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Healthy Environments: Strategies for Avoiding Flame Retardants in the Built Environment

Sparking a conversation about opportunities to design healthier building environments

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Healthy Environments: Sources of Flame Retardants in Buildings and Available Alternatives

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PURPOSE STATEMENT

This paper was prepared by Perkins+Will as part of a larger effort to promote health in the built environment. Indoor environments commonly have higher levels of pollutants,[1] and architects and designers may frequently have the opportunity to help limit this exposure. Flame retardants are chemicals added to products to delay or prevent ignition and the spread of fire. The scientific community long ago identified flame retardants as ubiquitous pollutants in the built environment, and has linked them with a range of adverse health effects including cancer, endocrine disruption, and neurodevelopmental problems.[2] While flame retardants have been identified as a public health concern for decades, the regulatory and market drivers that encourage their use have only recently begun to change. This paper reviews the state of the science on flame retardants, their evolving market and regulatory contexts, and identifies both new and existing opportunities to design healthier buildings without compromising fire safety or code compliance.

"Don't you owe people an apology?"

California Sen. Barbara Boxer.
The Tribune series prompted two Senate hearings, including one in which senators assailed executives from the world's largest manufacturers of flame retardants.
Chicago Tribune, May 2014

EXECUTIVE SUMMARY

It is important for architects and interior designers to be familiar with flame retardants because many are persistent, bioaccumulative, and/or toxic, and the building products that incorporate them can be avoided in many cases. For decades, flame retardants have been added to materials to meet specific flammability code requirements in developed countries; as a result, they are ubiquitous in globally distributed products, and their waste and residue is evident in air and water currents and in the food chain.[3] Flame retardants are associated with and suspected contributors to diseases that cost hundreds of billions of dollars annually in the US alone,[4] and incalculable suffering around the world.

To protect the occupants of a building, this paper recommends that designers not specify products with added flame retardants whenever possible. When this is not possible, this paper provides simple guidelines to help determine which flame retardants are more likely to be problematic. This paper strongly recommends that designers not specify products containing halogenated flame retardants, and in the absence of comprehensive health and exposure data, avoid those containing organophosphate flame retardants. Instead, when possible, this paper recommends the selection of products containing non-volatile mineral/salt/amine compounds wherever added flame retardance is required.

This paper provides a list of 193 flame retardants, including 31 discovered in building materials and household products, 51 discovered in the indoor environment, and 33 discovered in human blood, milk, and tissues. This list can help specifiers identify which products should be subjected to extra scrutiny during the design and construction process. The list also helps to identify potential gaps in the current understanding of the sources and paths of chemical exposure.

Building and flammability codes help protect buildings and occupants, but can also drive the use of flame retardants. For each material, this paper outlines current flammability requirements (see Appendix 5) and provides examples of alternatives that avoid the use of problematic flame retardants. The intent of this paper is to dispel the notion that harmful flame retardants are always required, and to provide information to facilitate specifying alternate products that meet the most widely used building and fire codes in most jurisdictions.

> "For something like PBDE, a persistent pollutant, the cost will be borne by at least the next generation or more. After it's already out there, it's really hard to put the genie back in the bottle."
>
> **Bruce Lanphear**, Professor of Health Sciences at Simon Fraser University in British Columbia.
> *Huffington Post, June 3rd, 2014*

FUNCTION AND USES OF FLAME RETARDANT CHEMICALS

Flame retardants are chemicals added to products to delay or prevent ignition and the spread of fire. Historically, they have been used primarily in wood and textiles. The increasing use of flammable materials such as plastics in building and consumer products has been met with an increasing use of flame retardant chemicals. A partial list of products and materials that can contain flame retardants is included below.

PLASTICS

- appliance and consumer product cases
- baby products
- cable jackets
- computers cases
- couches (polyurethane foam with a synthetic fabric covering)
- mattresses (polyurethane foam with a synthetic fabric covering)
- monitor cases
- plastic toys
- polyisocyanurate/polyurethane insulation
- polystyrene insulation
- Styrofoam products
- textiles (most interior finishes and furnishings are synthetic/plastic)
- TV cases
- upholstery foam (polyurethane)
- upholstery textiles (most but not all are synthetic/plastic)

NON-PLASTICS

- textiles (natural textiles such as cotton)
- wood and wood products

EXPOSURE TO FLAME RETARDANTS

Humans are exposed to flame retardants from a variety of sources. Biomonitoring studies have found flame retardants in the blood and body tissues of nearly all Americans tested, with the highest levels in young children.[5] In the US, the bulk of our exposure likely occurs indoors, in part because that is where we spend most of our time.[6] The chemicals migrate from products and stick to dust,[7] which gets on our hands and into our mouths.[8] Adults might ingest the dust on their hands while eating popcorn or pizza. For infants, ingesting dust through frequent hand-to-mouth behavior is thought to be responsible for their much higher body burdens. Regular hand washing can reduce this exposure, but not eliminate it.[9] The best solution is to avoid consumer products, building products, and finishes that contain flame retardants, to the extent possible.

Diet is thought to be a secondary source of exposure in most cases.[10] The flame retardants emitted from factories,[11] washed down drains,[12] and leached from landfills[13] can accumulate in plants[14] and animals[15] that ultimately become our food. Exposure in utero and from breastfeeding are especially important since fetuses and infants are the most vulnerable to many of the harmful effects. Avoiding building products and finishes containing flame retardants could also eventually decrease dietary exposure, though the benefit would be delayed and diffused.

> Diabetes, neurobehavioral and developmental disorders, cancer, reproductive health effects, and alteration in thyroid function have all been associated with exposure to flame retardants.

HEALTH EFFECTS AND COSTS OF FLAME RETARDANTS

Diabetes, neurobehavioral and developmental disorders, cancer, reproductive health effects, and alteration in thyroid function have all been associated with exposure to flame retardants.[16] Except in the well-studied case of IQ lost due to PBDE exposure, the complexity of these diseases makes it impossible to estimate what fraction of the cases or costs could be ascribed to specific chemical exposures. Nevertheless, the huge annual costs for a few diseases have been included to help provide some understanding of the magnitude of the potential impacts.

Neurodevelopmental Effects

- Flame retardants are linked to hyperactivity, and decreased attention, motor functioning, and IQ.[17]
- The estimated cost of IQ lost to the flame retardant PBDE exposure exceeds $10 billion annually.[18]

Endocrine Disruption

- Flame retardants are linked to obesity, diabetes, early puberty,[19] and longer times to become pregnant.[20]
- The estimated cost of diagnosed diabetes from all causes was $245 billion in 2012.[21] No estimate has yet been made for the cost of diabetes caused by flame retardants.

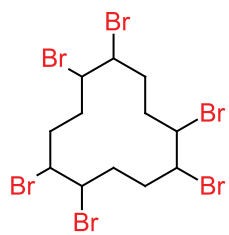
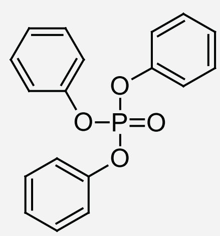
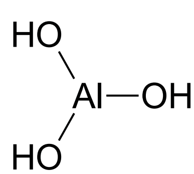
Cancer

- The estimated cost of cancer from all causes was $216.6 billion in 2009.[22] No estimate has yet been made for the cost of cancers caused by flame retardants.

CATEGORIZING FLAME RETARDANTS

Flame retardants can be divided into three broad categories based on their chemical composition: halogenated, organophosphate, and mineral/salt/amine flame retardants. These distinctions are important because they can be used to predict which chemicals are more likely to have ecological and health effects, in the absence of specific data on individual chemicals.[23] The discussion below is based on currently known and available data.

TABLE 1. Examples of Flame Retardant Chemicals

Type	Example Structure	Example
Halogenated Flame Retardants *Highest concern*		One exampe is HBCD, which is found in polystyrene insulation, electronics cases, and textiles, as well as in house dust and people.
Organophosphate Flame Retardants *High concern*		One example is TPP, which is found in electronics cases, upholstered furniture, house dust, and people.
Mineral Flame Retardants *Lower concern*		One example is aluminum hydroxide, which is found in halogen-free cable jackets.

Halogenated flame retardants contain a halogen—chlorine or bromine—bound to carbon, and are the most concerning class of flame retardants for a number of reasons. Many are semi-volatile, meaning that they can move out of products and into air and dust, and then enter our bodies.[24] Because halogens are rarely found in nature in this form, neither our bodies nor microbes are able to break them down efficiently, making many of them highly persistent. This persistence, combined with a tendency to be stored in fat cells, results in the bioaccumulation of these chemicals, meaning that they increase in concentration as they move up the food chain and into our bodies.[25] Some of these flame retardants have been associated with adverse health effects, such as cancer and neurotoxicity.[26] Finally, their presence in plastic often prevents recycling or responsible disposal as they can form extremely toxic halogenated dioxins when burned,[27] and leach out of landfills when buried.[28] Because both halogenated flame retardants and the dioxins created when they are burned are persistent, they can be expected to be distributed widely across the globe regardless of where they are produced, used, and disposed.[29]

This problem of halogens and dioxin formation in burning has several ramifications that are even more significant than those associated with incineration disposal. Dioxin production is worse under uncontrolled burn situations such as landfill fires, e-waste processing, and structural fires. Dioxin generation in structural fires is particularly important since the chemicals added to slow fire spread in buildings (and so presumably to help firefighters) are creating highly potent carcinogens that may be contributing to high observed rates of cancers and other diseases in those same fire fighters.[30]

Organophosphate flame retardants contain phosphate groups bound to carbon. These chemicals can have serious health effects such as endocrine disruption[31] and neurotoxicity,[32] although the evidence to date suggests they tend to be less persistent and bioaccumulative than halogenated flame retardants. Many are also semi-volatile, which as described above, enables the chemicals to enter our bodies via evaporation out of products and into the air and dust. Unfortunately, their impact on health is less understood because they have not been as thoroughly studied as halogenated flame retardants. For this reason, organophosphate flame retardants are sometimes proposed as a safe replacement option. However, this practice of moving from a known to an unknown hazard can lead to regrettable substitution, where the new product is as bad, or even worse than the old.

Mineral/salt/amine flame retardants is a broad category that contains flame retardants that are not halogenated or organophosphate. These compounds can contain boron, aluminum, inorganic phosphorus (not bound to carbon), nitrogen, calcium, and magnesium. Scientific studies to date suggest that these chemicals tend to be far less volatile than the other classes of flame retardants, which makes them less likely to migrate out of products. While many are persistent, it is believed that our bodies are much less able to absorb and store them, so they typically do not bioaccumulate. The tradeoff is that chemicals in this category often have weaker flame retardant behavior or can be more difficult to incorporate into plastics.

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A LIST OF FLAME RETARDANTS IN THE BUILT ENVIRONMENT

This paper includes a list of 193 flame retardants in Appendix 1, compiled from three published lists of flame retardants,[33] as well as scientific, government, and industry literature.[34] While every effort has been made to be as comprehensive as possible, the list is likely incomplete. Because of the secrecy that surrounds the use of these chemicals, they can be included in products for years before scientists discover their use and alert the public to their presence. It is likely that flame retardants are present in many additional products that have not yet been studied. These lists are based on currently available information.

The compiled list was used to guide the collection of available papers on the potential exposure in the built environment and human body burden and of each chemical. This was done by searching the published scientific literature for measurements of products in buildings, the air and dust in buildings, and human exposure (blood, milk, tissue, urine, hand wipes). Lists of flame retardants in each of these categories (products, buildings, and people) are included in Appendices 2-4.

The research shows that 31 flame retardants have been discovered in building and household products, 51 discovered in the indoor dust or air, and 33 have been discovered in people. The overlap between these lists is striking, as more than half of the flame retardants identified in products have also been found in the indoor environment and people's bodies. This strongly suggests that our body burden reflects our indoor environment, and that building products contribute to this exposure.

Many of the remaining chemicals found in people are so new that scientists have yet to identify their potential sources. Given the frequent lack of transparency in product formulations, these lists provide a framework for designers to understand what substances could potentially be found within building products and finishes, and alert them to ask questions about the composition of the products they specify.

