TECHNICAL BRIEF

Chemical Insights
An Institute of Underwriters Laboratories Inc.

Chemical Releases from Burning Upholstered Furniture and Electronics

Introduction

Newer homes today are prone to burn faster due to open floor plans and the use of complex mixtures of materials and finishes. When materials burn, they can produce lethal gases and many people die from smoke inhalation, not burns. Synthetic materials are prolific throughout most modern homes within furnishings, toys, appliances and electronics. During a fire, these materials can burn hotter and faster and result in more toxic smoke than natural materials. Household products like upholstered furniture are prone to burn when they are in contact with a fire source. Furniture that contains polyurethane foam as padding can act as a fuel source for a fire. Current statistics report that of fires that cause death, residential upholstered furniture is the leading item to ignite in a home. Recent data shows when residential upholstered furniture was the first item to catch fire, it resulted in 17% of home deaths. Electronics, such as televisions and laptops, are also prolific in homes today and they may also be potential ignition sources.

Consumers are currently concerned about chemical exposure and the flammability potential of household products. Chemicals of concern, such as volatile organic compounds (VOCs), flame retardants, PFAS (per- and polyfluoroalkyl substances), phthalates, antimicrobials, and others, are associated with the construction of these materials and are available for release into the indoor environment. Further concern is growing about the combustion gases that may be released from these products during a fire. What might home occupants be exposed to as they escape from a fire or reenter their homes after a fire? And what might first responders be exposed to when addressing a fire situation?

Chemical Insights conducted a study called "Human Health in the Built Environment: A Study of Chemical Exposure Risk and Flammability of Upholstered Furniture and Consumer Electronics," where VOC and flame retardant exposure risks and flammability performance of selected furniture and electronics were assessed. As a part of the study, upholstered chairs and electronics studied were assessed for their flammability performance following an established methodology using large-scale open calorimeters and a burn room. During the flammability assessment, volatile chemical hazards emitted during the open flame burns were monitored. The studied chairs had cushions made of polyurethane foam with different flame retardant technologies applied. These included no flame retardants (NFR); an organophosphate chemical FR (OPFR) added to the foam; a reactive chemical FR (RFR) added to the foam; and no FR used, but with a barrier material applied between the foam and the cover fabric (BNFR). All other chair construction materials were the same. Electronic devices, specifically televisions and laptops, were studied for comparison to the furniture. Since the VOC sampling method had not been optimized for the burn settings, much higher concentrations than reported are expected.

Most Commonly Emitting VOCs From Burns

Overall, there were 334 individual VOCs detected from the chair burns and 109 VOCs from the electronic burns; all together 399 chemicals were detected. VOCs that were detected from more than half of the chair burns (detect frequency > 50%) are listed in Table 1; frequencies of those VOCs detected from electronics are also compared in Table 1. Toluene and formaldehyde were detected from all chair burns, and toluene was detected from all electronics burns. The most commonly emitting VOCs were mainly aromatic hydrocarbons and aldehydes.

TABLE 1. VOCS WITH DETECT FREQUENCIES ABOVE 50% FOR CHAIR OPEN FLAME TESTS, COMPARED TO THOSE FOR ELECTRONICS.

CAS	Chemical	Chairs (n=16)	Electronics (n=4)
108-88-3	Toluene (Methylbenzene)	100%	100%
50-00-0	Formaldehyde	100%	75%
100-52-7	Benzaldehyde	88%	100%
71-43-2	Benzene	88%	75%
100-42-5	Styrene	81%	100%
75-07-0	Acetaldehyde	81%	75%
98-86-2	Acetophenone (Ethanone, 1-phenyl)	63%	75%
124-19-6	Nonyl aldehyde (Nonanal)	63%	100%
536-74-3	Phenylethyne	56%	50%
91-20-3	Naphthalene	56%	50%

Highest Emitting VOCs From Burns

The average total VOC (TVOC) concentration for chair burn emissions was 1.0×10^4 µg/m³; that for electronics was 2.5×10^3 µg/m³. These values are estimated to be low since sampling methodologies had not been adapted for the high levels of VOCs. As a reference, TVOC emissions for the same chairs and electronics during normal residential use were measured at 70 – 400 µg/m³.

