Flame Retardants: Are they a Health Risk for Children?

Heather M. Stapleton, Ph.D.
Duke University
Nicholas School of the Environment

Child Task Force Meeting
Raleigh, NC
January 11, 2010
1. What are flame retardants?
   • How do they work? What types are used?

2. What types of products contain flame retardants?

3. What are the current flammability standards which require the use of flame retardants?

4. Do flame retardants leach out of consumer products?

5. Children’s Exposure to Flame Retardants
   • What is their potential exposure? Are their health consequences?

6. What are the alternatives to using flame retardants?
   • Are there safer options? Do we need flame retardants in all these products?
Statistics:

- Every year in the U.S. there are over a million fires reported
- Direct losses account for billions in damages

Flame Retardants

*Definition:*
“A substance added or a treatment applied to a material in order to suppress, significantly reduce or delay the combustion of the material” *EHC:192, WHO 1997*
What Type of Products Contain Flame Retardants?
Regulations That Govern the Use of Flame Retardants:

- California Technical Bulletin 117
- California Technical Bulletin 603
- Federal Mattress Flammability Standard (CFR 1633)
What is TB 117?

- Promulgated by California Bureau of Home Furnishing and Thermal Insulation, within the Department of Consumer Affairs

- Requires 12-second open flame testing for polyurethane inside furniture

- Has required the use of large quantities of halogenated flame retardants (FR), primarily pentaBDE

- CA standard affected furniture composition throughout the U.S.

- No good evidence that TB 117 is even effective in preventing fire deaths
What are the Different Types of Flame Retardants (FR)?

**REACTIVE FRs:**

- Chemically bound to the product they are flame retarding….less likely to leach out into the environment

**ADDITIVE FRs:**

- Mixed in with the resin during extrusion process…..more likely to leach out of products over time

Examples: \[
\begin{align*}
\text{PentaBDE} & \\
\text{OctaBDE} & \\
\text{DecaBDE} & 
\end{align*}
\]

\} Commercial Mixture Names
Types of Brominated Flame Retardants:

**ADDITIVE BFRs**
- Decaabromobiphenyl
- Decabromodiphenyl ethane
- Decabromodiphenyl ether
- Octabromodiphenyl ether
- Pentabromodiphenyl ether
- Tetrabromobisphenol A Derivatives
  - bis-(2,3-dibromopropyl ether)
  - bis-(2-hydroxyethyl ether)
  - bis-(allyl ether)
  - dimethyl ether
- Hexabromocyclododecane
- Bis(tribromophenoxy)-ethane
- Pentabromotoluene
- Bromo-chlorinated paraffins
- Di-(2-ethylhexyl)tetrabromophthalic ester
- Ethylene-bis-(tetrabromophthal imide)
- Tetradecabromodi phenoxybenzene
- 1,2-Dibromo-4(1,2 dibromomethyl) cyclohexane
- Ethylene-bis(5,6-dibromo-norbornane-2,3-dicarbox imide
- 1,3,5-tris(2,3-dibromo-propoxy)-2,4,6-triazine

**REACTIVE BFRs**
- Tetrabromobisphenol A
- Tetrabromobisphenol S
- 2,4-Di-, 2,4,6-Tri- and pentabomophenol
- Tribromoneopentyl alcohol
- Vinylbromide
- Tribromophenyl allyl ether
- 2,3-Dibromo-2-butene-1,4-diol
- Tetrabromophthalic acid Na salt
- Tetrabromophthalic anhydride
- N,N´-Ethylene-bis-(tetrabromophthal imide)
Polybrominated Diphenyl Ethers (PBDEs)

- 3 Different Commercial Mixtures
  - PentaBDE
  - OctaBDE
  - DecaBDE

- Present in consumer products up to 30% by weight
  - PUF 3-5%
  - TV enclosures – 15%

- Several concerns regarding:
  - neurodevelopmental effects
  - thyroid dysregulation
**Current Regulation on PBDEs**

- **United States**
  - Voluntary phase out of PentaBDE, OctaBDE by chemical companies
  - Bans passed in Maine and Washington (DecaBDE)
  - Proposed bans in other states are pending