The research shows that 31 flame retardants have been discovered in building and household products, 51 discovered in the indoor dust or air, and 33 have been discovered in people.

REGULATORY DRIVERS FOR THE USE OF FLAME RETARDANTS IN BUILDINGS

Building regulations exist primarily to mitigate risks associated with events such as fires and structural failures that threaten the health and safety of occupants. To this end, materials vulnerable to fire or heat are required to be protected or treated so they pose less of a risk to the structure or occupants. These requirements take the form of flammability tests, which might measure the distance the flame has progressed or the amount of smoke generated or heat released. Since the inclusion of flame retardant chemicals can be a cost-effective way to pass a test, these regulations have the unintended consequence of driving the use of harmful flame retardants in building products, finishes, and consumer products.

These drivers, detailed in Appendix 5, include building and fire codes, California's furniture regulations, and retailer requirements. The seven classes of materials subject to these codes, regulations, and requirements are insulation, furniture, textiles, carpet, steel, electronics, and wood. All of these materials can include flame retardants, but do not have to. For example, there are products in each of these categories that meet code requirements without the use of harmful flame retardants by being inherently fireproof, by substituting a safer alternative flame retardant, or through redesign.

"Changing standards is way more important than banning chemicals. Banning chemicals raises awareness and is useful, but you really want to look at the whole problem. Why move from one toxic chemical to another chemical that may or may not be toxic?"

Arlene Blum, PhD, Biophysical Chemist.
San Jose Mercury News, March 19th, 2014

FIGURE 1. Commonly Flame Retarded Products in Buildings

GUIDELINES TO SELECTING MATERIALS WITHOUT HARMFUL FLAME RETARDANTS

	Item	Are products without potentially harmful flame retardants available?
1a	Polyisocyanurate Foam Boards Insulation	Rare or Unavailable*
1b	Spray Polyurethane Foam (SPF) Insulation	Rare or Unavailable*
1c	Polystyrene Foam Boards (XPS and EPS) Insulation	Rare or Unavailable*
2	Upholstered Furniture	Uncommon
3	Curtains, and Textile Wall and Ceiling Covers	Common
4	Padding Under Broadloom Carpet	Uncommon
5	Steel Protected with Intumescent Paint	Common
6a	Televisions and Other Electronics with Plastic Cases	Uncommon
6b	Computers with Plastic Cases	Uncommon

** Alternatives to plastic foam insulation that do not include potentially harmful flame retardants are described in the following text.*

GUIDELINES TO SELECTING MATERIALS WITHOUT HARMFUL FLAME RETARDANTS (cont.)

1. Insulation

Polystyrene and polyurethane/polyisocyanurate (polyiso) foam insulations are used extensively in buildings due to their high insulation value, water resistance, and low cost. Because they are composed of foamed plastic, these materials can burn or melt when exposed to fire. Building codes address this flammability by requiring both:

1. a fire-resistive barrier such as gypsum board between insulation and occupied spaces and
2. a minimum flammability rating for the insulation

To meet this second requirement, manufacturers add halogenated flame retardants to the vast majority of foam plastic insulation products (except for use in Norway and Sweden, which prohibit this addition[35]). Listed below (Table 2) are insulations containing potentially hazardous flame retardants and suggested alternatives. A more detailed comparison of flame retardants is available at the **Safer Insulation Solution website**.[36]

Fungus-based insulation is not yet commercially available, but is one product that may offer a promising alternative to synthetic foams in the future. It is advertised as meeting flammability requirements without the use of flame retardant chemicals.

2. Upholstered Furniture

In the US, there are primarily three levels of furniture flammability requirements. They are listed here in order of increasing stringency:

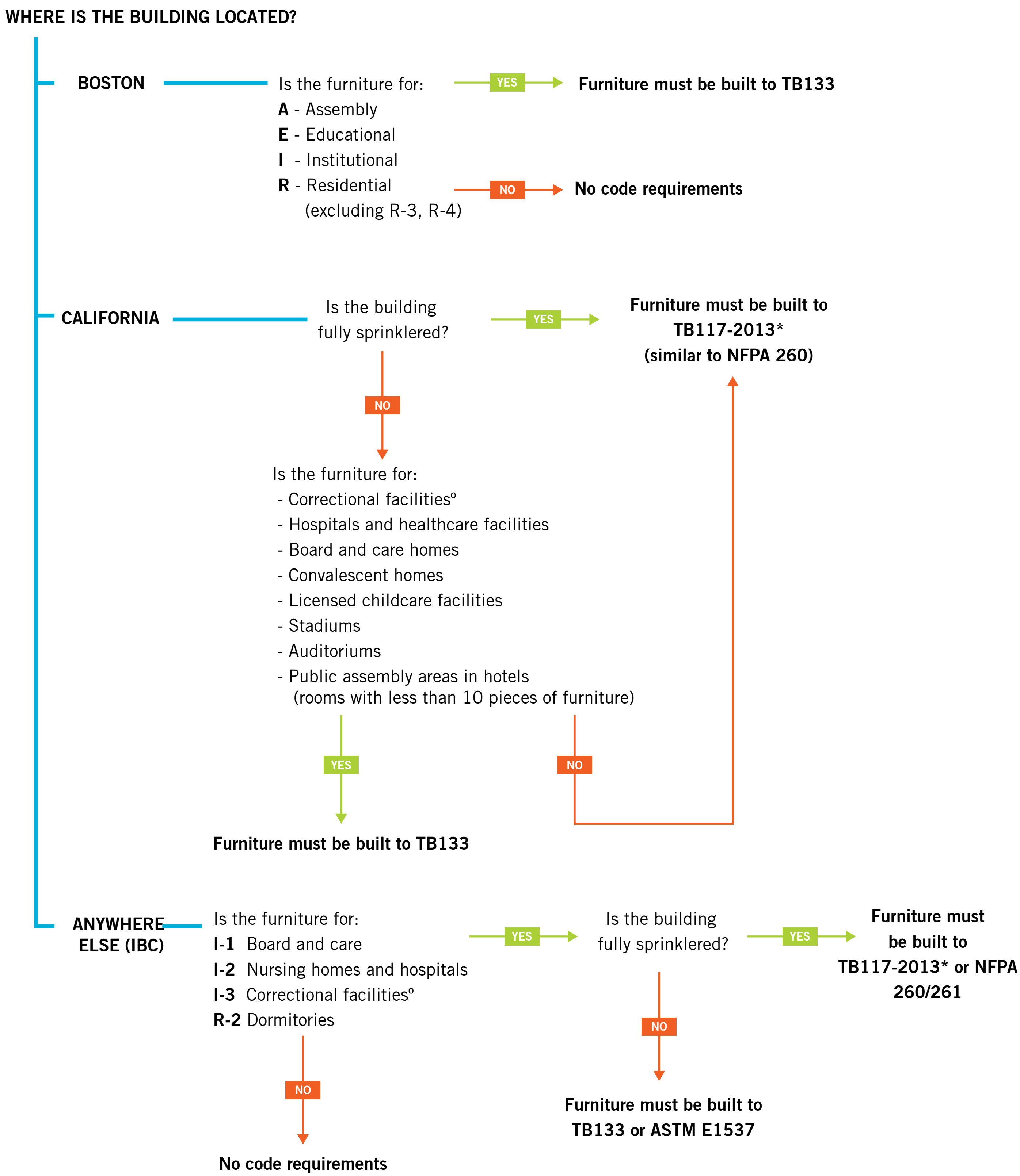
- unregulated
- California TB117-2013
- California TB133

Numerous manufacturers market furniture to meet any of these flammability requirements without using flame retardants, but the default is often to include flame retardant chemicals in all levels. The location and type of building will determine which level of flammability is required, as governed by a number of overlapping regulations.[39] For ease of navigation, the primary substance of these regulations have been distilled into a flow chart (Figure 2). For clarity, this chart omits some details and exceptions, so please consult the actual text of the appropriate regulations in each case. Appendix 5 contains links to the relevant sections. Local fire marshals may also impose additional requirements.

TABLE 2. Preferred Alternatives to Commonly Used Insulations

Material / Location	Preferred Insulation	Typically Used Insulation
rigid wall insulation	mineral wool boardstock	polystyrene panels (XPS and EPS)[37]
wall/ceiling cavities	fiberglass bats, mineral wool bats, or spray-in fiberglass	spray polyurethane foam (SPF)
structural/metal insulated panels	mineral wool core panels	foam core panels
commercial/industrial roofs	mineral wool panels polyisocyanurate panels using a non-halogenated flame retardant[38]	other polyisocyanurate panels
below grade or below slab	foamglass, rigid mineral wool, or fiberglass	polystyrene panels (XPS and EPS), polyisocyanurate panels, and spray polyurethane foam (SPF)

FIGURE 2. Furniture Flammability Requirements by Location



** Requirement for TB117-2013 can also be met by TB133*
° Furniture in correctional facilities must always meet TB133, regardless of sprinklers

GUIDELINES TO SELECTING MATERIALS WITHOUT HARMFUL FLAME RETARDANTS (CONT.)

2. Upholstered Furniture (cont.)

A list of manufacturers that market furniture meeting TB117-2013 without flame retardants is available on the website of the **Center for Environmental Health**.

A list of manufacturers that market furniture meeting TB133 without flame retardants is available on the **Perkins+Will Transparency Site.**

The complexity of furniture regulations is best understood with some historical context. Flame retardants have been added to upholstered furniture to meet California's TB117 and TB133 standards since they went into effect in 1975 and 1992, respectively. The state of California updated its regulations in 2013 after it was presented with evidence showing that the flame retardants commonly used in upholstered furniture provided little fire safety benefit and some had the potential to cause adverse health effects.[40] TB117 was changed to focus on ignition that begins on the surface of the furniture, rather than at the foam interior. Beginning January 1, 2014, this change to TB117 allowed furniture to be built to resist smoldering ignition without using chemical flame retardants. This update also more closely aligned California's furniture regulations with those of the International Fire Code, which serves as a model code in the US[41] as well as other countries (see Table of Regulatory Drivers). Because the revised TB117 did not ban the use of flame retardants, another regulation was subsequently enacted to require furniture manufacturers to label products to specify the presence or absence of flame retardant chemicals in fabric and upholstery.[42] Non-foam plastic components will be exempt from reporting. The labeling requirement will go into effect January 2015.

3. Textiles

The flammability of textiles is regulated when they are used to cover furniture, windows, walls, or ceilings. Each of these applications is covered by separate sections of the International Building or Fire Code, and each application can involve separate flammability tests (see Appendix 5). Textiles that meet the requirements of all of these applications are available with and without harmful flame retardants. Because there are many ways to treat a fabric to pass the required tests, care is required when specifying flame retardant-free fabrics.

Textiles are commonly grouped according to the durability of their flammability treatment; this grouping can provide insight into their chemical makeup. The categories are as follows:

- Inherently flame retardant (IFR) fabric should withstand any number of washes
- Durable flame retardant (DFR) treatment should withstand any number of washes
- Semi-durable flame retardant treatment should withstand 5-15 washes
- Non-durable flame retardant treatment can be removed by a single wash

The inherently flame retardant fabrics are less likely to include harmful flame retardants. Many are polyesters that have been co-polymerized with an organophosphate flame retardant. The flame retardant is chemically reacted into the polyester threads and unlikely to migrate out in significant quantities, which is preferable to flame retardants that are soaked in or back-coated onto fabric. Cellulosic textiles such as cotton are commonly treated to achieve durable flame retardancy by coating the fibers with a polymer containing phosphorus and urea, which are of low concern. Other methods of achieving durable and semi-durable fabric can involve halogenated flame retardants, which should be avoided when possible. Many non-durable flame retardants are water-soluble mineral salts (low concern), but some treatments include halogenated or organophosphate flame retardants (high concern).

