Replacement Flame Retardants

Collaborative on Health and the Environment
Pioneers Under 40 in Environmental Public Health
October 24, 2017

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Flame retardants

WHERE FLAME RETARDANTS ARE FOUND

- In home insulation
- In upholstered furniture containing polyurethane foam — manufacturers add it to meet flammability standards enacted by California but followed nationwide
- In dust — children are exposed to higher doses of flame retardants than adults because they spend more time on the floor and put things in their mouths
- In carpet padding made with recycled foam
- In the plastic casing of some electronics
- In some baby products containing polyurethane foam, including highchairs and diaper-changing pads

SOURCES: EPA, Tribune reporting

KATIE NIELAND/TRIBUNE
**Total daily dose**

Nanograms (billionths of a gram) of PBDE per kilogram of body weight, per day

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>7.1</td>
</tr>
<tr>
<td>Ages 12-19</td>
<td>8.3</td>
</tr>
<tr>
<td>Ages 6-11</td>
<td>13</td>
</tr>
<tr>
<td>Ages 1-5</td>
<td>47.2</td>
</tr>
<tr>
<td>Infants</td>
<td>141</td>
</tr>
</tbody>
</table>

Source: EPA  
Graphic: Chicago Tribune  
© 2012 MCT
Polybrominated diphenyl ethers (PBDEs)

- **Thyroid Hormone**
  - Reduced TSH and T\(_4\)

- **Neurodevelopment**
  - Behavior, cognition and motor skills in birth cohorts

- **Reproductive**
  - Increased time to pregnancy and failed implantation, decreased birth weight, altered growth trajectory
Replacements in Foam

PentaBDE
Phased-Out
(2005)

TDCIPP

Firemaster
550®

EH-TBB
BEH-TBPH
TPHP
ITPs
Characterizing Human Exposure

Nursing Mothers

Office Workers

Gymnasts
Biomonitoring Study Framework

Data & Sample Collection

Data & Sample Processing & Storage

Data Analysis

Normalize

\[ e^\beta \]
Mothers with 7 or more electronic items had average HBCD concentrations that were 153% higher than those who had 4 or fewer (95% CI=34-375%).

Carignan et al. ES&T (2012)
EPA’s Intervention

- Alternatives Assessment
- Significant New Use Rule
Urinary TDCIPP Metabolite

29 Office workers

Parent Compound

Urinary Metabolite

TDCIPP

100% Detection Frequency

Carignan et al. Environ Int (2013)

Linear regression: Evaluate associations with demographic, dietary, and behavioral characteristics
Predicated by Office Building

GM concentration 26% lower among workers in Building A (p=0.01)
Office environment a source of exposure

Carignan et al. Environ Int (2013)
Predicted by Handwashing

Carignan et al. Environ Int (2013)
Public Health Interventions

1. Hand-washing

2. Change in Boston Fire Codes negating requirement for flame retardants in upholstered furniture for public spaces
Foam in Gymnastics Safety Equipment
Loose Foam Pit
Elevated in Gym Air and Dust

Dust: 200x higher in gym compared to residences (371 vs 1.69 ug/g)

Air: 400x higher in gym compared to residences (120 vs 0.29 ng/m³)

Consistent with first gym and with a second study (Laguardia et al. 2014)
Light Degrades Foam into Dust
Elevated in Gymnast Serum

Carignan et al. ES&T (2013)
89% contained flame retardants

Components of Firemaster® 550

Carignan et al. Environ Int (2016)
The Gymnast Flame Retardant Collaborative

addressing concerns regarding flame retardants in gymnastics equipment

www.gymnastcollaborative.org

The Collaborative
About Us

Flame Retardants
The Data

Take Action
Reducing Gymnast Exposure

Stay Updated
By Email or Social Media
Flame Retardants Act on the Hypothalamic Pituitary Thyroid Axis

- Polybrominated diphenyl ethers (PBDEs)
- Hexabromocyclododecane (HBCD)
- Tetabromobisphenol-A (TBBP-A)

Chemical Structures:
- Tris(1,3-dichloro-2-propyl) phosphate (TDCIPP)
- Triphenyl Phosphate (TPHP)
- Isopropyl triphenyl phosphate (mono-ITP)
Health Effects of Replacements