- **European Union**
  - Penta- and OctaBDE Banned in 2006
  - DecaBDE Banned in Sweden - January 2007
  - DecaBDE Banned in EU – July 2008
  - Production Banned in Canada – July 2008
Environmental Contamination

Widespread PBDE contamination of air, water, sediments, biosolids, biota

- Dominant mixture in humans: PentaBDE
- DecaBDE increasing in wildlife and humans
- Bioaccumulation of all PBDEs

Sediments and biosolids:
- Tens to thousands of ug/kg dw total ΣPBDEs
- DecaBDE up to mg/kg dw levels

Humans:
- ΣPBDEs in human blood, milk, tissue:
  - Inc by ~100x in past 30 yrs
  - ~17X higher in NA vs Europe
  - ~2 ng/g lipid (Europe) vs ~35 ng/g lipid (NA)

Hale et al., 2003; Hites, 2004; Schecter et al., 2003
Bioaccumulation

From 1970 – 2003:

Marine Mammals –
• Doubling time ~7 years
  • Canadian Arctic - <10 ng/g lipid
  • Other regions - >>1000 ng/g lipid

Bird Eggs –
• Herring gulls (Great Lakes) and Guillemot (Sweden) doubling ~3-6 years
  • Mean ~1700 ng/g lipid

Fish –
• NA: 310 ng/g lipid ΣPBDEs
• Europe: 49 ng/g lipid ΣPBDEs

More Recently, 1982 – 2006:

• BDE-209, nonaBDEs, octa-BDEs increasing
• Herring gull eggs (Great Lakes) doubling times ~2-3 years, 3-11 years, and 2-5 years, respectively
• Consistent with BDE-47, -99, -100 trend

Gauthier et al., 2008; Hites, 2004; Norstrom et al., 2002
**Major Concerns about PBDEs:**

- Rapidly accumulating in humans and animals
- **Hormonal disruption**
  - Effects on thyroid, estrogen and testosterone
- **Developmental effects**
  - Irreversible learning/behavioral effects in young animals
  - Decreased ovarian follicles, sperm counts
  - Recent Scandinavian study – maternal PBDE associated with genital birth defect in baby boys
- **Cancer?**
  - Structures similar to known carcinogens (PCBs, PBBs)
  - Environmental conversion to known carcinogens (dioxins and furans)
Toxic Effects from PBDEs

- PBDEs have chemical structures which are very similar to known cancer causing and toxic compounds: **PCBs, dioxins, furans, etc.**

- Laboratory studies now demonstrate that PBDEs have very similar toxic effects as these legacy contaminants.
PBDEs in Human Samples From Around the World

Total PBDE concentrations in human blood, milk and tissue (in ng/g lipid) shown as a function of sampling year. From Hites et al., 2005
Are Children’s Body Burdens Greater than Adults?
A Case Study from Berkeley, California

Serum
Data from Fisher et al., 2006

<table>
<thead>
<tr>
<th>Total PBDEs (ng/g lipid)</th>
<th>Father</th>
<th>Mother</th>
<th>Daughter 5 yrs</th>
<th>Son 18 mos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Children’s Exposure to Chemicals Found in Dust

- Children are spending more time indoors
- Children have a high number of hand-to-mouth contacts
- Indoor environments are often more polluted than outdoor environments

Models Suggest Children Have Greatest Exposure

Jones-Otazo et al., 2005
Is Exposure Greater Outdoor or Indoors?
Answer: Indoors Much Higher!

![Graph showing the comparison between indoor and outdoor air exposure to PBDEs.](image)

- **Indoor Air**
  - Personal Air
  - Main Living Room
  - Bedroom
  - Indoor (Ottawa, CA)

- **Outdoor Air**
  - Chicago, US
  - L. Superior, US
  - Ottawa, CA
  - Birmingham, UK

**Present Study Reference Values**

Standberg et al., 2001, Wilford et al., 2004, Harrad et al., 2006
# PBDE Levels (ppb) in Indoor Dust