4. Carpet

Though carpets and carpet tiles are required to pass one or two flammability tests,[43] research suggests they may contain mineral flame retardants (if any), which are of low concern.[44] The padding used under broadloom carpeting is not subject to flammability tests; however, padding often contains harmful flame retardants because the most common "rebond" product is made from recycled polyurethane foam from furniture, which is often loaded with high levels of halogenated flame retardants. Prime or virgin polyurethane foam padding is more likely to be available without flame retardants.

5. Steel

Structural steel elements must be protected from fire because heat can weaken the metal to the point where it can no longer support its load. Steel can be protected by either encasing it in concrete, surrounding it with gypsum, coating with a fibrous or cementitious spray-applied fire-resistive material, or coating it with intumescent paint. Intumescent paint is typically reserved for steel elements exposed in occupied spaces because it is more attractive and more expensive than other methods. Of all the methods to protect steel from fire, only intumescent paint has been identified as a product containing harmful flame retardants, in the form of chlorinated paraffins. Formulations free of chlorinated paraffins are available with fire ratings of at least three hours.

6. Electronics

The plastic housings for televisions and other electronics in the US are commonly built to achieve a V-0 rating in the UL 94 flammability test, which requires the plastic to stop burning within ten seconds after a flame is removed. This requirement is commonly met through the use of halogenated flame retardants, but can be achieved without them. A certification for electronics is available from TCO Development that prohibits plastic parts weighing more than 25 grams from containing >0.1% halogenated flame retardants. While a threshold of 0% would have some advantages, the current threshold facilitates the use of recycled plastic and is far below the 12% commonly used for flame retardancy. The TCO certification similarly limits a number of non-halogenated flame retardants with adverse health effects.

The database at **TCO Development** currently lists more than 3100 certified products in seven categories: displays, notebooks, tablets, smartphones, desktops, all-in-one PCs, and headsets. Independent of the TCO certification, Apple advertises that its products have been free of brominated flame retardants since 2008.[45] They do not specify if other high concern flame retardants are restricted.

Unlike the flame retardants used in plastic cases, the brominated flame retardant commonly used in circuit boards is chemically locked in. This eliminates exposure during use, but responsible disposal of these circuit boards is still a challenge. Some companies, including Apple, have switched to non-brominated flame retardants for their circuit boards.

7. Wood

Wood is used in buildings as both a structural element and a finish material. The published studies to date indicate that none of the flame retardants identified as commonly used in or on wood are believed to be of high concern.

- Heavy timber has an inherent ability to resist fires through charring. Dimensions are specified in building codes to ensure posts and beams retain adequate strength to support their load after some loss to fire.
- Fire-retardant-treated wood can often be used in place of noncombustible materials. It is commonly produced by pressure-treating lumber products with mineral/salt/amine flame retardants[46] such as guanylurea phosphate and boric acid, which are believed to be of relatively low concern.
- Wood used on walls and ceilings can be required to achieve various ASTM E84 ratings depending on the type of room and presence of sprinklers.[47] Topical wood treatments advertise the ability to provide the highest (class A) rating using mineral flame retardants, which are believed to be of relatively low concern.
- Millwork has no code-mandated flammability requirements.

STAKEHOLDER EDUCATION

Architects and designers can help to create healthy buildings by minimizing specification of products that contain flame retardants, but this is only the first step. The decisions made by the owners and occupants about what products to bring into the building post occupancy can have even greater impact on their degree of chemical exposure than those made by the building's designers. Awareness needs to be raised around ways to help improve indoor air quality and minimize chemical exposure.

There are already models for engagement in the sustainability arena. Post-construction building monitoring is done to track energy use, water quality, and some aspects of indoor environmental quality. Just as building occupants are educated in personal actions they can take to maximize the potential energy and water efficiency in buildings with innovative designs, they can also be educated about minimizing chemical exposure. As a result of changes in industry knowledge and client demand, architects and designers may become much more deeply involved in improvement to the indoor environment.

SUGGESTED EDUCATION STEPS

1. Engage client and design team at the project outset in a discussion regarding healthy materials and exposure to flame retardants.
2. Prioritize products that can be replaced with alternatives.
3. Where preferable alternatives are not applicable, prioritize those used in largest quantity and with most exposure to the interior environment for further research into minimizing their use.
4. Request information from product manufacturers regarding the types of flame retardants with the aim of encouraging greater transparency and material disclosure.
5. Include language in specifications to allow non-flame retardant products.
6. Share information with project teams, including contractors, on the importance of seeking out alternatives.
7. During the post-occupancy phases, offer to assist the client to implement a program to test the indoor environment for flame retardants.
8. Offer to assist the client in establishing a purchasing policy so that any new materials purchased after project completion meet the objectives of eliminating flame retardants from the indoor environment.

CONCLUSION

Fifty-one flame retardants have been found in indoor environments to date (see Appendix 3), and many of these have also been detected in people. It has taken decades of painstaking work for scientists to catalogue what is probably only some of the occupant exposure and the myriad health effects these chemicals can have. We have enough indicators of the hazard from these chemicals already to warrant precautionary action now to avoid harm. It is up to architects, designers, owners, and contractors to exercise precaution and work together to design and construct buildings with as few of these chemicals as possible. By specifying the products without harmful flame retardants that are available and by requesting manufacturers develop them when no alternatives exist, designers can drive the market toward healthier products.

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Michel Dedeo is a visiting scholar at the UC Berkeley Center for Green Chemistry, and received his Ph.D. in Chemistry from UC Berkeley. As Perkins+Will's inaugural science fellow, he helps develop strategies to curb the building community's reliance on products that contain hazardous chemicals. He has researched flame retardants and other chemicals of concern in the built environment with the Green Science Policy Institute and the Healthy Building Network.

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39 The flame retardant used in polystyrene (HBCD) is in the process of being banned in Europe and is being completely or largely replaced by a new polymeric halogenated flame retardant. The new chemical is manufactured under a number of trade names, including Emerald 3000. Exposure to the new flame retardant may be lower, though little to no health and exposure information is available. Since the replacement chemical is halogenated, disposal is still a problem.

40 Johns Mansville ENRGY 3.E polyiso panel uses a reactive organophosphate alternative to the halogenated TCPP. The identity of the new flame retardant is proprietary, so health effects are unknown. The potential for exposure to the new flame retardant is lower.

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46 Depending on location. See Appendix 5 / IBC sec. 804

47 Brominated flame retardants based on bromine bound to carbon are a subset of the class of halogenated flame retardants

Appendix 1:
Full List of Flame Retardants

APPENDIX 1 - FULL LIST OF FLAME RETARDANTS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People	Found in Indoor Env.	Found in Products
37853-59-1	BTBPE	BTBPE or TBPE	1,2-Bis(2,4,6-tribromophenoxy)ethane	HFR	YES	YES	YES
183658-27-7	EH-TBB	EH-TBB or TBB	Benzoic acid, 2,3,4,5-tetrabromo-, 2-ethylhexyl ester (firemaster 1 of 4)	HFR	YES	YES	YES
26040-51-7	BEH-TEBP	TBPH or BEHTBP or BEH-TEBP	1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, 1,2-bis(2-ethylhex-yl) ester (firemaster 1 of 4)	HFR	YES	YES	YES
84852-53-9	DBDPE	DBDPE or DeBDe-thane	Decabromodiphenylethane	HFR	YES	YES	YES
87-82-1	HBB	HBB	Benzene, 1,2,3,4,5,6-hexabromo-	HFR	YES	YES	
25495-98-1	HBCYD	HBCD or HBCYD	Cyclodecane, hexabromo-	HFR	YES	YES	YES
79-94-7	TBBPA	TBBPA	Phenol, 4,4'-(-methylethylidene)bis[2,6-dibromo-]	HFR	YES	YES	YES
13674-84-5	TCIPP	TCPP or TCIPP	Tris(1-chloro-2-propyl)phosphate	HFR	YES	YES	YES
19186-97-1	TTBNPP	TTBNPP	1-Propanol, 3-bromo-2,2-bis(bromomethyl)-, 1,1',1''-phosphate	HFR			
13674-87-8	TDCIPP	TDCPP or TDCIPP or TDCP	2-Propanol, 1,3-dichloro-, phosphate (3:1)	HFR	YES	YES	YES
1163-19-5		DecaBDE	Benzene, 1,1'-oxybis [2,3,4,5,6-penta-bromo- or Decabromodiphenyl ether	HFR		YES	YES
55205-38-4	TBBPA-BA	TBBPA-BA or TBBPA-BAcr	2-Propenoic acid, 1,1'-[(1-methylethyli-dene)bis(2,6-dibromo-4,1-phenylene)] ester	HFR			
4162-45-2	TBBPA-BHEE	TBBPA-BHEE	Ethanol, 2,2'-[(1-methylethylidene) bis[(2,6-dibromo-4,1-phenylene)oxy]] bis-	HFR			
37419-42-4	TBBPA-BP	TBBPA-BPrt or TBBPA-BP	Phenol, 4,4'-(1-methylethylidene) bis[2,6-dibromo-, dipropanoate (9CI)	HFR			
66710-97-2	TBBPA-BHEEBA	TBBPA-BHEEBA	2-Propenoic acid, 1,1'-[(1-methylethyli-dene)bis[(2,6-dibromo-4,1-phenylene) oxy-2,1-ethanediyl]] ester	HFR			
37853-61-5	TBBPA-BME	TBBPA-BME	Benzene, 1,1'-(1-methylethylidene) bis[3,5-dibromo-4-methoxy- [Di-Me-TBBPA is proba-bly not produced and used specifically as a flame retardant but may be a primary but very minor degradation product of TBBPA in the en-vironment, although results are inconclu-sive (Environment Agency, 2007- based on Nordic Screening, 2008).]	HFR			
25327-89-3	TBBPA-BAE	TBBPA-DAE or TBBPA-AE or TBBPA-BAE	Benzene, 1,1'-(1-methylethylidene) bis[3,5-dibromo-4-(2-propen-1-yloxy)-	HFR			
3072-84-2	TBBPA-BGE	TBBPA-DGE or TBBPA-BGE	Oxirane, 2,2'-[(1-methylethylidene) bis[(2,6-dibromo-4,1-phenylene) oxymethylene]]bis-	HFR			
21850-44-2	TBBPA-BDBPE	TBBPA-DBPE or TBBPA-bis or TBBPA-BDBPE	Benzene, 1,1'-(1-methylethylidene) bis[3,5-dibromo-4-(2,3-dibromopro-poxy)-	HFR		YES	YES

