of Firefighters

Gordon Nelson, PhD, Florida Institute of Technology

A participant expressed concern that missing from all the talk about foam and flammability is the issue of smoke and smoke toxicity from flame retardants. Panelists agreed that carbon monoxide remains the number one cause of fire deaths, but firefighters' chronic and repeated exposure to smoke is a different question. "Fire is extremely toxic," one panelist said, recalling Heather Stapleton's comment about there being 11,000 different chemicals in house dust. Another agreed that the flame retardant present in polyurethane foam "is just one item in the built environment."

Another participant asked whether the incomplete combustion created by flame retardants might actually increase the smoke. Gordon Nelson said the "per gram yield of carbon monoxide is not the issue." Rather, the toxic load that blasts out of a room during flashover is the big concern. In other words, flame retardants are needed to prevent flashover from occurring. Disagreeing with Nelson, another participant referred to a recent study by U.K. fire scientist Richard Hull, who found that foam treated with flame retardants generated far more carbon monoxide while burning than untreated foam.

A participant asked about hydrogen cyanide as the chemical that actually incapacitates people, leading them to be unable to feel the fire so that they eventually die from carbon monoxide poisoning. Kenny Fent agreed that this is a problem. Nelson replied that what should concern people is the prevention of flashover.

Christopher Weis said he has yet to see fire scientists demonstrate quantitatively the ability of flame retardants to suppress fire. Meanwhile, tens of millions of people are being exposed to flame retardants in the built environment. Weis asked whether there is a tipping point at which approaches other than chemical means become more effective. "Why do we choose chemical suppression?" he asked.

Returning to the question about smoke, Pat Morrison said that "while we know that the smoke is what kills," many people do not want to talk about this. He noted, in particular, that the EPA's tests on flame retardants are not conducted under fire conditions.

Said Nurbakhsh suggested that while smoke tests used to be conducted, practicality rules in current practice where only the heat release test is used. Weis expressed indignation that practicality should be the guide here.

In response to Weis's question about a tipping point, participants discussed the costs and benefits of seeking non-chemical means to limit fires. One said the anti-flame retardant position is a knee-jerk reaction, but the history of flame retardant failure and poisoning is indeed reprehensible. Marty Ahrens asked about the value of "going backwards" in order to move forward and asked whether researchers should consider data that today's upholstered furniture is "burning hotter and faster."

Nelson responded first by championing the role of sprinklers, though he later noted the aggressive and highly politicized opposition to sprinklers on the part of building associations across the country, who fear that such an addition would make homes more expensive and therefore less desirable. He told the story of General Electric's success in making cathode ray televisions fire retardant in the 1970s. Participants debated the relevance of fire retardants in today's LCD televisions, where the risk of fire is much less.

Participants discussed the need for and the value of educating retail staff about furniture in terms of both its chemically fire-safe and its physically fire-safe formulations. A representative from the Sustainable Purchasing Leadership Council suggested that education is growing, and the public is increasingly concerned that "their homes are making them sick." A representative from the Upholstered Furniture Action Council replied that far too much attention is being paid to flame retardants when there are much larger issues surrounding flammability that should be addressed.

Participants raised the question of the role of mattress pads in fires and the extent to which they are or should be regulated.

A participant who is a furniture manufacturer commented that building with wood is "inherently dangerous by design," and that without flame retardants, "you are opening the door to a quicker burn," but also "trading off one hazard for another."

Update on the Upholstered Furniture Flammability Project at the Consumer Product Safety Commission

SPEAKER

Andrew Lock, PhD, Consumer Product Safety Commission

Dr. Lock presented an introduction to the U.S. Consumer Product Safety Commission (CPSC) and an overview of their Upholstered Furniture Flammability Project.

The CPSC's mission is to keep consumers safe. It has jurisdictional authority over many types of products granted in several Congressional including the Consumer Product Safety Act (CPSA) and the Flammable Fabrics Act (FFA). CPSC does not have authority over product types that are under the jurisdiction of another federal agency. The CPSC estimates that consumer products are responsible for 43,000 deaths, 40 million injuries, and a trillion dollars in costs to society every year.

CPSC's standards are performance-based which means that manufacturers are free to choose their ways of meeting the standard. They do not specify how manufacturers must meet them. Standards must address hazards in technically practicable ways at reasonable costs.

Upholstered furniture fires, an average of 4,500 per year, result in 400 to 500 deaths, 660 injuries, and $230 million in losses each year. Research and studies suggest that furniture may be the biggest contributor to flame spread within dwellings, and that open flame ignitions may be attributed to more than just candles and lighters.