<table>
<thead>
<tr>
<th>Type of Dust</th>
<th>Study Location</th>
<th>Range $\sum$PBDEs</th>
<th>Range DecaBDE</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>House</td>
<td>USA</td>
<td>700 - 69,000</td>
<td>143 – 66,000</td>
<td>Schecter et al., 2005</td>
</tr>
<tr>
<td>House</td>
<td>USA</td>
<td>780 - 31,000</td>
<td>160 - 8750</td>
<td>Stapleton et al., 2005</td>
</tr>
<tr>
<td>House</td>
<td>USA</td>
<td>200 - 269,000</td>
<td>60 - 263,000</td>
<td>Allen et al., 2008</td>
</tr>
<tr>
<td>House</td>
<td>Canada</td>
<td>170 - 170,000</td>
<td>74 – 10,000</td>
<td>Wilford et al., 2005</td>
</tr>
<tr>
<td>House</td>
<td>Germany</td>
<td>25 - 25,000</td>
<td>20 – 19,100</td>
<td>Knoth et al., 2003</td>
</tr>
<tr>
<td>House</td>
<td>Kuwait</td>
<td>1 - 390</td>
<td>0.8 - 340</td>
<td>Gevao et al., 2006</td>
</tr>
<tr>
<td>Car</td>
<td>USA</td>
<td>7785**</td>
<td>4651**</td>
<td>Webster et al., 2010</td>
</tr>
</tbody>
</table>

**represents geometric mean value (n=20)**
Alternate FRs Being Used to Replace PBDEs:

What’s being used in new flame retardant mixtures being added to consumer products?

Answer: We don’t always know.....companies not required to release information to the public.
How can we find out what chemicals are used in consumer products?

Answer: Scientists have to chemically test foam in the lab using mass spectrometry, which sometimes, but not always, provides the answer.

Couch:
• Manufactured by Flexsteel
• $\sum$TBB & TBPH = 4.2% of foam
• Ratio of TBB:TBPH suggests BFR is FM 550
Identifying FRs in Consumer Products (Stapleton et al., 2009)

• 26 Foam Samples Voluntarily Collected From Current Use Furniture Items in The US

• 15 samples were found to contain TDCPP (1-5% by weight)

Tris (1,3-dichloro-2-propyl) phosphate (TDCPP)

TDCPP was used in children’s pajamas up until the late 1970s; it was found to be absorbed through the skin and was shown to be mutagenic (Gold et al., 1978, Lynn et al., 1981)
## FR Levels in Indoor Dust
*(Stapleton et al., 2009; Webster et al., 2010)*

<table>
<thead>
<tr>
<th>Flame Retardant</th>
<th>% Detection</th>
<th>Range</th>
<th>Geometric Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPP</td>
<td>98</td>
<td>&lt;150-1,798,000</td>
<td>4496</td>
</tr>
<tr>
<td>TCPP</td>
<td>24</td>
<td>&lt;140-5490</td>
<td>572</td>
</tr>
<tr>
<td>TDCPP</td>
<td>96</td>
<td>&lt;90-980,000</td>
<td>6307</td>
</tr>
<tr>
<td>PBDEs</td>
<td>100</td>
<td>980-44,550</td>
<td>4740</td>
</tr>
<tr>
<td>BTBPE</td>
<td>100</td>
<td>1.4-950</td>
<td>21</td>
</tr>
<tr>
<td>HBCD</td>
<td>92</td>
<td>&lt;2-2,750</td>
<td>166</td>
</tr>
<tr>
<td>TBB</td>
<td>44</td>
<td>&lt;450-75,000</td>
<td>248</td>
</tr>
<tr>
<td>TBPB</td>
<td>60</td>
<td>&lt;300-47,110</td>
<td>923</td>
</tr>
</tbody>
</table>

Alternate BFRs now in Use
Toxic Properties of TDCPP

- Considered a “Probable human carcinogen by the U.S. Consumer Product Safety Commission

- Considered a “Moderate Hazard” for reproductive and developmental effects by the EPA

- Metabolism of TDCPP leads to more toxic and bioreactive metabolites that are known mutagens

- Has very similar chemical structure to organophosphate pesticides

\[ \text{Tris (1, 3-dichloro-2-propyl) phosphate} \]

\[ \text{TDCPP} \]

\[ \text{Chlorpyrifos} \]
What Does This Imply?