APPENDIX 1 - FULL LIST OF FLAME RETARDANTS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People	Found in Indoor Env.	Found in Products
1195978-93-8		Emerald 3000	benzene, ethenyl-, polymer with 1,3-butadiene, brominated	HFR			
88497-56-7			Benzene, ethenyl-, homopolymer, brominated or Brominated polystryene	HFR			
59447-57-3		PBBA	Polypentabromobenzyl acrylate PBB-MA Brominated polyacrylate or 2-Propenoic acid, (2,3,4,5,6-pentabromophenyl) methyl ester, homopolymer	HFR		YES	
148993-99-1			Poly(dibromostyrene)	HFR			
135229-48-0			Brominated epoxy resin end-capped with tribromophenol	HFR			
117-08-8	TECP-Anh	TCP-Anh	1,3-Isobenzofurandione, 4,5,6,7-tetrachloro- AKA TETRACHLOROPHTHALIC ANHYDRIDE	HFR			
118-79-6	TBP	TBP or 2,4,6-TBP or BP3	Phenol, 2,4,6-tribromo-	HFR	YES	YES	YES
168434-45-5	TBPD-TBP	TBPD-TBP	Phenol, 2,4,6-tribromo-3-(tetrabromopentadecyl)-	HFR			
20566-35-2	HEEHP-TEBP	HEEHPTBP or HEEHP-TEBP	1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, 1-[2-(2-hydroxyethoxy)ethyl] 2-(2-hydroxypropyl) ester	HFR			
23488-38-2	TBX	TBX or TBPx	Benzene, 1,2,4,5-tetrabromo-3,6-dimethyl-	HFR		YES	
25713-60-4	TTBP-TAZ	TBP-TAZ	1,3,5-Triazine, 2,4,6-tris(2,4,6-tribromophenoxy)-	HFR		YES	YES
31780-26-4	DBS	DBS	Benzene, dibromoethenyl-	HFR			
32588-76-4	EBTEBPI	EBTBP or EBT-EBPI	N-N-Ethylene-bis(tetrabromophthalimide	HFR			
3278-89-5	TBP-AE	ATE, TBP-AE or ATT	Benzene, 1,3,5-tribromo-2-(2-propen-1-yloxy)-	HFR		YES	
33798-02-6	TBBPA-BOAc	TBBPA-BOAc	Phenol, 4,4'-(1-methylethylidene) bis[2,6-dibromo-, 1,1'-diacetate	HFR			
35109-60-5	TBP-DBPE	DPTE or TBP-DBPE	Benzene, 1,3,5-tribromo-2-(2,3-dibromopropoxy)-	HFR		YES	
3555-11-1	PBP-AE	PBP-AE	Benzene, 1,2,3,4,5-pentabromo-6-(2-propen-1-yloxy)-	HFR			
38521-51-6	PBBB	PBBB	Benzene, 1,2,3,4,5-pentabromo-6-(bromomethyl)-	HFR			
39569-21-6	TBCT	TBoCT or TBCT	Benzene, 1,2,3,4-tetrabromo-5-chloro-6-methyl-	HFR		YES	
39635-79-5	TBBPS	TBBPS	Phenol, 4,4'-sulfonylbis[2,6-dibromo-	HFR			
42757-55-1	TBBPS-BDBPE	TBBPS-BDBPE	Benzene, 1,1'-sulfonylbis[3,5-dibromo-4-(2,3-dibromopropoxy)-	HFR			
497107-13-8	DBDBE	BPBBE or DBDBE	Benzene, 1,1'-[oxybis(methylene)] bis[2,3,4,5,6-pentabromo- (9CI)	HFR			
52434-90-9	TDBP-TAZTO	TDBP-TAZ or TBC or TDBP-TAZTO	1,3,5-Triazine-2,4,6(1H,3H,5H)-trione, 1,3,5-tris(2,3-dibromopropyl)-	HFR			

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People	Found in Indoor Env.	Found in Products
57829-89-7	DBP-TAZTO	DBP-TAZ or DBP-TAZTO	1,3,5-Triazine-2,4,6(1H,3H,5H)-trione, 1-(2,3-dibromopropyl)-3,5-di-2-propen-1-yl-	HFR			
58495-09-3	PBBC	PBBC	Benzene, 1,2,3,4,5-pentabromo-6-(chloromethyl)-	HFR			
59447-55-1	PBB-Acr	PBB-Acr	2-Propenoic acid, (2,3,4,5,6-pentabromophenyl)methyl ester	HFR			
608-71-9	PBP	PBP or BP5	Phenol,2,3,4,5,6-pentabromo-	HFR	YES		
615-58-7	DBP	DBP	Phenol, 2,4-dibromo-	HFR			
632-79-1	TEBP-Anh	TEBP-Anh or PHT 4	Tetrabromophthalic anhydride	HFR			
70156-79-5	TBBPS-BME	TBBPS-BME	Benzene, 1,1’-sulfonylbis[3,5-dibromo-4-methoxy-	HFR			
85-22-3	PBEB	PBEB	Benzene, 1,2,3,4,5-pentabromo-6-ethyl-	HFR		YES	
87-83-2	PBT	PBT	Benzene, 1,2,3,4,5-pentabromo-6-methyl-; Pentabromotoluene	HFR	YES	YES	
31977-87-4		OBPB	1,4,-Bis(2,4,6-tribromophenoxy)-2,3-dibromobutene	HFR			
82001-21-6		BPBTB	Bis(pentabromobenzyl) tetrabromophthalate	HFR			
90075-91-5		BPBTerP	Bis(pentabromobenzyl) terephthalate	HFR			
68928-70-1			Phenol, 4,4’-(1-methylethylidene) bis[2,6-dibromo-, polymer with 2,2’-[(1-methylethylidene)bis[(2,6-dibromo-4,1-phenylene)oxymethylene]] bis[oxirane]	HFR			
32534-81-9		PentaBDE	Pentabromodiphenyl ether	HFR		YES	YES
32536-52-0		OctaBDE	Octabromodiphenyl ether	HFR		YES	YES
72625-95-7			Tetrabromophthalic anhydride or 4,5,6,7-tetrabromo-2-benzofuran-1,3-dione	HFR			
77098-07-8		PHT4-Diol™	1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, mixed esters with diethylene glycol and propylene glycol	HFR			
191680-81-6		Flamestab Nor 116	Flamestab Nor 116 or 1,3-Propanediamine, N,N’-1,2-ethanediylbis-, reaction products with cyclohexane and peroxidized N-butyl-2,2,6,6-tetramethyl-4-piperidinamine-2,4,6-trichloro-1,3,5-triazine reaction products	HFR			
855993-01-0		TTMN	1,2,3,9-Tetrabromo-1,2,3,4-tetrahydro-1,4-methanonaphthalene (1 of 2 CAS#s)	HFR			
58965-66-5	4□-PeBPO-BDE208	4□-PeBPO-BDE208	Benzene, 1,2,4,5-tetrabromo-3,6-bis(2,3,4,5,6-pentabromophenoxy)-	HFR			

APPENDIX 1 - FULL LIST OF FLAME RETARDANTS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People	Found in Indoor Env.	Found in Products
1084889-51-9	OBTMPI	Octa-BTMPI or OBTMPI or OBIND	Octabromotrimethylphenylindane; 1H-Indene, 4,5,6,7-tetrabromo-2,3-dihydro-1,1,3-trimethyl-3-(2,3,4,5-tetrabromophenyl)-	HFR	YES	YES	
34571-16-9	HCTBPH	Dec 604 or HCTBPH	Bicyclo[2.2.1]hept-2-ene, 1,2,3,4,7,7-hexachloro-5-(2,3,4,5-tetrabromophenyl)-	HFR	YES		
115-27-5	HCBCH-DCAnh	HCBCH-DCAnh	4,7-Methanoisobenzofuran-1,3-dione, 4,5,6,7,8,8-hexachloro-3a,4,7,7a-tetrahydro- aka Chlorendic anhydride	HFR			
115-28-6	HCBCH-DCA	HCBCH-DCA, HET acid, Hetron 92, Hetron 92C	Chlorendic acid or 1,4,5,6,7,7-hexachlorobicyclo[2.2.1]-hept-5-ene-2,3-dicarboxylic acid	HFR			
13560-89-9	DDC-CO	DP or DDC-CO	1,4:7,10-Dimethanodibenzo[a,e]cyclooctene, 1,2,3,4,7,8,9,10,13,13,14,14-dodecachloro-1,4,4a,5,6,6a,7,10,10a,11,12,12a-dodecahydro-	HFR	YES	YES	
2385-85-5	MIREX	MIREX	1,3,4-Metheno-1H-cyclobuta[cd]pentalene, 1,1a,2,2,3,3a,4,5,5,5a,5b,6-dodecachlorooctahydro-	HFR			
31107-44-5	DDC-DBF	DDC-DBF or Dec 602	1,4:6,9-Dimethanodibenzofuran, 1,2,3,4,6,7,8,9,10,10,11,11-dodecachloro-1,4,4a,5a,6,9,9a,9b-octahydro-	HFR	YES	YES	
3194-55-6	HBCDD	HBCD (α-, β-, γ-)	1,2,5,6,9,10-Hexabromocyclodecane	HFR			
3194-57-8	TBCO	TBCO	Cyclooctane, 1,2,5,6-tetrabromo-	HFR		YES	YES
3322-93-8	DBE-DBCH	TBEC or TBECH or DBE-DBCH	Cyclohexane, 1,2-dibromo-4-(1,2-dibromoethyl)-	HFR		YES	
75795-16-3	BDBP-TAZTO	BDBP-TAZ	1,3,5-Triazine-2,4,6(1H,3H,5H)-trione, 1,3-bis(2,3-dibromopropyl)-5-(2-propen-1-yl)-	HFR			
51936-55-1	DBHCTD	DBHCTD or HCDBCO	hexachlorocyclopentadienyl-dibromocyclooctane	HFR	YES	YES	
85535-85-9		MCCP	Medium chain chlorinated paraffins	HFR			
13560-92-4	DDC-Ant	DDC-Ant or Dec 603	1,4:5,8:9,10-Trimethanoanthracene, 1,2,3,4,5,6,7,8,12,12,13,13-dodecachloro-1,4,4a,5,8,8a,9,9a,10,10a-decahydro-	HFR	YES	YES	
85535-84-8		SCCP	Alkanes, C10-13, chloro (1 of 2 CAS#s)	HFR			
3296-90-0	DBNPG	DBNPG	1,3-Propanediol, 2,2-bis(bromomethyl) OR 2,2-Bis(bromomethyl)-1,3-propanediol	HFR			
1522-92-5	TBNPA	TBNPA	Tribromoneopentylalcohol; 1-Propanol, 3-bromo-2,2-bis(bromomethyl)-	HFR			
38051-10-4	BCMP-BCEP	V6 or BCMP-BCEP	Tetrakis(2-chloroethyl)dichloroisopentyldiphosphate or bis[bis(2-chloroethyl) phosphate] or Phosphoric acid, P,P'-[2,2-bis(chloromethyl)-1,3-propanediyl] P,P,P',P'-tetrakis(2-chloroethyl) ester	HFR		YES	YES

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People	Found in Indoor Env.	Found in Products
66108-37-0			Tris(2,3-dichloro-1-propyl)phosphate	HFR			
78-43-3	TDCPP	TDCPP	-Propanol, 2,3-dichloro-, 1,1',1''-phosphate	HFR			
115-96-8	TCEP	TCEP	Ethanol, 2-chloro-, phosphate (3:1)	HFR	YES	YES	YES
126-72-7	TDBPP	TDBPP	1-Propanol, 2,3-dibromo-, 1,1',1''-phosphate	HFR		YES	
5412-25-9		TDBPP hydrolysis product	1-Propanol, 2,3-dibromo-, hydrogen phosphate	HFR			
57137-10-7		Pyrocheck 68	tribrominated polystyrene	HFR			
25357-79-3		FR 756	Disodium tetrabromophthalate	HFR			
125997-20-8			Phosphoric acid, mixed 3-bromo-2,2-dimethylpropyl and 2-bromoethyl and 2-chloroethyl esters	HFR			
97416-84-7		Pyroguard SR-130 or SR-130	NA	HFR			
		TBP-BAE or BATE	2-Bromoallyl-2,4,6-tribromophenyl ether	HFR		YES	
67888-96-4		BB-101	2,2',4,5,5'-Pentabromobiphenyl	HFR		YES	
608-90-2		PBB	Pentabromobenzene	HFR	YES	YES	
77-47-4	HCCPD	HCCPD	Hexachlorocyclopentadiene	HFR			
1047637-37-5	BCMP-BCMEP	U-OPFR or BCMP-BCMEP	2,2-Bis(chloromethyl)-1,3-propanediol	HFR			
		PBDE	mixture of or unspecified polybrominated diphenylethers	HFR	YES	YES	YES
		PBBs	polybrominated biphenyls	HFR	YES		YES
		PBPs	polybrominated phenols	HFR			YES
		iBPBCDs	Isobutoxypentabromocyclododecanes	HFR			YES
615-58-7		BP2	Phenol, 2,4-dibromo-	HFR	YES		
147-82-0		TBA	tribromoaniline	HFR	YES		
87-84-3		PBCC	pentabromochlorocyclohexane	HFR			YES
52434-90-9			1,3,5-Triazine-2,4,6(1H,3H,5H)-trione, 1,3,5-tris(2,3-dibromopropyl)-	HFR			
4351-70-6			1-(Bis(2-chloroethoxy)phosphinyl)ethyl 2-chloroethyl (1-(((2-chloroethoxy)(2-chloroethyl)phosphinyl)oxy)ethyl) phosphonate	HFR			
7415-86-3			1,2-(2,3-dibromopropyl) benzenedicarboxylate	HFR			
21645-51-2			Aluminium tri-Hydroxide	MFR			
1318-23-6			Boehmite (Aluminium oxide hydroxide)	MFR			