CPSC released a Notice of Proposed Rulemaking (NPR) in 2008. In an attempt to address both smoldering and small open flam ignition, they incorporated modified UFAC and BS 5852 test methods. Bench scale performance did not demonstrate prediction of real furniture flammability performance. Open flame ignition, bench scale qualification tests for fire barriers (Type II) showed some improvement in full scale fire performance[1]. In 2016 the CPSC staff prepared a briefing package evaluating the 2008 NPR and TB 117-2013 for potential adoption as a national rule and found that neither was appropriate and recommended the Commission terminate rulemaking[2].

CPSC staff has recently conducted extensive testing of full scale furniture in a variety of material constructions[3] [4]. Cover fabrics (such as polyester blends or cotton) and cushion materials (such as polyester batting or foam) vary in flammability. Fire barrier materials integrated into furniture tend to reduce or delay the spread of fire, but both materials and labor are considered costly. Barriers that perform well for smoldering fires may perform poorly with open flames, and vice versa. For example, polyester batting is effective for smoldering but not for open flame. In tests, some sheet barriers did not burn at all, but all loose-fill barriers burned eventually.

There are chemical hazard concerns associated with some additive flame retardants (FRs) which might be used to meet a potential upholstered furniture flammability standard. The CPSC was recently petitioned to ban non-polymeric additive organohalogen FRs (OFRs) in certain products, and this petition was granted. The Commission directed staff to convene a Chronic Hazard Advisory Panel (CHAP) to assess the toxicity and exposure to OPRs, and the National Academy of Sciences is completing a scoping and feasibility study in administering the CHAP.

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[1] https://www.cpsc.gov/s3fs-public/ufmemos.pdf

[2] https://www.cpsc.gov/s3fs-public/The%20Feasibility%20Benefits%20and%20Costs%20of%20Adopting%20-TB117-2013%20-%20September%208%202016.pdf

[3] https://www.cpsc.gov/s3fs-public/FY14_Chair_Study_Memos.pdf

[4] https://www.cpsc.gov/s3fs-public/FY16_Loose_Fill_Chair_Study_Memos-Final_0.pdf?WYVoiGP5gimn.HkTBjPVtABniDuMIVcs

Bench-Scale Testing of Residential Upholstered Furniture: Flaming and Smoldering Combustion

Speaker

Mauro Zammarano, PhD, National Institute of Standards and Technology

According to NFPA reports, residential upholstered furniture (RUF) is the single largest cause of civilian deaths in U.S. house fires—more than 600 deaths per year.

There are two major ways to reduce RUF fire deaths:

- Prevent furniture fires by stopping ignition (eliminate the ignition source or make the furniture harder to ignite); and
- Mitigate furniture fires by reducing the rate of heat generated when furniture is ignited.

This presentation covers bench scale testing studies to evaluate (1) RUF fire prevention in terms of smoldering ignition resistance and (2) RUF fire mitigation in terms of heat release rate reduction.

Smoldering ignition studies carried out at the National Institute of Standards and Technology (NIST) showed that the rate and extent of smoldering is strongly affected by the type of bench-scale test adopted. We selected four bench-scale mock-up tests in which natural convection was tuned by varying foam thickness (51 mm and 76 mm) and/or replacing the wooden panels (used as a foam substrate) with air-permeable metal wire mesh. Data showed that smoldering (measured as dynamic mass loss) increases with natural convection and that the substrate type (i.e., permeable vs. non-permeable) and foam thickness played a major role on smoldering.

The bench-scale smoldering tests adopted in the US (UFAC, ASTM E1353, NFP 260, and CA TB 117) (non-permeable substrate and 51 mm thick foam) is the least smoldering prone of the four tests (lowest smoldering mass loss).

NIST changed the foam thickness in this test and/or replaced the wood panels with a metal wire mesh. As compared to this standards set-up:

- By just increasing the foam thickness from 51 mm to 76 mm, NIST measured a significant increase in smoldering propensity (about 1.3-fold increase in mass loss after 35 min).
- By just replacing the wooden substrate with an air permeable wire mesh, NIST measured the highest degree of smoldering (about 5-fold increase in mass loss after 35 min).
- By increasing the foam thickness from 51 mm to 76 mm and replacing the wooden substrate with an air permeable wire mesh, NIST measured smoldering lower than just replacing the substrate, but higher than just increasing the foam thickness (about 1.7-fold increase in mass loss after 35 min).

The reason for the measured increased smoldering by increasing foam thickness or adopting a metal wire mesh is an increase in natural convection. These modified test set-ups no longer starve the smoldering front of oxygen and allows smoldering to occur naturally without interference from the testing set-up[1]. The convective airflow and smoldering increase slightly with the foam thickness but noticeably when the wooden substrate is replaced by an air permeable mesh. This effect is obvious with a 51 mm thick foam. In fact, an increase in foam thickness from 51 mm to 76 mm will cause a decrease in natural convection as a result of the increased pressure drop throughout the foam[2].