- There is no doubt that people, and particularly children, are chronically (daily) exposed to flame retardants, including PBDEs, TDCPP, FM 550.....

- Children are receiving greater exposure to flame retardants compared to adults

- Effects from exposure to flame retardants are more pronounced in developing organisms (i.e. children). Rodent studies clearly show critical windows of exposure to flame retardants that coincide with rapid brain development (Erikkson et al., 2002; Viberg et al., 2002, 2003, 2005)

- Children’s exposure to TDCPP is similar, or greater than, exposure to PBDEs......
Which Baby Products Contain Halogenated Flame Retardants?
A Significant Number of Products........
The California Flammability Standard Labels:

From My Son’s Highchair

From a Daycare Center Infant Mattress Contains FM 550 in Foam
The Federal (CPSC) Mattress Standard Label:

From a Daycare Center Infant Mattress
Do Portable Crib Mattresses Need Flame Retardants to Meet the Federal Mattress Standard?

• Answer: No!
• Why?
  – The federal standard (CFR 1633) measures heat emitted from the burning of the mattress. Crib mattresses are too small and will never produce enough heat to reach the criteria of the standard. Flame retardants do nothing to help the mattress meet this standard.
• So Why are they in the Crib Mattress?
  – To meet the CA TB 603 (a home furnishings standard)
Excerpt from Letter to Assemblyman Mark Leno from the U.S. CPSC:

Thank you for your September 10, 2008 letter requesting information on the fire risk associated with children’s furnishings and other juvenile products containing polyurethane foam. As you know, the U.S. Consumer Product Safety Commission* (CPSC) has the authority to regulate hazards to children under the Federal Hazardous Substance Act (FHSA) and the authority to regulate fire risks associated with interior furnishings under the Flammable Fabrics Act (FFA). The Commission can regulate specific products if it determines that the products pose an unreasonable risk of death or injury under foreseeable conditions of use.

To date, the Commission has not made such a determination with respect to the risk of fire for most of the juvenile products you mentioned; however, crib mattresses (including portable crib mattresses) are subject to the Commission’s mattress regulations (16 CFR Parts 1632 and 1633), and children’s upholstered furniture articles are covered under the Commission’s March 2008 proposed rule on upholstered furniture (proposed 16 CFR Part 1634). Although both of these categories of products may contain polyurethane foam fillings, none of these standards contains performance requirements specifically applicable to polyurethane foam components.

A review of the available consumer product-related fire injury data from the Commission’s National Electronic Injury Surveillance System (NEISS) for 2000-2008 does not identify any incidents in which a stroller, infant carrier, bassinet or nursing pillow was the item first ignited. Since the category of “infant carriers” may include car seats, you may wish to check with the National Highway Traffic Safety Administration (NHTSA) about flammability standards applicable to those products. The question of how California Technical Bulletin 117 is applied to various products is, of course, one best addressed in the context of California law and regulatory authority.

▪ A copy of this letter is provided in the handouts
Is TB 117 Effective?

• Major cause of decrease in national fire deaths is:
  – Decreased cigarette smoking
  – Smoke alarms, Building sprinklers,
  – Child proof lighters, Fire safe cigarettes, etc.

• No evidence that TB 117 has had any greater effect in preventing fire deaths here than in other states (which have no furniture flammability standards)
U.S. Home Fire Deaths, 1981-2005

Residential Fire and Flame Death Rates in U.S. and California, trend data with linear estimation line, 1981-2005

Source: WISQARS, Centers for Disease Control and Prevention
Prepared by: California Department of Public Health, EPIC Branch
Decline in Fire Deaths

<table>
<thead>
<tr>
<th>State</th>
<th>Decrease (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>- 40%</td>
</tr>
<tr>
<td>Georgia</td>
<td>- 36%</td>
</tr>
<tr>
<td>Illinois</td>
<td>- 45%</td>
</tr>
<tr>
<td>Michigan</td>
<td>- 38%</td>
</tr>
<tr>
<td>New York</td>
<td>- 48%</td>
</tr>
<tr>
<td>Ohio</td>
<td>- 41%</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>- 41%</td>
</tr>
<tr>
<td>Texas</td>
<td>- 37%</td>
</tr>
</tbody>
</table>

“US Unintentional Fire Death Rates by State”
National Fire Protection Association, 2008
In December 2007 the Consumer Product Safety Commission (CPSC) proposed a national furniture flammability standard that can be met without fire retardant chemicals in foam.