APPENDIX 1 - FULL LIST OF FLAME RETARDANTS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People	Found in Indoor Env.	Found in Products
7782-42-5			Expandable graphite	MFR			
13760-51-5			Magnesium di-hydroxide	MFR			
108-78-1			Melamine	MFR			
53587-44-3			Melamine Borate	MFR			
37640-57-6			Melamine Cyanurate	MFR			
68953-58-2			Surface treated, Inorganic, mineral based FR synergist	MFR			
12027-96-2			ZnHS-Zinc Hydroxystannate	MFR			
12036-37-2			ZnS-Zinc Stannate	MFR			
7784-22-7			Hypophosphite, aluminium salt (with synergists)	MFR			
41583-09-9			Melamine phosphate	MFR			
218768-84-4			Melamine polyphosphate	MFR			
1271168-40-1			Melamine-poly(aluminium phosphate)	MFR			
1271172-98-5			Melamine-poly(zinc phosphate)	MFR			
66034-17-1			Diphosphoric acid, compd. with pipera-zine (1:1)	MFR			
7789-79-9			Hypophosphite, calcium salt	MFR			
68333-79-9		APP	Ammonium polyphosphate	MFR			
7723-14-0			Red phosphorus	MFR			
10124-31-9			Ammonium orthophosphate	MFR			
7783-28-0		DAP	Di-ammonium phosphate	MFR			
		FM550	mixture including EH-TBB, BEH-TEBP, TPHP	mix of OPFR and HFR			YES
4090-51-1			2,2-Oxybis[5,5-dimethyl-1,3,2-dioxaphosphorinane]2,2-disulphide	OPFR			
181028-79-5			Bisphenol-A bis (diphenyl phosphate)	OPFR			
5945-33-5	BPA-BDPP	BPA-BDPP or BDP	Bisphenol-A bis (diphenyl phosphate)	OPFR		YES	YES
26444-49-5			Cresyldiphenyl phosphate - (diphenyl tolyl phosphate)	OPFR			

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People	Found in Indoor Env.	Found in Products
78-38-6			Diethylethane phosphonate	OPFR			
225789-38-8			Diethylphosphinate, aluminium salt	OPFR			
756-79-9			Dimethyl methyl phosphonate	OPFR			
242-555-3			Dimethyl propane phosphonate	OPFR			
1241-94-7		EHDPP	Diphenyl (2-ethylhexyl) phosphate; ethylhexyl diphenyl phosphate	OPFR	YES	YES	
35948-25-5	DOPO	DOPO	DOPO - 9,10-Dihydro-9-oxa-10-phosp-haphenanthren-10-oxide	OPFR			
14852-17-6			Ethylenediamine-o-phosphate	OPFR			
68937-41-7			Isopropylated phenol phosphate (Phenol, isopropylated, phosphate (3:1))	OPFR			
28108-99-8		IPDP or ip-TPHP	Isopropyl phenyl diphenyl phosphate	OPFR	YES		
1003300-73-9			Mixtures of esters of phosphoric acid	OPFR			
2781-11-5			N,N-(bis)-hydroxyethyl-aminomethane phosphonic acid diethyl ester	OPFR			
77226-90-5			Polcarbonate-Polyphosphonate copo-lymer	OPFR			
68664-06-2			Polyphosphonate homopolymer / oligo-mers	OPFR			
57583-54-7	PBDPP	PBDPP or RBDPP or RDP	Resorcinol bis (diphenyl phosphate)	OPFR		YES	YES
1330-78-5	TMPP	TMPP or TCP or TCrP	Tricresyl phosphate	OPFR	YES	YES	YES
78-40-0	TEP	TEP	Triethyl phosphate	OPFR	YES	YES	
115-86-6	TPHP	TPP or TPHP	Triphenyl phosphate (Firemaster 550 component)	OPFR	YES	YES	YES
78-42-2	TEHP	TEHP	Tris-(2-ethylhexyl) phosphate	OPFR		YES	
68952-33-0			Trixylyl phosphate	OPFR			
56803-37-3		BPDP or tb-TPHP	t-butylphenyl diphenyl phosphate	OPFR	YES		
65652-41-7			Bis(t-butylphenyl) phenyl phosphate	OPFR			
78-33-1		TBPP	Tris(4-(t-butyl)phenyl)phosphate	OPFR			YES
29761-21-5			Isodecyl diphenyl phosphate	OPFR			
78-51-3	TBOEP	TBEP or TBOEP	Tris(2-butoxyethyl) phosphate	OPFR	YES	YES	YES
126-71-6	TIBP	TIBP	Tri-iso-butyl phosphate	OPFR		YES	
512-56-1	TMP	TMP	trimethyl phosphate	OPFR		YES	
126-73-8	TNBP	TNBP	tri-n-butyl-phosphate	OPFR	YES	YES	

APPENDIX 1 - FULL LIST OF FLAME RETARDANTS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People	Found in Indoor Env.	Found in Products
139189-30-3	PBDMPP	PBDMPP	Resorcinol bis[di(2,6-dimethylphenyl) phosphate]	OPFR			
2502-15-0	TIPPP	TIPPP	Tris(4-isopropylphenyl) phosphate	OPFR			
46355-07-1	IPPP	IPPP	Isopropyl phenyl phosphate	OPFR			
513-08-6	TPP	TnPP or TPrP or TPP	Tris(propyl) phosphate	OPFR		YES	
995-32-4		TEEdP	tetraethyl ethylenediphosphonate	OPFR		YES	YES
6161-81-5		DOPP	di-n-octylphenyl phosphate	OPFR		YES	YES
140-08-9		CLP1	tris(2-chloroethyl)phosphite	OPFR		YES	
2528-38-3		TPEP	tripentyl phosphate	OPFR	YES		
63562-34-5			Bis(2-Hydroxyethyl) (6H-dibenz[c,e][1,2] oxaphosphorin-6-ylmethyl)succinate P-oxide (65 wt% in ethylene glycol)	OPFR			
78-30-8		o-TCP or TOCP or TOTP or ToCrP	Tri-o-cresylphosphate	OPFR			
563-04-2		m-TCP or TMTP	Tri-m-cresylphosphate	OPFR			
78-32-0		p-TCP or TPCP or TPTP	Tri-p-cresylphosphate	OPFR			
803-19-0		BCCPO	Bis(4-carboxyphenyl)phenylphosphine oxide	OPFR			
78-36-6		DEEP	Diethyl ethyl phosphonate	OPFR			
4090-51-1			2,2-Oxybis[5,5-dimethyl-1,3,2-dioxaphosphorinane]2,2-disulphide	OPFR			
813-76-3			Diethylphosphinic acid 3,9-Di-hydroxy-,4,8,10-tetraoxa-3,9-diphosphaspiro[5,5]-undecane-3,9-di-oxide	OPFR			
756-79-6		DMMP	Dimethyl methyl phosphonate	OPFR			
868-85-9		DMHP or DMP	Dimethyl phosphonate	OPFR			
20120-33-6			3-(Dimethylphosphono)propionic acid methyloamide	OPFR			
18755-43-6			Dimethyl propyl phosphonate	OPFR			
60763-39-5			Diphenyl isopropyl phosphate	OPFR			
115-89-9			Diphenyl methyl phosphate	OPFR			
838-85-7		DPK or DPP	Diphenylphosphate	OPFR			
61451-78-3			Hydroxymethylphenyl phosphinic acid	OPFR			
115-88-8			Octyl diphenyl phosphate	OPFR			

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People	Found in Indoor Env.	Found in Products
63562-33-4		DDP	[(6-Oxido-6H-dibenz[c,e][1,2]oxa-phosphorin-6-yl)-methyl]-butanedioic acid	OPFR			
1779-48-2		PPA	Phenylphosphinic acid	OPFR			
41203-81-0		HMPPA	Phosphonic acid, methyl(5-methyl-2-methyl-1,3,2-dioxaphosphorinan-5-yl) methyl,methylester, P-oxide p-Methoxy-phenylhydroxymethylphosphinic acid	OPFR			
53534-65-9			p-Methoxyphenyl-phosphinic acid	OPFR			
55566-30-8		THPS	Tetrakis(hydroxymethyl)phosphonium sulfate	OPFR			
2528-39-4			Trihexyl phosphate	OPFR			
513-02-0			Tri-iso-propyl phosphate	OPFR			
1806-54-8			Trioctyl phosphate	OPFR			
791-28-6		TPPO	Triphenylphosphine oxide	OPFR			
1067-12-5			Tris(hydroxymethyl)	OPFR			
25155-23-1		TXP	Trixylenyl phosphate	OPFR			

Appendix 2:
Flame Retardants in Products

APPENDIX 2 - LIST OF FLAME RETARDANTS IN PRODUCTS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
79-94-7	TBBPA	TBBPA	Phenol, 4,4'-(-methylethylidene)bis[2,6-dibromo-]	HFR	adipose tissue (9) blood (39, 58) breast milk (39, 70)	cars (11, 23) houses (11, 15, 20, 23, 28, 36, 82) indoor dust (52) offices (11, 23, 28)	applicances (75) baby products (75) computers (63, 64, 75, 81) polystyrene insulation (62) styrofoam products (62) toys (75) TVs (40, 63, 64, 75, 77)
		PBDE	mixture of polybrominated diphenylethers	HFR	adipose tissue (48, 65) blood (8, 25, 38, 41, 49, 55, 58, 69, 71, 85) breast milk (35, 37, 38, 42, 43, 44, 46, 47, 54, 70, 85) hands (2, 25) placental tissue (50, 61)	cars (11, 27) dorms (31) hotels (31) houses (2, 8, 11, 15, 21, 28, 32, 53, 73, 82) kindergardens (31) offices (11, 25, 27, 28, 31, 73) schools (32, 73)	applicances (75) baby products (75) computers (63, 75) couches (6) toys (75) TVs (63, 67, 75, 77)
25495-98-1	HBCYD	HBCD or HBCYD	Cyclodecane, hexabromo-	HFR	adipose tissue (9) blood (69) breast milk (35, 44, 70) fetal liver (84) hands (2) placental tissue (84)	cars (11, 23) houses (2, 10, 11, 12, 13, 15, 20, 22, 23, 26, 28, 33, 36, 82) offices (11, 23, 28) stores (26)	applicances (75) baby products (75) computers (75) polystyrene insulation (62, 81) styrofoam products (62, 66) textiles (59, 81) toys (75) TVs (75, 77) upholstry textiles (81)
38051-10-4	BCMP-BCEP	V6 or BCMP-BCEP	Tetrakis(2-chloroethyl) dichloroisopentyldiphosphate or bis[bis(2-chloroethyl)phosphate] or Phosphoric acid, P,P'-[2,2-bis(chloromethyl)-1,3-propanediyl] P,P,P',P'-tetrakis(2-chloroethyl) ester	HFR		cars (4) houses (4)	baby products (4) couches (6)

APPENDIX 2 - LIST OF FLAME RETARDANTS IN PRODUCTS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
13674-87-8	TDCIPP	TDCPP or TDCIPP or TDCP	2-Propanol, 1,3-dichlo-ro-, phosphate (3:1)	HFR	breast milk (60) hands (2) urine (5, 30)	cars (27) cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (2, 5, 12, 15, 17, 26, 29, 32, 33, 74, 80) indoor air (56, 76) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (26, 29)	computers (29) couches (6) monitors (29) upholstry foam (33)
115-96-8	TCEP	TCEP	Ethanol, 2-chloro-, phos-phate (3:1)	HFR	breast milk (60) hands (2)	cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (2, 12, 15, 29, 32, 68, 74, 80) indoor air (56, 76, 80) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (29, 31) prisons (29) public halls (29) schools (32) stores (29)	computers (29) couches (6) monitors (29, 80) TVs (80)
115-86-6	TPHP	TPP or TPHP	Triphenyl phosphate (Fire-master 550 component)	OPFR	breast milk (60) urine (5, 30)	cars (27) cinemas (29) dorms (31) hospitals (29) hotels (29, 31) houses (5, 12, 17, 29, 32, 33, 68, 74, 80) indoor air (56, 76) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (29)	computers (29) couches (6) monitors (29, 80) TVs (80)