These tests results indicate that the current testing configuration used by UFAC, ASTM E1353, NFPA 260, and CA TB 117 is influencing the physics of natural smoldering by starving the smoldering front of the oxygen necessary to sustain the natural smoldering. By modifying the set-up as done by NIST, this allows for smoldering to occur naturally and, therefore, the results of the test will now depend on the smoldering propensity of the upholstery materials being tested, which is the reason for the test.

While the results from the bench-scale tests make scientific sense, ultimately, what is important is to understand, which bench-scale set-up (the existing standard set-up, switch to thicker foam, switch to an air permeable wire mesh, or switch to thicker foam and wire mesh) produces smoldering results that are best aligned with smoldering of real furniture. NIST conducted full-scale smoldering tests of real-scale furniture mock-ups (cushions supported by metal frame rather wood). The smoldering measured in the full-scale tests was strongly aligned with the smoldering measured in the bench-scale tests that used a metal wire mesh. The smoldering using the existing standard set-up didn't correlate with the full-scale tests as it well under predicted the extent of smoldering.

In conclusion on smoldering, a standardized test method is expected to predict the behavior observed in a product when it is used as intended in its end-use application. Inaccurate predictions can be catastrophic. For furniture, if the bench-scale test is too strong, viable fabrics (low smoldering) will be eliminated from the market or cause manufacturers to install mitigating technologies that aren't providing any additional level of safety. The end result is higher cost and limiting consumer choices without any improved fire safety. If the bench-scale test method is too weak, it is allowing fabrics that promote smoldering to be used in furniture. This means there will be more fires and fire losses involving furniture than expected because the furniture using these stronger smoldering fabrics aren't as fire safe as suggested by the bench-scale tests. NIST research shows modifying the UFAC, ASTM E1353, NFPA 260, and CA TB 117-2013 smoldering test method by lifting the substrate on a metal wire mesh produces smoldering results directly aligned with smoldering of full-scale furniture. It also shows that using the existing test set-up is under predicting smoldering – fabrics appear as weaker smolderers in the bench-scale test than they actual are when used in real-like furniture. The reason for this poor correlation is this current set-up restricts natural smoldering behavior by not allowing natural flow of oxygen within the test substrate – a problem easily corrected by just lifting the substrate off of the holder with a metal wire mesh.

Flaming RUF items with low heat release rate are less likely to spread the fire to other combustibles and prevent room flashover. This greatly reduces the threat to people outside the fire room. In most RUF fires, the primary fuel is the padding material(s), often polyurethane foam. Wrapping the padding in a fire barrier can contain the burning rate in two ways, without relying on FR additives:

1. Decreasing the heat transfer from the burning upholstery fabric and an external heat source to the padding. This, in turn, reduces the rate of generation of combustible gases.
2. Decreasing the mass transfer of padding pyrolysis products from within the RUF cushions to the air and flames on the outside.

It has been recognized that full scale testing of all combinations of upholstered furniture materials is not economically feasible and RUF fire mitigation requires a small-scale test to assess heat release rate during flaming combustion. NIST recently developed a prototype bench-scale test to assess the fire barrier's effect on the heat release rate of the test specimen. The test specimen represents the center of an actual upholstered cushion (i.e., away from the edges). It consists of upholstery fabric layers covering the top and bottom faces of a polyurethane foam cube (105 mm side length). The side faces of the foam cube are insulated and sealed to prevent pyrolysis gases from escaping. Layers of an additional barrier material can be placed between the upholstery fabric and the foam. The test specimen is exposed to an external heat flux of 50 kW/m2 in a cone calorimeter. NIST is currently evaluating the correlation between bench-scale and full-scale HRR.

[1] Zammarano et al., Polymer Degradation and Stability, Volume 106, August 2014, Pages 97-107 https://doi.org/10.1016/j.polymdegradstab.2013.12.010

[2] Zammarano, M.; Matko, S.; Davis, D., Rick *NIST Technical Note 1799 - Impact of Test and Foam Design on Smoldering* National Institute of Standards and Technology: Gaithersburg, MD, 2013.

An Update on Barrier Studies

Speaker

Said Nurbakhsh, PhD, CA Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (BEARHFTI)

Dr. Nurbakhsh presented a proposal for a study on ways to reduce the open-flame flammability of upholstered furniture. When TB 117-2013 was adopted, fire safety advocates expressed concern about the lack of open flame requirements. In response, the Bureau announced that they would start a two year study on available and emerging fire material barriers and other relevant technologies. They would examine their open flame resistance properties and determine their applicability and cost to implement.

His team developed a small-scale open flame test method for barriers, procured barrier materials to test, and contracted out a study (now under way) of the economic impact of using barriers.

In the test method, butane burners on the underside of a device and heat-sensitive foam on the top were separated by a barrier material being studied. A single test specimen of a barrier fails to meet the requirements of this test procedure if the standard polyurethane foam ignites. A barrier material passes the test if three initial specimens pass the test. If more than one initial specimen fails, the barrier material fails the test. If any one of the three initial specimens fail, the test is repeated on three additional specimens. If any one of the additional three specimens fails, the barrier sample fails the test.