“No one wants to trade fire risks for chemical toxicity risks.”

*CPSC Commissioner Thomas Moore*
What Can We Do To Reduce Children’s Exposure to These Toxic Chemicals?

• Support California in their bid to exempt baby products from TB 117 (SB 772 and AB 706)
• Prohibit the sale of TB 117 labeled products in North Carolina
• Offer tax incentives to companies that are enrolled in the CertiPur Program
• Offer tax incentives to companies that sell products without flame retardants added (give consumers a choice!)
Baby products are now advertised as being “BPA Free”, “Lead Free”, or “Phthalate Free”……there’s a large market for baby products that are free of these chemicals.

But why do we not have the CHOICE to be “Flame Retardant Free”?
FRs in Children’s Toys: Concentration, Composition, and Children’s Exposure and Risk Assessment

Introduction

A number of brominated flame retardants (BFRs), such as polybrominated diphenyl ethers (PBDEs), tetrabromobisphenol A, hexabromocyclododecane, and novel decabromodiphenyl ether (DEBP) and 1,2-bis(4,5-tribromophenoxy)ethane (BBP), have been used to enhance the safety of a variety of commercial and consumer products (1). Over the past few decades much attention has been given to PBDEs in the environment and their effects on humans (2). Three PBDE technical mixtures were commercially available, that is, pentabDE, octaBDE, and decabDE, but the former two products have been banned or voluntarily withdrawn from use in some regions of the world (3–5) because of their ubiquitous presence, bioaccumulation, and potential toxicities (2, 6). DecaBDE, made up mostly of BDE209, has become controversial in recent years because of increasing evidence of its bioaccumulation (7) and tendency to breakdown into more toxic lower brominated congeners in the environment, as well as within the bodies of biota (8–10). DecaBDE has been banned in parts of the United States, and the European Union banned its use in electronic products on July 1, 2008 (8, 11). Recently, more concerns have arisen

PBDEs and Alt FRs now detected in children’s toys…..more exposure....
What is CertiPUR?

CertiPUR is a voluntary standard introduced to flexible foam manufacturers in order to advance the industry’s response to SHE (safety, health and environmental) matters specifically affecting the furniture and bedding industries. Based upon existing standards and scientific research, this scheme allows foamers to demonstrate the commitment to SHE to their customers. The standard only covers foams used in bedding and upholstery applications. It is designed as a common European standard covering the chemical compounds and substances used to produce flexible PU foams or which may be contained in them and does not apply to physical characteristics of the foam.

To be a certified supplier of CertiPUR foams, manufacturers must meet technical requirements relating to the use or prohibited use of heavy metals, phthalate plasticisers, organo-tin compounds, TDA, MDA, VOCs, certain dyes, CFC, HCFC and Halon blowing agents, materials affected by certain R phrases and biocides. Isocyanates used in the manufacture of CertiPUR foams must not exceed the maximum content of 0.07 % total chlorine content.
**What Will the Chemical Companies Try to Tell You:**

**Tactic**: If you remove flame retardants from children’s products more children will die in fires.

This is not true. There is no data demonstrating or even suggesting that flame retardants reduce the number of fires or reduce fire associated deaths. Ask them for some proof that chemical additives save lives…. there is none. Fire deaths have diminished everywhere due to education, reduced smoking rates, self-extinguishing cigarettes, etc.

Nursing pillows, strollers, changing pads, and portable crib mattresses are not fire hazards. We do not need chemical additives in these products.
Thank you! Questions??

www.environmentcalifornia.org

www.watoxics.org/issues/pbde/pbde-free-pictures-2

**Fact Sheets for California SB 772 and AB 706 are included in your handouts**