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
13674-84-5	TCIPP	TCPP or TCIPP	Tris(1-chloro-2-propyl) phosphate	HFR	hands (2) urine (30)	cars (27) cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (2, 12, 15, 26, 29, 32, 33, 68, 74, 80) indoor air (56, 76, 80) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (26, 29)	computers (29) mattresses (81) monitors (29) polyiso insulation (81) TVs (80) upholstry foam (33, 81)
78-51-3	TBOEP	TBEP or TBOEP	Tris(2-butoxyethyl) phosphate	OPFR	breast milk (60)	cars (7, 27) cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (7, 12, 15, 26, 29, 32, 68, 74, 80) indoor air (56, 76, 80) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (26, 29)	computers (29) monitors (29)
995-32-4		TEEdP	tetraethyl ethylenediphos-phonate	OPFR		cinemas (29) hospitals (29) hotels (29) houses (29) libraries (29) lobbies (29) offices (29) prisons (29) public halls (29) stores (29)	computers (29) monitors (29)
6161-81-5		DOPP	di-n-octylphenyl phos-phate	OPFR		cinemas (29) hospitals (29) houses (29) libraries (29) lobbies (29) offices (29) prisons (29) public halls (29) stores (29)	computers (29) monitors (29)

APPENDIX 2 - LIST OF FLAME RETARDANTS IN PRODUCTS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
118-79-6	TBP	TBP or 2,4,6-TBP or BP3	Phenol, 2,4,6-tribromo-	HFR	adipose tissue (65)	cinemas (29) hospitals (29) hotels (19, 29) houses (20, 29, 80) indoor air (56, 76, 80) libraries (29) lobbies (29) offices (29) prisons (29) public halls (29) stores (29)	computers (29) monitors (29, 80)
		PBBs	polybrominated biphenyls	HFR	adipose tissue (48) blood (38) breast milk (38)		computers (63) TVs (40, 63)
37853-59-1	BTBPE	BTBPE or TBPE	1,2-Bis(2,4,6-tribromo-phenoxy)ethane	HFR	blood (8, 69)	dorms (31) hotels (31) houses (8, 10, 12, 13, 15, 22, 24, 32, 33, 73, 82) kindergardens (31) offices (24, 31, 73) schools (24, 32, 73)	computers (63, 64) polystyrene insulation (62) styrofoam products (62) TVs (63, 64)
1163-19-5		DecaBDE	Benzene, 1,1'-oxybis [2,3,4,5,6-pentabromo- or Decabromodiphenyl ether	HFR		houses (22, 36) indoor dust (51)	computers (64) textiles (81) TVs (64) upholstry textiles (81)
32536-52-0		OctaBDE	Octabromodiphenyl ether	HFR		houses (22)	computers (64) TVs (64, 81)
25713-60-4	TTBP-TAZ	TBP-TAZ	1,3,5-Triazine, 2,4,6-tris(2,4,6-tribro-mophenoxy)-	HFR		houses (16)	consumer products (16) plastic consumer products (16)
5945-33-5	BPA-BDPP	BPA-BDPP or BDP	Bisphenol-A bis (diphenyl phosphate)	OPFR		houses (14)	consumer products (3) plastic consumer products (3)
57583-54-7	PBDPP	PBDPP or RBDPP or RDP	Resorcinol bis (diphenyl phosphate)	OPFR		houses (14)	consumer products (3) plastic consumer products (3)
78-33-1		TBPP	Tris(4-(t-butyl)phenyl) phosphate	OPFR			couches (6)
32534-81-9		PentaBDE	Pentabromodiphenyl ether	HFR		houses (15, 22)	couches (6) upholstry foam (33)
		FM550	mixture including EH-TBB, BEH-TEBP, TPHP	mix of OPFR and HFR			couches (6) upholstry foam (33)

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
1330-78-5	TMPP	TMPP or TCP or TCrP	Tricresyl phosphate	OPFR	breast milk (60)	cars (7, 27) dorms (31) hotels (19, 31) houses (7, 12, 15, 32, 74, 80) indoor air (56, 76) indoor dust (34) kindergardens (31) offices (27, 31) schools (32)	monitors (80)
		iBPBCDs	Isobutoxypentabromocy-clododecanes	HFR			polystyrene insulation (57)
84852-53-9	DBDPE	DBDPE or DeBDethane	Decabromodiphenyl-ethane	HFR	blood (8, 85) breast milk (85)	cars (11, 27) houses (8, 11, 12, 13, 15, 24, 32, 73) offices (11, 24, 27, 73) schools (24, 32, 73)	polystyrene insulation (62) styrofoam products (62)
3194-57-8	TBCO	TBCO	Cyclooctane, 1,2,5,6-tet-rabromo-	HFR		houses (15, 32) schools (32)	styrofoam products (66)
87-84-3		PBCC	pentabromochlorocyclo-hexane	HFR			styrofoam products (66)
		PBPs	polybrominated phenols	HFR			TVs (40)
21850-44-2	TBBPA-BDBPE	TBBPA-DBPE or TBBPA-bis or TBBPA-BDBPE	Benzene, 1,1'-(1-methy-lethylidene) bis[3,5-dibromo-4-(2,3-dibromopropoxy)-	HFR		houses (15, 24, 73) offices (24, 73) schools (24, 73)	TVs (45)
183658-27-7	EH-TBB	EH-TBB or TBB	Benzoic acid, 2,3,4,5-tet-rabromo-, 2-ethylhexyl ester (firemaster 1 of 4)	HFR	blood (85) breast milk (85) hands (2, 78) urine (30, 78)	dorms (31) hotels (31) houses (2, 10, 12, 13, 15, 22, 24, 32, 33, 73, 78, 82) kindergardens (31) offices (24, 31, 73) schools (24, 32, 73)	upholstry foam (33)
26040-51-7	BEH-TEBP	TBPH or BEHTBP or BEH-TEBP	1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabro-mo-, 1,2-bis(2-ethyl-hexyl) ester (firemaster 1 of 4)	HFR	blood (85) breast milk (85) hands (2)	cars (7) dorms (31) hotels (31) houses (2, 7, 10, 12, 13, 15, 15, 22, 24, 32, 33, 72, 73) indoor air (76) kindergardens (31) offices (24, 31, 72, 73) schools (24, 32, 73)	upholstry foam (33)

Appendix 3:
Flame Retardants in Buildings

APPENDIX 3 - LIST OF FLAME RETARDANTS IN BUILDINGS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
79-94-7	TBBPA	TBBPA	Phenol, 4,4'-(-methylethylidene)bis[2,6-dibromo-]	HFR	adipose tissue (9) blood (39, 58) breast milk (39, 70)	cars (11, 23) houses (11, 15, 20, 23, 28, 36, 82) indoor dust (52) offices (11, 23, 28)	applicances (75) baby products (75) computers (63, 64, 75, 81) polystyrene insulation (62) styrofoam products (62) toys (75) TVs (40, 63, 64, 75, 77)
25495-98-1	HBCYD	HBCD or HBCYD	Cyclodecane, hexabromo-	HFR	adipose tissue (9) blood (69) breast milk (35, 44, 70) fetal liver (84) hands (2) placental tissue (84)	cars (11, 23) houses (2, 10, 11, 12, 13, 15, 20, 22, 23, 26, 28, 33, 36, 82) offices (11, 23, 28) stores (26)	applicances (75) baby products (75) computers (75) polystyrene insulation (62, 81) styrofoam products (62, 66) textiles (59, 81) toys (75) TVs (75, 77) upholstry textiles (81)
		PBDE	mixture of polybrominated diphenylethers	HFR	adipose tissue (48, 65) blood (8, 25, 38, 41, 49, 55, 58, 69, 71, 85) breast milk (35, 37, 38, 42, 43, 44, 46, 47, 54, 70, 85) hands (2, 25) placental tissue (50, 61)	cars (11, 27) dorms (31) hotels (31) houses (2, 8, 11, 15, 21, 28, 32, 53, 73, 82) kindergardens (31) offices (11, 25, 27, 28, 31, 73) schools (32, 73)	applicances (75) baby products (75) computers (63, 75) couches (6) toys (75) TVs (63, 67, 75, 77)
84852-53-9	DBDPE	DBDPE or DeBDethane	Decabromodiphenylethane	HFR	blood (8, 85) breast milk (85)	cars (11, 27) houses (8, 11, 12, 13, 15, 24, 32, 73) offices (11, 24, 27, 73) schools (24, 32, 73)	polystyrene insulation (62) styrofoam products (62)

APPENDIX 3 - LIST OF FLAME RETARDANTS IN BUILDINGS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
13674-84-5	TCIPP	TCPP or TCIPP	Tris(1-chloro-2-propyl) phosphate	HFR	hands (2) urine (30)	cars (27) cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (2, 12, 15, 26, 29, 32, 33, 68, 74, 80) indoor air (56, 76, 80) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (26, 29)	computers (29) mattresses (81) monitors (29) polyiso insulation (81) TVs (80) upholstry foam (33, 81)
13674-87-8	TDCIPP	TDCPP or TDCIPP or TDCP	2-Propanol, 1,3-dichloro-, phosphate (3:1)	HFR	breast milk (60) hands (2) urine (5, 30)	cars (27) cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (2, 5, 12, 15, 17, 26, 29, 32, 33, 74, 80) indoor air (56, 76) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (26, 29)	computers (29) couches (6) monitors (29) upholstry foam (33)
115-86-6	TPHP	TPP or TPHP	Triphenyl phosphate (Firemaster 550 component)	OPFR	breast milk (60) urine (5, 30)	cars (27) cinemas (29) dorms (31) hospitals (29) hotels (29, 31) houses (5, 12, 17, 29, 32, 33, 68, 74, 80) indoor air (56, 76) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (29)	computers (29) couches (6) monitors (29, 80) TVs (80)

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
38051-10-4	BCMP-BCEP	V6 or BCMP-BCEP	Tetrakis(2-chloroethyl) dichloroisopentyldiphosphate or bis[bis(2-chloroethyl)phosphate] or Phosphoric acid, P,P'-[2,2-bis(chloromethyl)-1,3-propanediyl] P,P,P',P'-tetrakis(2-chloroethyl) ester	HFR		cars (4) houses (4)	baby products (4) couches (6)
26040-51-7	BEH-TEBP	TBPH or BEHTBP or BEH-TEBP	1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, 1,2-bis(2-ethylhexyl) ester (firemaster 1 of 4)	HFR	blood (85) breast milk (85) hands (2)	cars (7) dorms (31) hotels (31) houses (2, 7, 10, 12, 13, 15, 15, 22, 24, 32, 33, 72, 73) indoor air (76) kindergardens (31) offices (24, 31, 72, 73) schools (24, 32, 73)	upholstry foam (33)
78-51-3	TBOEP	TBEP or TBOEP	Tris(2-butoxyethyl) phosphate	OPFR	breast milk (60)	cars (7, 27) cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (7, 12, 15, 26, 29, 32, 68, 74, 80) indoor air (56, 76, 80) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (26, 29)	computers (29) monitors (29)
1330-78-5	TMPP	TMPP or TCP or TCrP	Tricresyl phosphate	OPFR	breast milk (60)	cars (7, 27) dorms (31) hotels (19, 31) houses (7, 12, 15, 32, 74, 80) indoor air (56, 76) indoor dust (34) kindergardens (31) offices (27, 31) schools (32)	monitors (80)