The team obtained 25 barriers of diverse types from suppliers and tested according to the proposed open flame test method and the TB 117-2013, sections 2 and 3 smoldering cigarette tests.

Five barriers were selected for full-scale mock-up validation tests. The tests, conducted in triplicate, included a control set with no barrier and a set with non–fire retardant foam.

A sample of each barrier material was analyzed by Dr. Heather Stapleton at Duke University. No detectable amount of added fire retardant chemicals was found in any of the barrier materials.

The report, "Barrier Materials" is available from the State of California BEARHFTI at http://www.bearhfti.ca.gov/bureau_activities/index.shtml.

Real-Scale Mock-up Flammability Testing (Effect of Fire Barriers, etc.)

SPEAKER

William Pitts, PhD, National Institute of Standards and Technology

An introduction presented NFPA statistics for residential upholstered furniture (RUF) fires as first item ignited, RUF was:

- The first item ignited in average of 5630 home fires per year.
- Responsible for average of 440 civilian deaths, 700 injuries, and $269M in fire losses.
- Responsible for 2% of reported fires, but 18%of home fire deaths.
- Fifty-nine percent of fires ignited on RUF were confined to one room, but 63% of fire deaths were associated with spread beyond room of origin.
- Fifty percent of fatal fires involving RUF ignition resulted from smoldering cigarettes and an additional 15% were due to other smoldering sources.
- U.S. regulatory approaches to RUF flammability focus on smoldering ignition, which is responsible for 65% of fatal fires where RUF is the first item ignited.
- Fire experts participating in a recent workshop concluded that most fire deaths from RUF fires ignited by smoldering sources occurred after smoldering transitioned to flaming.
- A recent analysis has shown that ignition of RUF by nearby flaming items increases the number of fire deaths associated with RUF flammability by roughly 30 %.

- An example of rapid fire growth to high release rate levels on an actual upholstered chair was described.
- One chair can bring a small room to flashover and many rooms contain multiple items of RUF.

These observations suggest that a very large fraction of deaths in fires involving RUF could be avoided if the fire growth rate and/or the maximum heat release rate of flaming RUF was substantially reduced.

NIST has been investigating the use of small-scale fire measurements to predict burning behavior of real-scale RUF mock–ups. This presentation focused on the real-scale results. Mock-ups were constructed with combinations of fire barrier fabrics (none, or one of two barriers); polyurethane foam (none or fire-retarded), polyester fiber wrap (with or without), cover fabric (cotton or thermal plastic) and sewing thread (nylon or Kevlar).

In the laboratory tests, cotton-covered mock-ups resisted flaming ignition better than those covered in thermal plastic. Flame spread on seat cushions tended to pilot flame spread on the chair back. Ignition of arms after flame spread often contributed to rapid early growth in the heat release rate.

Analysis showed that experimental responses characterizing flame spread rate and heat release rate were statistically significant for only three of the five factors--fabric, barrier, and foam. The strongest factor was fabric (with cotton superior to thermal plastic), followed closely by barrier (with use of barrier superior to no barrier), and less significantly by foam (with fire-retarded superior to non-fire retarded). Flame spread responses were more sensitive to fabric effects, while responses related to heat release rate were most sensitive to barriers. The responses were also shown to depend on multiple interactions between the factors.

Introduction to UL/Emory Research— Paths and Processes

MODERATOR

Marilyn Black, PhD, Underwriters Laboratories Inc.

SPEAKERS

Debra Harris, PhD, RAD Consultants

Aika Davis, PhD, Underwriters Laboratories Inc.

Jordan Cohen, MPH, Rollins School of Public Health, Emory University

Marilyn Black introduced the researcher partners, who discussed several years of research on the impact of fire retardants (FRs) and construction materials on flammability and chemical exposure characteristics of residential furniture. Researchers studied newly manufactured chairs that were constructed with different flammability control processes that included upholstered chairs with and without FRs; different chemistries of FRs; and the use of barrier materials between the polyurethane foam and external textile. Chemical exposure studies to evaluate if consumers could be exposed to FRs with furniture containing them were conducted in controlled environmental chambers. Air, particles, settled dust and dust transfer from furniture surfaces were measured using specialized exposure study techniques. Flammability characteristics were measured by two techniques. First, all materials were evaluated using the current California TB 117-2013 smoldering test, and full chairs were burned with an open flame ignition.

The studies involved market available furniture and other products provided by furniture manufacturers, furniture material suppliers, chemical companies supplying FRs, and other stakeholders.

Dr. Black indicated that the product burn methodologies would be discussed during the results presentation, but a high level review of methodologies for chemical studies would be presented here.