The top 20 most emitting VOCs (i.e., VOCs with the highest detect concentrations) are listed in Table 2. The top 20 emitting VOCs from chairs mostly included esters, hydrocarbons, very volatile organic compounds (VVOCs), fatty acids, aldehydes, and aromatics. The concentration levels for the top three emitting VOCs from chairs were above 10^4 µg/m³ and all top 20 chemicals had concentrations above 500 µg/m³. Electronic devices tended to have a different VOC emission profile than furniture due to the different materials making up the products. Compared to chair burns, electronic burns emitted more hydrocarbons, and the rest of the top 20 emitting chemicals included esters, VVOCs, aldehydes, and aromatics. Emission levels from electronics were generally lower, which ranged from 2100 µg/m³ to 80 µg/m³ for the top 20 chemicals. There were five chemicals listed as top 20 emitting chemicals for both chairs and electronics, which were benzene, acetaldehyde, styrene, toluene and formaldehyde.

TABLE 2. TOP 20 VOCS WITH HIGHEST EMISSION LEVELS ACROSS ALL CHAIR TYPES AS WELL AS FROM ELECTRONICS.

Chairs		Electronics	
CAS	**Chemical**	**CAS**	**Chemical**
103-23-1	Hexanedioic acid, bis(2-ethylhexyl) ester	100-42-5	Styrene
71-43-2	Benzene	110-54-3	Hexane
67-64-1	Acetone - VVOC	71-43-2	Benzene
57-10-3	Hexadecanoic acid	96-14-0	Pentane, 3-methyl - VVOC
75-07-0	Acetaldehyde	64-19-7	Acetic acid - VVOC
100-42-5	Styrene	108-88-3	Toluene (Methylbenzene)
91-20-3	Naphthalene	616-38-6	Carbonic acid, dimethyl ester
108-05-4	Vinyl acetate (Acetic acid ethenyl ester) - VVOC	75-07-0	Acetaldehyde
108-88-3	Toluene (Methylbenzene)	100-41-4	Benzene, ethyl
50-00-0	Formaldehyde	96-37-7	Cyclopentane, methyl
100-47-0	Benzonitrile	2051-30-1	Octane, 2,6-dimethyl
112-05-0	Nonanoic acid	541-05-9	Cyclotrisiloxane, hexamethyl
334-48-5	Decanoic acid	591-76-4	Hexane, 2-methyl
124-26-5	Octadecanamide	62238-14-6	Decane, 2,3,8-trimethyl
1454-84-8	1-Nonadecanol	75-05-8	Acetonitrile - VVOC
124-19-6	Nonyl aldehyde (Nonanal)	540-88-5	Acetic acid, 1,1-dimethylethyl ester (tert-Butyl acetate)
536-74-3	Phenylethyne	50-00-0	Formaldehyde
2595-97-3	D-Allose	589-34-4	Hexane, 3-methyl
544-63-8	Tetradecanoic acid	112-31-2	Decanal
84-66-2	Diethyl phthalate	13475-82-6	Heptane, 2,2,4,6,6-pentamethyl

a 2211 Newmarket Parkway, Suite 106, Marietta, Georgia 30067 w chemicalinsights.org e chemicalsafety@ul.org

Chemicals of Concern Emitted From Burns

Chemicals of concern are those listed in health-related regulation and guidance documents, including International Agency for Research on Cancer (IARC) monographs,[1] California Office of Environmental Health Hazard Assessment (OEHHA) Proposition 65 (Prop65),[2] OEHHA chronic reference exposure levels (RELs),[3] the American Conference of Governmental Industrial Hygienists (ACGIH®) threshold limit values (TLVs®),[4] and the German Ausschuss zur gesundheitlichen Bewertung von Bauprodukten (AgBB) evaluation procedure.[5] There were 85 and 36 chemicals of concern detected from burn tests for chairs and electronics separately. The top 20 most frequently detected chemicals of concern from chair burns are listed in Table 3, along with associated health hazards and whether they are listed in each reference document.

TABLE 3. TOP 20 CHEMICALS OF CONCERN THAT WERE MOST FREQUENTLY DETECTED FROM CHAIR BURNS.

Bold CAS number indicates this chemical was also in top 20 chemicals of concern list for electronics burns. "X" indicates a specific chemical is listed in reference documents with a recommended concentration limit and "**X**" indicates the measured concentration from burns exceeded the recommended level.