APPENDIX 3 - LIST OF FLAME RETARDANTS IN BUILDINGS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
115-96-8	TCEP	TCEP	Ethanol, 2-chloro-, phos-phate (3:1)	HFR	breast milk (60) hands (2)	cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (2, 12, 15, 29, 32, 68, 74, 80) indoor air (56, 76, 80) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (29, 31) prisons (29) public halls (29) schools (32) stores (29)	computers (29) couches (6) monitors (29, 80) TVs (80)
78-42-2	TEHP	TEHP	Tris-(2-ethylhexyl) phos-phate	OPFR		cinemas (29) hospitals (29) hotels (19, 29) houses (15, 29, 80) indoor air (56, 80) libraries (29) lobbies (29) offices (29) prisons (29) public halls (29) stores (29)	
118-79-6	TBP	TBP or 2,4,6-TBP or BP3	Phenol, 2,4,6-tribromo-	HFR	adipose tissue (65)	cinemas (29) hospitals (29) hotels (19, 29) houses (20, 29, 80) indoor air (56, 76, 80) libraries (29) lobbies (29) offices (29) prisons (29) public halls (29) stores (29)	computers (29) monitors (29, 80)
995-32-4		TEEdP	tetraethyl ethylenediphos-phonate	OPFR		cinemas (29) hospitals (29) hotels (29) houses (29) libraries (29) lobbies (29) offices (29) prisons (29) public halls (29) stores (29)	computers (29) monitors (29)

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
6161-81-5		DOPP	di-n-octylphenyl phosphate	OPFR		cinemas (29) hospitals (29) houses (29) libraries (29) lobbies (29) offices (29) prisons (29) public halls (29) stores (29)	computers (29) monitors (29)
13560-89-9	DDC-CO	DP or DDC-CO	1,4:7,10-Dimethanodibenzo[a,e] cyclooctene, 1,2,3,4,7,8,9, 10,13,13,14,14-dodecachloro-1,4,4a,5,6,6a,7,10, 10a,11,12,12a-dodecahydro-	HFR	blood (71, 83) breast milk (83)	dorms (31) hotels (31) houses (10, 15, 22, 32) kindergardens (31) offices (31) schools (32)	
126-73-8	TNBP	TNBP	tri-n-butyl-phosphate	OPFR	breast milk (60)	dorms (31) hotels (31) houses (12, 15, 32, 68, 74) kindergardens (31) offices (31) schools (32)	
1241-94-7		EHDPP	Diphenyl (2-ethylhexyl) phosphate; ethylhexyl diphenyl phosphate	OPFR	breast milk (60)	dorms (31) hotels (31) houses (15, 32, 74) kindergardens (31) offices (31) schools (32)	
183658-27-7	EH-TBB	EH-TBB or TBB	Benzoic acid, 2,3,4,5-tetrabromo-, 2-ethylhexyl ester (firemaster 1 of 4)	HFR	blood (85) breast milk (85) hands (2, 78) urine (30, 78)	dorms (31) hotels (31) houses (2, 10, 12, 13, 15, 22, 24, 32, 33, 73, 78, 82) kindergardens (31) offices (24, 31, 73) schools (24, 32, 73)	upholstry foam (33)
37853-59-1	BTBPE	BTBPE or TBPE	1,2-Bis(2,4,6-tribromophenoxy)ethane	HFR	blood (8, 69)	dorms (31) hotels (31) houses (8, 10, 12, 13, 15, 22, 24, 32, 33, 73, 82) kindergardens (31) offices (24, 31, 73) schools (24, 32, 73)	computers (63, 64) polystyrene insulation (62) styrofoam products (62) TVs (63, 64)
512-56-1	TMP	TMP	trimethyl phosphate	OPFR		hotels (19)	
78-40-0	TEP	TEP	Triethyl phosphate	OPFR	breast milk (60)	hotels (19) houses (12, 15, 26) indoor dust (34) stores (26)	
39569-21-6	TBCT	TBoCT or TBCT	Benzene, 1,2,3,4-tetrabromo-5-chloro-6-methyl-	HFR		houses (10)	

APPENDIX 3 - LIST OF FLAME RETARDANTS IN BUILDINGS /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
67888-96-4		BB-101	2,2',4,5,5'-Pentabromo-biphenyl	HFR		houses (10)	
87-82-1	HBB	HBB	Benzene, 1,2,3,4,5,6-hexabromo-	HFR	adipose tissue (65) blood (85) breast milk (85)	houses (10, 15, 32) indoor air (76) schools (32)	
3278-89-5	TBP-AE	ATE, TBP-AE or ATT	Benzene, 1,3,5-tribromo-2-(2-propen-1-yloxy)-	HFR		houses (10, 15, 32) schools (32)	
35109-60-5	TBP-DBPE	DPTE or TBP-DBPE	Benzene, 1,3,5-tribromo-2-(2,3-dibromopropoxy)-	HFR		houses (10, 15, 32) schools (32)	
1084889-51-9	OBTMPI	Octa-BTMPI or OBTMPI or OBIND	Octabromotrimethylphe-nylindane; 1H-Indene, 4,5,6,7-tetrabromo-2,3-dihydro-1,1,3-trimethyl-3-(2,3,4,5-tetrabromo-phenyl)-	HFR	blood (85)	houses (10, 15, 32) schools (32)	
		TBP-BAE or BATE	2-Bromoallyl-2,4,6-tribromophenyl ether	HFR		houses (10, 15, 32) schools (32)	
59447-57-3		PBBA	Polypentabromoben-zyl acrylate PBB-MA Brominated polyacrylate or 2-Propenoic acid, (2,3,4,5,6-pentabro-mophenyl)methyl ester, homopolymer	HFR		houses (10, 32) schools (32)	
23488-38-2	TBX	TBX or TBPx	Benzene, 1,2,4,5-tetra-bromo-3,6-dimethyl-	HFR		houses (10, 32) schools (32)	
85-22-3	PBEB	PBEB	Benzene, 1,2,3,4,5-pentabromo-6-ethyl-	HFR		houses (10, 32) schools (32)	
87-83-2	PBT	PBT	Benzene, 1,2,3,4,5-pentabromo-6-methyl-; Pentabromo-toluene	HFR	adipose tissue (65) blood (71)	houses (10, 32) schools (32)	
608-90-2		PBB	Pentabromobenzene	HFR	blood (71)	houses (10, 32) schools (32)	
5945-33-5	BPA-BDPP	BPA-BDPP or BDP	Bisphenol-A bis (diphenyl phosphate)	OPFR		houses (14)	consumer products (3) plastic consumer products (3)
57583-54-7	PBDPP	PBDPP or RBDPP or RDP	Resorcinol bis (diphenyl phosphate)	OPFR		houses (14)	consumer products (3) plastic consumer products (3)
126-72-7	TDBPP	TDBPP	1-Propanol, 2,3-dibro-mo-, 1,1',1''-phosphate	HFR		houses (15)	
51936-55-1	DBHCTD	DBHCTD or HCDBCO	hexachlorocyclopentadie-nyl-dibromocyclooctane	HFR	blood (83) breast milk (83)	houses (15, 18, 32) schools (32)	
32534-81-9		PentaBDE	Pentabromodiphenyl ether	HFR		houses (15, 22)	couches (6) upholstry foam (33)

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
21850-44-2	TBBPA-BDBPE	TBBPA-DBPE or TBBPA-bis or TBBPA-BDBPE	Benzene, 1,1'-(1-methylethylidene) bis[3,5-dibromo-4-(2,3-dibromopropoxy)-	HFR		houses (15, 24, 73) offices (24, 73) schools (24, 73)	TVs (45)
3194-57-8	TBCO	TBCO	Cyclooctane, 1,2,5,6-tetrabromo-	HFR		houses (15, 32) schools (32)	styrofoam products (66)
3322-93-8	DBE-DBCH	TBEC or TBECH or DBE-DBCH	Cyclohexane, 1,2-dibromo-4-(1,2-dibromoethyl)-	HFR		houses (15, 32) schools (32)	
25713-60-4	TTBP-TAZ	TBP-TAZ	1,3,5-Triazine, 2,4,6-tris(2,4,6-tribromophenoxy)-	HFR		houses (16)	consumer products (16) plastic consumer products (16)
32536-52-0		OctaBDE	Octabromodiphenyl ether	HFR		houses (22)	computers (64) TVs (64, 81)
1163-19-5		DecaBDE	Benzene, 1,1'-oxybis [2,3,4,5,6-pentabromo- or Decabromodiphenyl ether	HFR		houses (22, 36) indoor dust (51)	computers (64) textiles (81) TVs (64) upholstry textiles (81)
126-71-6	TIBP	TIBP	Tri-iso-butyl phosphate	OPFR		houses (26) indoor dust (34) stores (26)	
140-08-9		CLP1	tris(2-chloroethyl) phosphite	OPFR		houses (29) libraries (29) lobbies (29) offices (29) public halls (29) stores (29)	
31107-44-5	DDC-DBF	DDC-DBF or Dec 602	1,4:6,9-Dimethanodibenzofuran, 1,2,3,4,6,7,8,9, 10,10,11, 11-dodecachloro-1,4,4a,5a, 6,9,9a,9b-octahydro-	HFR	blood (83) breast milk (83)	houses (32) schools (32)	
13560-92-4	DDC-Ant	DDC-Ant or Dec 603	1,4:5,8:9,10-Trimethanoanthracene, 1,2,3,4,5,6, 7,8,12,12, 13,13-dodecachloro-1,4, 4a,5,8,8a, 9,9a,10,10a-decahydro-	HFR	blood (83) breast milk (83)	houses (32) schools (32)	
513-08-6	TPP	TnPP or TPrP or TPP	Tris(propyl) phosphate	OPFR		indoor air (76) indoor dust (34)	

Appendix 4:
Flame Retardants in People

APPENDIX 4 - LIST OF FLAME RETARDANTS IN PEOPLE /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
		PBBs	polybrominated biphenyls	HFR	adipose tissue (48) blood (38) breast milk (38)		computers (63) TVs (40, 63)
		PBDE	mixture of polybrominated diphenylethers	HFR	adipose tissue (48, 65) blood (8, 25, 38, 41, 49, 55, 58, 69, 71, 85) breast milk (35, 37, 38, 42, 43, 44, 46, 47, 54, 70, 85) hands (2, 25) placental tissue (50, 61)	cars (11, 27) dorms (31) hotels (31) houses (2, 8, 11, 15, 21, 28, 32, 53, 73, 82) kindergardens (31) offices (11, 25, 27, 28, 31, 73) schools (32, 73)	applicances (75) baby products (75) computers (63, 75) couches (6) toys (75) TVs (63, 67, 75, 77)
118-79-6	TBP	TBP or 2,4,6-TBP or BP3	Phenol, 2,4,6-tribromo-	HFR	adipose tissue (65)	cinemas (29) hospitals (29) hotels (19, 29) houses (20, 29, 80) indoor air (56, 76, 80) libraries (29) lobbies (29) offices (29) prisons (29) public halls (29) stores (29)	computers (29) monitors (29, 80)
608-71-9	PBP	PBP or BP5	Phenol,2,3,4,5,6-pentabromo-	HFR	adipose tissue (65)		
615-58-7		BP2	2,4-Dibromophenol	HFR	adipose tissue (65)		
147-82-0		TBA	tribromoaniline	HFR	adipose tissue (65)		
87-83-2	PBT	PBT	Benzene, 1,2,3,4,5-pentabromo-6-methyl-; Pentabromotoluene	HFR	adipose tissue (65) blood (71)	houses (10, 32) schools (32)	
87-82-1	HBB	HBB	Benzene, 1,2,3,4,5,6-hexabromo-	HFR	adipose tissue (65) blood (85) breast milk (85)	houses (10, 15, 32) indoor air (76) schools (32)	
79-94-7	TBBPA	TBBPA	Phenol, 4,4'-(-methylethylidene)bis[2,6-dibromo-]	HFR	adipose tissue (9) blood (39, 58) breast milk (39, 70)	cars (11, 23) houses (11, 15, 20, 23, 28, 36, 82) indoor dust (52) offices (11, 23, 28)	applicances (75) baby products (75) computers (63, 64, 75, 81) polystyrene insulation (62) styrofoam products (62) toys (75) TVs (40, 63, 64, 75, 77)