Complete detail would be provided in the final research report prepared by UL, Emory and RAD Consultants.

Debra Harris said it is important to look at flame retardants for several reasons:

- Known toxins include endocrine disrupters and carcinogens;
- These toxins persist in the indoor and outdoor environment; and
- Some toxins, while phased out, are still expected to be with us for years to come.

Flame retardants are found throughout the built environment — in insulations, furniture, electronics, electrical wiring, children's products, and more. This research focused on FR chemical exposure risks and fire performance of upholstered furniture and electronics such as flat screen TVs and computer laptops in the home.

An exposure pathway is the route a substance takes from its source to its destination. An exposure pathway has five parts:

1. A source of contamination (in the home or other indoor environment).
2. An environmental medium or transport mechanism (such as a surface, air, or groundwater).
3. A point of exposure (such as the furniture, floor, or air).
4. A route of exposure (eating, drinking, breathing, or touching).
5. A receptor population (people that are actually exposed).

When all five parts are in place, the exposure pathway is complete. These studies identified routes of FR exposure associated with furniture in the built environment.

The human body can tolerate, and in some cases eliminate harmful substances. However, the body may not be able to remove all chemicals that put an individual at risk for adverse health effects. Certain chemicals have been found to affect the neurodevelopmental, endocrine, reproductive, and respiratory systems.

Using existing and innovative technologies and methods, researchers look for the sweet spot for product safety, the convergence between chemical exposure risks and fire safety.

The researchers found a manufacturing partner to produce chairs to their specifications, and Harris worked with the representative to select the chair, textile and other materials. The manufacturer produced 20 chairs: five fabricated in the normal way without any added flame retardant; five with a barrier material and no flame retardant; five with a traditional organophosphate flame retardant, and five with a reactive flame retardant. The FRs were provided by a manufacturing chemical company who worked with the foam supplier to integrate into the polyurethane foam.

The basic chair contained polyurethane foam with 30% replaced with soy-based formulation. The chair has a good sustainability story, utilizing recycled and regenerated fibers and metals, and materials with low volatile organic compounds (VOCs). This study used a 100% cotton textile which did not contain any flame retardant.

The chair was very clean from a chemical standpoint. The nascent foam did not contain any FRs and very low VOCs were found to be associated with the basic chair materials. The barrier textile was a commercially available 100% fiberglass product with very low VOC emissions and was found to contain less than 1% chlorine. The reactive flame retardant foam was a proprietary formula and is believed to be the flame retardant that was given a green chemistry innovation award by the EPA. The traditional non-halogen, organophosphate FR represented a common FR being used in the industry applicable to polyurethane foam.

Several electronics were tested as well, primarily for flammability characteristics to provide a comparison of furniture to other common indoor products.

Study Outline:

Five chairs were tested for each of four groups:

- Non–flame retardant foam (control)
- Non–flame retardant foam with fire barrier material
- Traditional flame retardant foam
- Reactive flame retardant foam

Within each group, one set of chairs was tested new, and another set was mechanically aged to simulate 10 years of use prior to testing. Testing for VOC emissions and FRs was conducted in a controlled environment while simulating product use. Fire performance testing was conducted as a whole-chair open flame test measuring heat release rate, mass loss, smoke, fire effluent gasses, temperature, VOCs and FRs.

For comparison, the electronics equipment was also subjected to the open flame test.

Aika Davis spoke about UL/Emory research testing processes on furniture flammability and human health, focusing on exposure methods for detecting chemical emissions from the chairs with the four flame retardant profiles mentioned above. Samples, including upholstered chairs (new and mechanically aged), flat screen televisions, and computer laptops were placed in a stainless steel environmental chamber to quantify emissions from the samples.

A mechanical robot known as "RobieSitz" mimicked three months of chair use (a person sitting down and getting up) during the 24-hour contaminant sampling.

The sampling timeline included:

DAY 1

- Start FR airborne chamber background sample with chair agitation (using RobieSitz).
- Collect VOC chamber background.
- Collect first dermal filter patch sample on chair.

DAY 2

- Finish FR airborne background sampling.
- Collect dust wipe (settled dust) background sample.
- Load test sample and equilibrate inside the chamber.
- Start FR airborne sampling with agitation.
- Collect VOC sample 1.
- Collect VOC sample 2.
- Finish FR airborne sample.
- Collect second dermal filter patch sample on chair.

DAY 3

- Collect dust wipe (settled dust) sample.
- Clean chamber, equilibrate, and prepare for next sample.

Researchers analyzed for thousands of airborne VOCs and aldehydes using gas chromatography mass spectrometer (GC/MS) and high-performance liquid chromatography (HPLC).

Jordan Cohen spoke about collection and analysis of FRs from upholstered furniture and electronics. He reviewed the five-part exposure pathway a substance takes from its source to its end point — the point where humans and other species can come into contact with it: 1) source of contamination; 2) environmental media and transport; 3) point of exposure; 4) route of exposure; and 5) receptor population.