CAS	Chemical	IARC	Prop65	AgBB	REL	TLV®
108-88-3	Toluene (Methylbenzene)	3	developmental	X	X	X
50-00-0	Formaldehyde	1	cancer	**X**	**X**	**X**
71-43-2	Benzene	1	cancer		**X**	
100-52-7	Benzaldehyde			X		
100-42-5	Styrene	2B		**X**	X	X
75-07-0	Acetaldehyde	2B	cancer	**X**	**X**	X
124-19-6	Nonyl aldehyde (Nonanal)			X		
98-86-2	Acetophenone (Ethanone, 1-phenyl)			X		X
536-74-3	Phenylethyne			**X**		
91-20-3	Naphthalene	2B	cancer	**X**	**X**	X
112-31-2	Decanal			X		
108-05-4	Vinyl acetate (Acetic acid ethenyl ester) - VVOC	2B			**X**	
116-09-6	2-Propanone, 1-hydroxy			X		
66-25-1	Hexanal			X		
541-02-6	Cyclopentasiloxane, decamethyl			X		
108-95-2	Phenol	3		**X**	X	X
98-01-1	Furfural (2-Furaldehyde)	3		**X**		X
100-41-4	Benzene, ethyl	2B	cancer	X	X	X
78-93-3	2-Butanone (Methyl ethyl ketone, MEK)			X	X	X
80-62-6	Methyl methacrylate (2-Propenoic acid, 2-methyl-, methyl ester)	3		X		X

Note: IARC classifications: 1- carcinogenic to humans; 2B- possibly carcinogenic to humans; 3- not classifiable as to its carcinogenicity to humans.

There are seven chemicals listed as carcinogens or possible carcinogens, all of which had burn tests with concentrations exceeding recommended limits from reference documents, except ethylbenzene. There were 12 out of 20 chemicals of concern overlapped for both chair and electronic burns; other chemicals of concern from electronic burns included octamethylcyclotetrasiloxane, octanal, and heptane, which were less frequently detected from chair burns. For chemicals of concern with fewer detect frequencies (i.e., not listed in Table 3), their concentrations could also exceed reference levels. These chemicals included phthalic anhydride, acetone, 2-propenenitrile, caprolactam, 2-butenal from chairs and hexane from electronics among which, 2-propenenitrile is a possible carcinogen.

As shown in Table 1, among the 10 individual VOCs listed as frequently detected chemicals, formaldehyde and benzene are human carcinogens and styrene, acetaldehyde, and naphthalene are possible human carcinogens. Proposition 65 lists formaldehyde, benzene, acetaldehyde, and naphthalene as a cause of cancer, and toluene as a cause of developmental harm.

Flame Retardant Emissions From Burns

For chairs with added flame retardants, the detect frequencies of each measured flame retardant during burn are listed in Table 4. The OPFR chair that contains organophosphate flame retardants had a detect frequency of no less than 50% for all analyzed flame retardants. Flame retardant concentrations measured in the burn emissions were over three orders of magnitude higher than those detected in air during normal chair use.

TABLE 4. DETECT FREQUENCY OF FLAME RETARTDANTS FROM CHAIR BURNS

Chair type	OPFR (n=6)	RFR (n=7)
Tris (2-chloroethyl) phosphate (TCEP)	50%	43%
Tris (1-chloro-2-propyl) phosphate (TCPP)	67%	43%
Tris(1,3-dichloro-2-propyl) phosphate (TDCPP)	58%*	43%
Triphenyl phosphate (TPhP)	100%*	43%
Tris (4-butylphenyl) phosphate (TBPP)	100%**	100%**
(4-Tert-butylphenyl) diphenyl phosphate (4tBPDPP)	100%	
(2,4-Di-tert-butylphenyl) diphenyl phosphate (B4tBPPP)	100%	
Tris(4-tert-butylphenyl) phosphate (T4tBPP)	100%	

Note: * n=12; ** n=4; blank indicates not measured or not detected.

References

1. IARC. IARC Monographs, Volumes 1–122. World Health Organization: Geneva, Switzerland 2018.
2. OEHHA. PROPOSITION 65 SAFE HARBOR LEVELS: No Significant Risk Levels for Carcinogens and Maximum Allowable Dose Levels for Chemicals Causing Reproductive Toxicity. Office of Environmental Health Hazard Assessment: Sacramento, CA 2012.
3. OEHHA. Appendix D. Individual Acute, 8-Hour, and Chronic Reference Exposure Level Summaries. Office of Environmental Health Hazard Assessment: Sacramento, CA 2014.
4. ACGIH. TLVs® and BEIs®: Threshold Limit Values for Chemical Substances and Physical Agents Biological Exposure Indices.; Signature Publications: Cincinnati, OH, 2018.
5. AgBB. Health-Related Evaluation Procedure for Volatile Organic Compounds Emissions (VVOC, VOC and SVOC) from Building Products 1. February 1, 2015.

a 2211 Newmarket Parkway, Suite 106, Marietta, Georgia 30067 **w** chemicalinsights.org **e** chemicalinsights@ul.org