Life Cycle Assessment of Fire Retardants

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SP Fire Technology
Flame retardants

- Environmental effect discussed since 1980’s
- Qualitative analysis too subjective
- SP and partners developed quantitative analysis method developed based on LCA (start mid-90’s)
- Risks
  - Exposure during manufacture, use, disposal
  - Fires
- International legislation, one of many drivers
Fire-LCA model
Fire-LCA Model: Aim

• Evaluate environmental benefits of a flame retardant (FR) relative to the environmental costs of their production and use

• Traditional eco-evaluation of FRs:
  – Concentrate on perceptions of hazard rather than risk
  – No effort made to consider risks associated with fires, i.e., functionality of FRs marginalised
Crude material preparation

Fire retardant production

0 or X % FR in material

Recycling processes

Material production

Decontamination processes

Production of primary product

Replacement of primary product

Use of primary product

Fire of secondary products

D %

Replacement of primary products

Fire extinguishing

A %

Fire of primary product

B %

Fire of secondary product

C %

Fire of primary products

Landfill

Ash

As A+B+C+D=100 %

Landfill fire

Replacement of secondary product

Ash

Incineration

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Fire Statistics

- Most countries keep detailed fire statistics
- Variation between sources within a country and between different countries
  - Fire brigade – typically large fires
  - Insurance companies – both large and small fires
  - Differences due to different regulations between countries, e.g. USA and Europe
TV Case Study

Investigate the environmental impact of choosing higher level of fire safety in enclosure material
TV Fire Severity, Fire Statistics Model

- Statistical model based on European and US statistics
- Division of fire sizes into: minor, full TV, full room, full house

<table>
<thead>
<tr>
<th>European TV</th>
<th>US TV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>F R</td>
</tr>
<tr>
<td>160 minor, 30% replace</td>
<td>×</td>
</tr>
<tr>
<td>58 minor, 100% replace</td>
<td>×</td>
</tr>
<tr>
<td>88 TV only</td>
<td>×</td>
</tr>
<tr>
<td>8 full room</td>
<td>×</td>
</tr>
<tr>
<td>11 full house</td>
<td>×</td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
</tr>
<tr>
<td>4 full house (6 TV only)</td>
<td>×</td>
</tr>
</tbody>
</table>
# LCA Results - Scenarios

<table>
<thead>
<tr>
<th>Present</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 % Incineration</td>
<td>1 % Incineration</td>
</tr>
<tr>
<td>2 % Disassembly</td>
<td>89 % Disassembly</td>
</tr>
<tr>
<td>~97 % Landfill (+ Fires)</td>
<td>~10 % Landfill (+ Fires)</td>
</tr>
</tbody>
</table>

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Energy Use (10^6 TVs, 10 years)

- NFR TV Today
- FR TV Today
- NFR TV Future
- FR TV Future

Energy sources:
- Hydro
- Nuclear
- Natural gas
- Crude oil
- Coal

Energy Use:
- 1.6 \times 10^{10}
- 1.2 \times 10^{10}
- 8.0 \times 10^{9}
- 4.0 \times 10^{9}
- 0 MJ
PAH emissions to air \((10^6 \text{ TVs, 10 years})\)

<table>
<thead>
<tr>
<th></th>
<th>NFR TV Today</th>
<th>FR TV Today</th>
<th>NFR TV Future</th>
<th>FR TV Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg PAH</td>
<td>697</td>
<td>14.5</td>
<td>686</td>
<td>3.61</td>
</tr>
</tbody>
</table>

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TXDD-equivalents to air (10^6 TVs, 10 years)

- TBDD equiv.: 3 × 10^{-5}
- TCDD equiv.: 1 × 10^{-5}

<table>
<thead>
<tr>
<th></th>
<th>NFR TV Today</th>
<th>FR TV Today</th>
<th>NFR TV Future</th>
<th>FR TV Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Today</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Future</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Why are PAH, TXDD-equiv. lower for US TV

• Minimised from controlled combustion (TBDD-equivalent is a special case due to allocation)
• Major constituents of fire cases from flashed-over fires
• European TV Fire Statistics model has European TV involved in more and larger fires
Conclusions

• Minor energy difference between US and European TVs
• Fires insignificant source of CO, CO$_2$, NO$_x$ ....
• European:US TV-difference most marked for large organic species
• PAH most significant toxicologically
• Full risk assessment must consider risk for death and injury:
  – Conservative estimate: 16 dead, 197 injured in Europe each year from TV fires
  – Upper limit: 160 dead and 2000 injured
Furniture Case Study

Investigate the environmental impact of choosing higher level of fire safety in sofa
Sofa Fire Severity, Fire Statistics Model

- Statistical model based on UK and mainland European statistics

<table>
<thead>
<tr>
<th>Fires/million sofas</th>
<th>FR sofa</th>
<th>Non-FR sofa</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary fires</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small fires</td>
<td>215</td>
<td>187</td>
</tr>
<tr>
<td>Starting in sofa</td>
<td>0,33</td>
<td>28</td>
</tr>
<tr>
<td>Confined to sofa</td>
<td>0,18</td>
<td>12</td>
</tr>
<tr>
<td>Confined to room</td>
<td>0,12</td>
<td>14</td>
</tr>
<tr>
<td>Confined to building</td>
<td>0,03</td>
<td>2,5</td>
</tr>
<tr>
<td><strong>Secondary fires</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confined to room</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>Confined to building</td>
<td>115</td>
<td>115</td>
</tr>
</tbody>
</table>
HCN emissions to air (10^6 Sofas, 10 years)
PAH emissions to air (10^6 Sofas, 10 years)

![Graph showing PAH emissions to air for different methods of disposal or production.](image)

- **Non-**
- **FR**
- **P-FR**
- **Br-FR**

**kg/million sofas**

**PAH**

- Furniture prod
- Repl Prod
- Landfill
- Incineration
- Heat Recovery
- FR production
- Fire
- Total
TXDD-equivalents to air ($10^6$ Sofas, 10 years)
PAH and dioxin background levels

• Chlorinated dioxins and furans from sofa fires approximately 0.003% of background emission in UK each year

• PAH from sofas approximately 1% of emissions from fires each year (0.05 % of background from all sources)
Conclusions

- Minor energy difference between FR and non-FR sofas
- Fires insignificant source of CO, CO$_2$, NO$_x$
- Fires important source of PAH, HCN, dioxins and furans
- PAH most significant toxicologically
- Use of flame retardants in upholstered furniture does NOT have an adverse impact on the environment based on this study (toxicology not included)
- Full risk assessment must consider risk for death and injury
- Available evidence demonstrates (UK) that the use of flame retardants can significantly improve the fire performance of furniture thus reducing fire death and injuries
Fire emissions have a significant potential to effect both people and the Environment.