The route of exposure is the way humans come into contact with a hazardous substance:

- Inhalation. We agitate furniture when we sit on it. Our furniture “exhales” chemicals and particles in air and we breathe them in.
- Ingestion. Every time we touch our furniture — every time our food touches our furniture — we risk transferring particulates and dust to our mouths or our food. This is a particular concern for infants and small children.
- Dermal contact. This is a longer-term issue. It is another concern for infants and small children, who may spend a great deal of time with exposed skin in contact with furniture or floor coverings.

The various methods used in this study to measure the level of FR contamination included sample collection during the environmental chamber exposure studies of each product:

- Air sampling. Polyurethane foam (PUF), a well-established medium for gathering semi volatile organics in air samples, was used in this study. This method requires the use of a vacuum pump for a defined time period of air collection and a pre-cleaned form of PUF, prepared specifically for low level chemical analysis. A quartz filter was used upstream to collect larger particles and was useful tool for the fractionation of particles up to 2.5 micrometers. Samples were collected of the chamber air during product exposure.

- Dust sampling. Dust wipes or sterile gauze wipes that are the standard for hard surfaces dust collection were used in our study. Dust wipes can be used with or without solvent; but in our study a solvent was used to effectively collect the settled dust from the chamber floor, following product exposure.

- Dermal sampling. Specially prepared filter paper patches were used as a proxy for skin contact, to estimate dermal transfer. Sample media were placed directly above the product cushion. Sample media were chemical extracted for analysis by gas chromatography, mass spectrometry (GC/MS). The sample extraction process was designed to extract as many compounds of interest as possible using a single procedure. Extracted and eluted samples are identified and quantified for specific flame retardants of interest using GC/MS with known standards.

Samples are all at trace concentrations, so great care was taken in handling, tracking, and labeling. Positive air pressure in the chamber reduced the risk of contamination.

UL/Emory Research and Results

Speakers

Marilyn Black, PhD, Underwriters Laboratories Inc.

Barry Ryan, PhD, Rollins School of Public Health, Emory University

Pravinray Gandhi, PhD, UL LLC

Marilyn Black presented the results from the UL/Emory study of the emissions of VOCs from chairs and electronics, both in general and after burning.

In terms of general emissions for all of the chairs, researchers measured complex mixes of many VOCS, but at very low levels. All fell below GREENGUARD, California 1350, and ASHRAE 189 minimums. All the chairs contained "very similar primary VOCS including hexanal, butanol, propanoic acid, 2-butoxyethanol, and formaldehyde," with little difference between the aged and the new chairs. Hexanal registered in the greatest proportion, probably from the wood frame, while the formaldehyde level was one of the lowest Dr. Black has ever seen in upholstered furniture.

She also said both the barrier and the non–fire retardant chairs showed very low VOC readings; the aged chairs showed more polyurethane-specific VOCs such as dioxolane; while the reactive fire retardant showed a series of bisphenols and diols. The traditional fire retardant chair showed phenol, propylene carbonate, and heavy hydrocarbons. None of the chairs emitted aromatics or halogenated organics.

Turning to the general VOC emissions from the TV (which, like the laptop, was turned on throughout the testing), Black indicated that VOC emissions were a lot more complex. For the TV, measurements showed a mixture of about 100 VOCs, with key emissions of 2 ethyl-1-hexanol, cyclopentasiloxane, dodecamethylsiloxane, phenol, and xylenes, as well as alcohols, aromatics, acrylates, styrenes, phthalates, tetramethylsuccinonitrile, and chlorophenyl esters.

On the other hand, the laptop measured very low on the emissions scale, and the VOCs present were fairly benign such as normal hydrocarbons, aldehydes, and alcohols.

Overall, the TV had the highest emissions, followed, in descending order, by the traditional fire retardant chair, the non–fire retardant barrier chair, the non–fire retardant (control) chair, the reactive fire retardant chair, and the laptop.

Turning to the chair burn data summary, Black related that burning produced a lot more chemicals. She also noted that because they had not measured VOCs from combustion sources before that we should consider these results semi-quantitative. The identification is good, but the levels are semi-quantitative since analytical methodology had not been optimized.

Benzene, a Class 1 carcinogen, was present in very high levels during the chair burns, especially in the non–fire retardant and traditional fire retardant chairs. It was the most dominant VOC present overall. Also present in the total VOC burn mix were chlorinated alkanes, heavy hydrocarbons, and styrene. About 60–70% of the observed VOCs were aromatics.

The TV burn revealed a high level of VOCs, whereas the laptop burn registered only basic hydrocarbons and aldehydes.

Diverse types of chairs did emit different VOCs, with the traditional fire retardant chair being the most concerning from a toxicology point of view with "a lot of nitriles, aromatics, and chlorinated organics.