APPENDIX 4 - LIST OF FLAME RETARDANTS IN PEOPLE /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
25495-98-1	HBCYD	HBCD or HBCYD	Cyclodecane, hexabromo-	HFR	adipose tissue (9) blood (69) breast milk (35, 44, 70) fetal liver (84) hands (2) placental tissue (84)	cars (11, 23) houses (2, 10, 11, 12, 13, 15, 20, 22, 23, 26, 28, 33, 36, 82) offices (11, 23, 28) stores (26)	applicances (75) baby products (75) computers (75) polystyrene insulation (62, 81) styrofoam products (62, 66) textiles (59, 81) toys (75) TVs (75, 77) upholstry textiles (81)
608-90-2		PBB	Pentabromobenzene	HFR	blood (71)	houses (10, 32) schools (32)	
13560-89-9	DDC-CO	DP or DDC-CO	1,4:7,10-Dimethanodibenzo[a,e] cyclooctene, 1,2,3,4,7,8,9,10, 13,13,14,14-dodecachloro-1,4,4a,5,6,6a,7,10, 10a,11,12,12a-dodecahydro-	HFR	blood (71, 83) breast milk (83)	dorms (31) hotels (31) houses (10, 15, 22, 32) kindergardens (31) offices (31) schools (32)	
37853-59-1	BTBPE	BTBPE or TBPE	1,2-Bis(2,4,6-tribromo-phenoxy)ethane	HFR	blood (8, 69)	dorms (31) hotels (31) houses (8, 10, 12, 13, 15, 22, 24, 32, 33, 73, 82) kindergardens (31) offices (24, 31, 73) schools (24, 32, 73)	computers (63, 64) polystyrene insulation (62) styrofoam products (62) TVs (63, 64)
84852-53-9	DBDPE	DBDPE or DeBDethane	Decabromodiphenyl-ethane	HFR	blood (8, 85) breast milk (85)	cars (11, 27) houses (8, 11, 12, 13, 15, 24, 32, 73) offices (11, 24, 27, 73) schools (24, 32, 73)	polystyrene insulation (62) styrofoam products (62)
31107-44-5	DDC-DBF	DDC-DBF or Dec 602	1,4:6,9-Dimethanodibenzofuran, 1,2,3,4,6,7,8,9,10,10,11,11-do-decachloro-1,4,4a,5a,6,9,9a,9b-octahydro-	HFR	blood (83) breast milk (83)	houses (32) schools (32)	
51936-55-1	DBHCTD	DBHCTD or HCDBCO	hexachlorocyclopentadie-nyl-dibromocyclooctane	HFR	blood (83) breast milk (83)	houses (15, 18, 32) schools (32)	
13560-92-4	DDC-Ant	DDC-Ant or Dec 603	1,4:5,8:9,10-Tri-methanoanthracene, 1,2,3,4,5,6,7,8,12,12,13,13-do-decachloro-1,4,4a,5,8,8a,9,9a,10,10a-decahydro-	HFR	blood (83) breast milk (83)	houses (32) schools (32)	
1084889-51-9	OBTMPI	Octa-BTMPI or OBTMPI or OBIND	Octabromotrimethylphe-nylindane; 1H-Indene, 4,5,6,7-tetrabromo-2,3-dihydro-1,1,3-trimethyl-3-(2,3,4,5-tetrabromo-phenyl)-	HFR	blood (85)	houses (10, 15, 32) schools (32)	

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
26040-51-7	BEH-TEBP	TBPH or BEHTBP or BEH-TEBP	1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, 1,2-bis(2-ethylhexyl) ester (firemaster 1 of 4)	HFR	blood (85) breast milk (85) hands (2)	cars (7) dorms (31) hotels (31) houses (2, 7, 10, 12, 13, 15, 15, 22, 24, 32, 33, 72, 73) indoor air (76) kindergardens (31) offices (24, 31, 72, 73) schools (24, 32, 73)	upholstry foam (33)
183658-27-7	EH-TBB	EH-TBB or TBB	Benzoic acid, 2,3,4,5-tetrabromo-, 2-ethylhexyl ester (firemaster 1 of 4)	HFR	blood (85) breast milk (85) hands (2, 78) urine (30, 78)	dorms (31) hotels (31) houses (2, 10, 12, 13, 15, 22, 24, 32, 33, 73, 78, 82) kindergardens (31) offices (24, 31, 73) schools (24, 32, 73)	upholstry foam (33)
1241-94-7		EHDPP	Diphenyl (2-ethylhexyl) phosphate; ethylhexyl diphenyl phosphate	OPFR	breast milk (60)	dorms (31) hotels (31) houses (15, 32, 74) kindergardens (31) offices (31) schools (32)	
1330-78-5	TMPP	TMPP or TCP or TCrP	Tricresyl phosphate	OPFR	breast milk (60)	cars (7, 27) dorms (31) hotels (19, 31) houses (7, 12, 15, 32, 74, 80) indoor air (56, 76) indoor dust (34) kindergardens (31) offices (27, 31) schools (32)	monitors (80)
78-40-0	TEP	TEP	Triethyl phosphate	OPFR	breast milk (60)	hotels (19) houses (12, 15, 26) indoor dust (34) stores (26)	
78-51-3	TBOEP	TBEP or TBOEP	Tris(2-butoxyethyl) phosphate	OPFR	breast milk (60)	cars (7, 27) cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (7, 12, 15, 26, 29, 32, 68, 74, 80) indoor air (56, 76, 80) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (26, 29)	computers (29) monitors (29)

APPENDIX 4 - LIST OF FLAME RETARDANTS IN PEOPLE /

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
126-73-8	TNBP	TNBP	tri-n-butyl-phosphate	OPFR	breast milk (60)	dorms (31) hotels (31) houses (12, 15, 32, 68, 74) kindergardens (31) offices (31) schools (32)	
2528-38-3		TPEP	tripentyl phosphate	OPFR	breast milk (60)		
115-96-8	TCEP	TCEP	Ethanol, 2-chloro-, phosphate (3:1)	HFR	breast milk (60) hands (2)	cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (2, 12, 15, 29, 32, 68, 74, 80) indoor air (56, 76, 80) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (29, 31) prisons (29) public halls (29) schools (32) stores (29)	computers (29) couches (6) monitors (29, 80) TVs (80)
13674-87-8	TDCIPP	TDCPP or TDCIPP or TDCP	2-Propanol, 1,3-dichloro-, phosphate (3:1)	HFR	breast milk (60) hands (2) urine (5, 30)	cars (27) cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (2, 5, 12, 15, 17, 26, 29, 32, 33, 74, 80) indoor air (56, 76) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (26, 29)	computers (29) couches (6) monitors (29) upholstry foam (33)

CASRN	Bergman Abbreviation	All Abbreviations	Chemical Name	Class	Found in People (reference)	Found in Indoor Env. (reference)	Found in Products (reference)
115-86-6	TPHP	TPP or TPHP	Triphenyl phosphate (Firemaster 550 component)	OPFR	breast milk (60) urine (5, 30)	cars (27) cinemas (29) dorms (31) hospitals (29) hotels (29, 31) houses (5, 12, 17, 29, 32, 33, 68, 74, 80) indoor air (56, 76) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (29)	computers (29) couches (6) monitors (29, 80) TVs (80)
34571-16-9	HCTBPH	Dec 604 or HCTBPH	Bicyclo[2.2.1]hept-2-ene, 1,2,3,4,7,7-hexachloro-5-(2,3,4,5-tetrabromo-phenyl)-	HFR	breast milk (83)		
13674-84-5	TCIPP	TCPP or TCIPP	Tris(1-chloro-2-propyl) phosphate	HFR	hands (2) urine (30)	cars (27) cinemas (29) dorms (31) hospitals (29) hotels (19, 29, 31) houses (2, 12, 15, 26, 29, 32, 33, 68, 74, 80) indoor air (56, 76, 80) indoor dust (34) kindergardens (31) libraries (29) lobbies (29) offices (27, 29, 31) prisons (29) public halls (29) schools (32) stores (26, 29)	computers (29) mattresses (81) monitors (29) polyiso insulation (81) TVs (80) upholstry foam (33, 81)

Appendix 5:
Table of Regulatory Drivers

APPENDIX 5 - TABLE OF REGULATORY DRIVERS /

Material	Code	Section	Section Name	Main Requirement (details omitted)
Foam Plastic Insulation	IBC 2012 / CBC 2013	2603	Foam Plastic Insulation	ASTM E84 max flame spread of 75 and smoke 450
Foam Plastic Insulation	IRC 2012 / CRC 2013	R316	Foam Plastic	ASTM E84 max flame spread of 75 and smoke 450
Foam Plastic Insulation	IFC 2012 / CFC 2013	not included	not included	Not included
Non-Foam Insulation	IBC 2012 / CBC 2013	603.1	Combustible Material...	ASTM E84 max flame spread 25, 100 in sandwich, 200 between floor and decking
Furniture	IBC 2012 / CBC 2013	not included	not included	Not included
Furniture	IFC 2012 / CFC 2013	805	Upholstered Furniture...	Institutional requires NFPA 260/261 (sprinklered) or ASTM E1537 / TB133 (non-sprinklered)
Furniture		1374	Flammability; Upholstered and Reupholstered Furniture	CA furniture must meet TB177-2013 (similar to ASTM E1353-08a) or TB133
Furniture	Boston Fire Department		Upholstered Furniture Regulation	Certain Boston public buildings require TB133 furniture
Textiles	IBC 2012 / CBC 2013	803.6	Textile ceiling coverings	ASTM E84 Class A+sprinklers or NFPA 286
Textiles	IBC 2012 / CBC 2013	803.5	Textile wall coverings	ASTM E84 Class A+sprinklers or NFPA 265/286
Textiles	IFC 2012 / CFC 2013	803.5	Textile wall or ceiling coverings	ASTM E84 Class A+sprinklers or NFPA 265/286
Textiles (Curtains)	IBC 2012 / CBC 2013	806.1	Decorative Materials and Trim	Curtains must pass NFPA 701 when installed in A, E, I, R-1, dorms in R-2
Textiles (Curtains)	IFC 2012 / CFC 2013	807.1	Decorative Materials...	Curtains must pass NFPA 701 when installed in A, E, I, R-1, dorms in R-2
Carpet	IBC 2012 / CBC 2013	804	Interior Floor Finish	Carpet must pass "pill test"; some must also pass NFPA 253
Carpet	IFC 2012 / CFC 2013	804.3	New Interior Floor Finish	Carpet must pass "pill test"; some must also pass NFPA 253
Structural Steel	IBC 2012 / CBC 2013	703.2	Fire-resistance ratings	Structural steel requires fire protection (1-5 hr)
Structural Steel	IBC 2012 / CBC 2013	722.5	Steel Assemblies	Requirements for non-intumescent fire protection of steel
Structural Steel	IFC 2012 / CFC 2013	not included	not included	Not included
Wood (Non-Textile Wall Finish)	IBC 2012 / CBC 2013	803.1	Wall and Ceiling Finishes	ASTM E84 requirement depends on location (Table 803.9)
Wood (Non-Textile Wall Finish)	IFC 2012 / CFC 2013	803.1	Interior Wall and Ceiling Finish	ASTM E84 requirement depends on location (Table 803.9)
Wood Floors	IBC 2012 / CBC 2013	804-805	Interior Floor Finish	Wood floors exempt from flammability requirements when properly installed
Wood Heavy Timber Framing	IBC 2012 / CBC 2013	602.4	Consutrction Classifications: Type IV	Minimum timber dimensions specified
Wood , Fire Retardant Treated	IBC 2012 / CBC 2013	2303.2	Fire-retardant-treated wood	ASTM E84 Class A, tested for 30 rather than 10 minutes
Wood , Fire Retardant Treated	IBC 2012 / CBC 2013	602-603	Construction Classification; Combustible Materials...	Describes appropriate situations for use of fire retarded treated wood
Wood Millwork (Cabinets, Etc)	IBC 2012 / CBC 2013	603.1	Combustible Material in Type I and II Construction	Millwork has no flammability requirements
Plastic TV Housing (US)	N/A	N/A	Required by retailers/ insurance	UL 94 V-0
Non-TV Electronics Housing (US)	N/A	N/A	Required by retailers/ insurance	UL 94 V-0 to V-2

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