• Potential carcinogen (TDCIPP)

• Neurologic
  – Neurotoxicity: in vitro effects similar to chlorpyrifos (TDCIPP)
  – Neurodevelopment: Increased anxiety (FM550)

• Reproductive
  – Reduced egg quality, spermiation, and fecundity in zebrafish (TDCIPP, TPHP)
  – Decreased semen quality in adult men (TDCIPP)
Benefits:

- Measure exposure preconception (sensitive)
- Include infertile couples (susceptible)
- Include male partner (important)
- Measure early developmental endpoints
Higher Among Women

Carignan et al. EHP 2017
Predictors and Trends

- Decreased with Age
- Increased with BMI
- Varied with time (year and season)
- Weak to Moderately Correlated ($r_s = 0.19$ to $0.25$; $p<0.05$)
- $ICC_{months} = 0.34$ to $0.37$; $ICC_{week} = 0.44$ to $0.53$
Carignan et al. EHP 2017

Quartiles of Organophosphate Flame Retardant Metabolites

<table>
<thead>
<tr>
<th>Metric</th>
<th>Quartile</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implantation</td>
<td>Q3</td>
<td>31%</td>
</tr>
<tr>
<td>Clinical Pregnancy</td>
<td>Q3</td>
<td>41%</td>
</tr>
<tr>
<td>Live Birth</td>
<td>Q3</td>
<td>38%</td>
</tr>
</tbody>
</table>
Carignan et al. EHP 2017

Quartiles of Organophosphate Flame Retardant Metabolites
Clinically Relevant

18% Decline in the proportion of live births
### Table: Fertilization, Implantation, Pregnancy, and Live Birth Association

<table>
<thead>
<tr>
<th>Oocyte Count</th>
<th>Fertilization</th>
<th>Implantation</th>
<th>Pregnancy</th>
<th>Live Birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive association (p&lt;0.05)</td>
<td>Negative association (p&lt;0.05)</td>
<td>Negative association, p&lt;0.20</td>
<td>Negative association, p&lt;0.05</td>
<td>Negative association, p&lt;0.20</td>
</tr>
</tbody>
</table>

#### Chemical Structures

- **TDCIPP**
- **TPHP**
- **Mono-ITP**

**Chemical Formulas**:

1. **TDCIPP**
   - Chemical Formula: \(\text{C}_8\text{H}_8\text{O}_4\text{S}\) (TDCIPP)
2. **TPHP**
   - Chemical Formula: \(\text{C}_8\text{H}_8\text{O}_4\text{S}\) (TPHP)
3. **Mono-ITP**
   - Chemical Formula: \(\text{C}_8\text{H}_8\text{O}_4\text{S}\) (Mono-ITP)
Consistent with other studies

- Promotion of oocyte maturation but reduction in egg quality, reduced spermiation, and decreased fecundity in zebrafish (Wang et al. 2015)
- Decreased sperm motility in adult men (Meeker et al. 2010)
Tips for Reducing Exposure

- Support programs like EPA’s Safer Choice
- Opt for FR-free products (www.greensciencepolicy.org)
- Limit electronic items (AV)
- Avoid installing carpet padding that uses recycled foam
- Wash hands before eating
Poly- and Perfluoroalkyl Substances

Hu et al. 2016 Environ Sci Technol Lett
Acknowledgements
Exposure Studies

Tom Webster
Mike McClean
Wendy Heiger-Bernays
Alicia Fraser
Deb Watkins
Nerissa Wu
Andreas Sjödin
Heather Stapleton
Ellen Cooper
Simon Roberts
Mingliang Fang
Craig Butt
Mohamed Abdallah
Stuart Harrad

Study Participants

T32ES014562, R01ES015829,
R01ES016088
Acknowledgements
Fertility Study

Russ Hauser
Paige Williams
Lidia Minguez Alarcon
Jennifer Ford & Staff

Thomas Toth & Clinicians

John Meeker
Heather Stapleton
Craig Butt

National Institute of Environmental Health Sciences
T32ES007069, R01ES009718, R01ES022955, R01ES000002