In terms of the burn emissions trends, the TV emissions were the highest, with the non–fire retardant chair having the second-highest emissions.

Concluding, Black indicated that except during burns, regular VOCs were at reasonably low levels." She said the final report would list all the VOCs found in the various consumer exposure and burn studies.

Barry Ryan presented a discussion of the SVOCs or FR emissions study, both the general emissions and the emissions from burning.

Ryan said the results for the electronics (both TV and laptop) general SVOCs emissions tests were not that interesting. Amounts of the flame retardants TCPP and TCEP were at or below the limit of detection or at a low limit of quantitation.

Turning to the chair emissions results, Ryan prefaced his comments by explaining that all FR analysis results are not yet complete so these are some preliminary findings. Complete data will be found in the final report. A "Goodwill" chair from 2003 was used for some preliminary methodology assessments, which was found to contain various and sundry flame retardants, including TDCPP, TPP, a bit of PBDE, and some phosphorous-containing compounds.

Methodology development in the environmental chamber indicated background levels of numerous FRs at very trace levels. These included some PBDE, organohalogen and organophospate FRs. This low level background contamination could be associated with the ventilation air or wiring and may indicate the omnipresence of FRs in our indoor environment.

Discussion

Participants asked a number of questions about the methodology, expressing concerns about a failure to account for or prevent contamination through the ventilation system, and also to prevent cross-contamination via the specially designed chairs. Participants also questioned the term "aged" to describe the chairs, as there is a difference between a chair that is mechanically "aged" by pounding, and one, like the 2003 Goodwill chair, whose aging would have involved oxidative degradation of the polyurethane foam. Another participant asked whether the polyurethane foam was tested before burning. Finally, a participant suggested that in future studies, an exemplar chair should be preserved.

Pravinray Gandhi shared the results of UL's Fire Performance of Upholstered Furniture: Cigarette Ignition Resistance and Open Flame Ignition Study. He indicated that this project consisted of limited replicates but still provided valuable information on general trends.

Gandhi reviewed the several fire protection strategies deployed by manufacturers:

- Cover fabrics and filling materials are selected to resist ignition from smoking materials.
- Polyurethane foam is treated with fire retardants to reduce fire growth.
- Fire barriers between the foam and the cover fabric are employed to reduce fire growth from the polyurethane.

The research objective of this study was to develop data on the flammability of upholstered furniture using: 1) the California TB 117 -2013 cigarette ignition (smoldering) test, which is applied to all soft components of upholstered furniture—cover fabric, barrier, filling, and decking material; and 2) an open flame test on a chair constructed using established industry practices. This was an important addition, as previous UL studies had been criticized for not using industry standard construction of chairs. To achieve this objective, the study examined the influence of fire retardants, use of afire barrier, and testing of "simulated in-use/ aging." The study also sought to develop comparisons with electronics in the home.

One unexpected result was that the fire barrier failed the TB 117-2013 cigarette char test, "probably because the barrier was fiberglass and the cigarette therefore remained on the surface of the fabric and the heat could not dissipate," Gandhi said.

Researchers used two configurations for the open flame test: under the heat release calorimeter, and within an ISO 9705 heat test room. The first configuration allowed for measurements of the heat release rate under well-ventilated conditions. On the other hand, the test room allowed researchers to measure the smoke that comes through the door and to calculate transmitted hazards as may be presented to other parts of the home.

The key finding was that the presence of a barrier clearly inhibited burning. In the heat release calorimeter, the barrier "made all the difference, regardless of the chemistry": without the barrier, the heat release rate was 1,500 kilowatts; with the barrier it was less than 60 kilowatts. A similar difference was seen in the fire test room setting; without the barrier, chairs lost 30 pounds of foam and fabric in about five minutes, whereas with the barrier, it took an hour for there to be a five-pound loss. "The barrier definitely protected the foam," Gandhi said. Also, without a barrier, the temperature at the doorway was high, and that "would drive hot gases into other parts of the home."

Turning to the chemistry, he noted that the chairs with fire retardants did burn with lower carbon monoxide production, but higher concentrations of hydrogen cyanide. However, with the presence of a barrier, the chairs emitted no hydrogen cyanide at all as the barrier prevented the foam from significant burning.

Aging did not seem to have degraded the barrier, and the formaldehyde found in the barrier chair, “probably evolved from the wood in this particular burn,” Gandhi said.

The heat release values of the electronics were very low compared to those of upholstered furniture without a barrier. Chairs with a barrier likewise had very low heat release rates. Chairs without a barrier, however, achieved very high heat release states very quickly.

Discussion

Participants recommended that the term “aging” be changed to something like “mechanically exposed in an accelerated way.” They also said the researchers need to more clearly distinguish between TB 117 and TB 117-2013 standards.

A participant said it is important to know how much flame retardant is in a standard flame retardant treated foam. In this case, the standard flame retardant was 3% TBPP, which several participants commented is actually well below the standard 9–12%. Participants also said foam density must be considered.

Participants discussed the success of the barrier in preventing fire, and this led to a discussion about standard practice. “While standard chairs do not currently come with barriers, barriers can be custom added for an additional cost of up to 20%”, Debra Harris said.

Panel II: Pathway to Fire and Chemical Safe Products

PANELISTS

Moderator: Marilyn Black, PhD, Underwriters Laboratories Inc.

Panelists:

Mauro Zammarano, PhD, National Institute of Standards and Technology

Nonnie Preuss, Wellness Within Your Walls

Joel Tenney, MS, ICL

Susan Inglis, Sustainable Furnishings Council

Participants addressed several topics related to achieving fire and chemical safe products. It was agreed that fire risks are significant, fires are more severe, modern homes burn faster, and that upholstered furniture is a major fuel source of fire spread. Convergence was acknowledged as important where we have to address the hazards of fire as well as chemicals that may be used to control or suppress flammability. It was noted that we should not rely on chemical control only to manage flammability since there are health concerns over the chemicals and consumers are asking to minimize chemical risks. There are new and more innovative flame retardants, but health data on inhalation and personal contact is scarce. The chemical industry continues to innovate to more benign formulations, but costs may be a factor in using.

There was some disagreement about the general use of flame retardants (FRs). Some indicated that more research into non-halogenated FRs was needed to understand their health impact before using, while others recommended that flame retardant chemicals be eliminated across the board. "Green chemistry" was defended as an alternative approach to consumer safe FRs, and it was said that reactive FRs should not be tarred with same brush as traditional added FRs. Other participants indicated that there were many other harmful chemicals that should be considered, beyond just FRs, and that we should not lose sight of that. These include formaldehyde, phthalates, per- and poly-fluoroalkyl substances, heavy metals, polyaromatics, and many more. There are hundreds of different chemicals that a consumer can be exposed to at one time, and over 140,000 different chemicals commonly used on a global basis to manufacturer products. Low dose mixtures of chemicals and use of chemicals prior to knowing their health impacts are of concern overall.

The concern of firefighter exposure was discussed, and the need to know more about smoke toxicity and composition. Carbon monoxide, hydrogen cyanide, and other chemicals and particles produce a toxic atmosphere. There is a desire to develop innovative processes for fire protection to promote safety and reduce toxicity.

Participants discussed the widespread public perception that fire standards for furniture are unnecessary, and whether an open flame test should be added to the next version of TB 117-2013. Many agreed about the urgent need to make TB 117-2013, or some variant, a national requirement outside of California, particularly in light of the fact that the upholstered furniture sold in the United States is increasingly manufactured offshore. Several participants agreed there is an equally urgent need to strengthen the NFIRS in order to determine whether an open-flame test should be created and added to TB 117-2013. There was also a discussion around the open flame test being needed as a test separate from TB 117-2013 so that it could be outside of the purview of California who eliminated it in the update of TB 117 in 2013.

Panelists talked about the relationship between the regulations and test standards and what researchers tend to test for (and manufacturers to produce). For example, if the test standard focuses on heat release rates — mitigation rather than prevention — the solutions suggested, and produced, will tend to support flame retardants. On the other hand, if the focus is on outright prevention, fire barriers would come to the fore.

The availability of a national standard was debated as the management of imports may be difficult because of the fragmented residential furniture supply chain. It was noted that we are missing good bench scale tests that can evaluate the flammability potentials of materials and mock-up of furniture systems that are predictive of full scale, finished furniture. It was noted that the NIST research work could have this test available within a year, and that this should be supported.

The strongest discussion centered on the success of barrier fabrics in controlling flammability, and the production of upholstered furniture with barriers built in should therefore to be encouraged. This would reduce the need to rely on chemical control, and the lengthy studies and debates over their health hazards. It was noted that the manufacturer partnering in the current research is using barrier materials in their products, and that these products are currently available in the marketplace. To this end, it was strongly recommended that a bench scale test that addressed open flame and smoldering be developed and implemented.

Participants noted that the current research reveals two very important facts:

1. From a VOC standpoint, the numbers are reassuringly low.
2. Barriers work and are available for use.

There was strong support for an ongoing research and demonstration process that has, as its core principle, the convergence between complex chemical analysis and material design that tries very hard to reflect the way people actually live, and how we can protect those people from unintended hazards. Continuing research on the use of barriers of varying material composition, their efficacy and costs of use should be encouraged as well as the support of the NIST bench scale test methods for measuring flammability of materials and mock ups that could be predictive for full scale furniture. A bench scale /predictive test could be effective for a wide range of materials and mock ups and could potentially lower cost of testing and verification, leading to protection.