Smoke Gas Toxicity

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BMVI, Section StV 22
Structure

1. Previous research on bus fire safety
2. Accidentology
3. Smoke gas toxicity
4. Upcoming research
5. Other activities that contribute to bus safety
6. Summary
Previous Research

- Study on smoke production, development and toxicity in bus fires
- Project duration 2009-2013
- Research project by BAM, the Federal Material Research Institute, financed by BASt
- Recommendations for the upgrade of the fire safety requirements for bus interior materials
  - Burning behavior
  - **Smoke gas toxicity**
  - Technical assistance systems (e.g. fire detectors)

- General conclusion of the researchers: alignment of vehicle standards to rail standards necessary!
Accidentology

- Approximately 75% of all bus fires start in engine compartment
- Approximately 85% of busses were driving while fire started
- Mostly city busses (60%)
- Fatalities typically from catastrophic bus fires

- Study leaves open how often accidents contributed to the fire or to the injuries
Improved Standards: Modifications to UN R118, UN R107

- Fire sensor in engine compartment  
- Burning behavior internal materials (cables)  
  *(eff. 9.12.2015/9.12.2015)*
- Fire extinguisher system in engine compartment  
  *(eff. 10.6.2018/10.6.2019)*
- Burning behavior internal materials (fire speed, test direction)  
  *(eff. 26.7.2017/26.7.2020)*
- Emergency exits  
  *(eff. 10.6.2018/10.6.2020)*
### Conventional Index of Toxicity – „Average Toxicity?“

The Conventional Index of Toxicity (CIT) is a method for calculating the toxicity of smoke emissions. It is defined as:

\[
CIT = 0.0805 \cdot \sum_{i=1}^{8} \frac{c_i}{C_i}
\]

where:
- \(c_i\) is the concentration of the smoke component \(i\) in the chamber after 4 or 8 minutes respectively (mg/m\(^3\)).
- \(C_i\) is the reference concentration of the smoke component \(i\) (mg/m\(^3\)).

The formula represents an average toxicity index based on the concentrations of the eight most toxic substances:

- Carbon Dioxide (\(\text{CO}_2\))
- Carbon Monoxide (\(\text{CO}\))
- Hydrogen Bromide (\(\text{HBr}\))
- Hydrogen Chloride (\(\text{HCl}\))
- Hydrogen Cyanide (\(\text{HCN}\))
- Hydrogen Fluoride (\(\text{HF}\))
- Nitrous Gases
- Sulphur Dioxide (\(\text{SO}_2\))

The reference concentrations for these substances are given in the table below:

<table>
<thead>
<tr>
<th>Smoke gas component</th>
<th>(\text{CO}_2)</th>
<th>(\text{CO})</th>
<th>(\text{HBr})</th>
<th>(\text{HCl})</th>
<th>(\text{HCN})</th>
<th>(\text{HF})</th>
<th>(\text{NO}_2)</th>
<th>(\text{SO}_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference concentration</td>
<td>72000</td>
<td>1380</td>
<td>99</td>
<td>75</td>
<td>55</td>
<td>25</td>
<td>38</td>
<td>262</td>
</tr>
</tbody>
</table>
Threshold Values For CIT Calculation And Their Meaning

<table>
<thead>
<tr>
<th>Smoke gas component</th>
<th>CO₂</th>
<th>CO</th>
<th>HBr</th>
<th>HCl</th>
<th>HCN</th>
<th>HF</th>
<th>NOₓ</th>
<th>SO₂</th>
</tr>
</thead>
<tbody>
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<td>Reference concentration</td>
<td>72000</td>
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<td>38</td>
<td>262</td>
</tr>
</tbody>
</table>

- CO₂: 80000 ppm → Unconsciousness, **short-termed death**
- CO: 1380 ppm → Headaches in 20 min, **fatal within 1-2 hours**
- HBr: 99 ppm → Hard incapacitating impact on escape after 10 min
- HCl: 50 ppm → breathes stopped by lung irritation
- HCN: 100 ppm → **Fatal after almost 1 hour**
- HF: 24 ppm → Hard incapacitating impact on escape after 1 hour
- NOX: 50 ppm → Strong irritation on respiratory tract and eyes
- SO₂: 100 ppm → **Life-threatening**

**CIT = 0.64: all values at threshold**
Experiments

- Body insulation
- Floor covering
- Side panel
- Ceiling (seats, gangways)
- Foam of seats
## Results

- **CIT**: “Conventional Index for Toxicity“
- **CIT = 0.64** if all components approach the specified reference concentration

<table>
<thead>
<tr>
<th>Component</th>
<th>4 min – CIT OK?</th>
<th>8 min – CIT OK?</th>
<th>Individual concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body insulation</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
<tr>
<td>Floor covering</td>
<td>Not Ok</td>
<td>Not Ok</td>
<td>Toxic HCl</td>
</tr>
<tr>
<td>Side panel</td>
<td>Ok</td>
<td>Ok</td>
<td>4 min: Fatal ~ 10 min&lt;br&gt;8 min: Fatal &lt;= 10 min&lt;br&gt;8 min: Fatal 30-60 min</td>
</tr>
<tr>
<td>GRP part</td>
<td>Ok</td>
<td>Ok</td>
<td>HCN</td>
</tr>
<tr>
<td>Ceiling seat</td>
<td>Not Ok</td>
<td>Not Ok</td>
<td>Toxic HCl</td>
</tr>
<tr>
<td>Ceiling gangway</td>
<td>Not Ok</td>
<td>Not Ok</td>
<td>Toxic HCl</td>
</tr>
<tr>
<td>Foam of seats</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
</tbody>
</table>
## Results (2)

<table>
<thead>
<tr>
<th>Material (material requirement)</th>
<th>Components of CIT-value</th>
<th>CIT-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMO MSC 61(67) Annex 1, Part 2</td>
<td>-</td>
<td>1450</td>
</tr>
<tr>
<td>ABD 00031 (Airbus)</td>
<td>-</td>
<td>1000</td>
</tr>
<tr>
<td>BSS 7239 (Boeing)</td>
<td>-</td>
<td>3500</td>
</tr>
<tr>
<td>SMP 800-C (Bombardier)</td>
<td>90000</td>
<td>3500</td>
</tr>
<tr>
<td>First symptoms of intoxication</td>
<td>20000</td>
<td>200</td>
</tr>
<tr>
<td>Lethal concentrations</td>
<td>80000</td>
<td>1000</td>
</tr>
<tr>
<td>Body insulation (R1)</td>
<td>4 min</td>
<td>5500</td>
</tr>
<tr>
<td></td>
<td>8 min</td>
<td>6900</td>
</tr>
<tr>
<td>Floor covering (R9)</td>
<td>4 min</td>
<td>7500</td>
</tr>
<tr>
<td></td>
<td>10 min</td>
<td>100</td>
</tr>
<tr>
<td>Side panel (R1)</td>
<td>4 min</td>
<td>3600</td>
</tr>
<tr>
<td></td>
<td>8 min</td>
<td>4400</td>
</tr>
<tr>
<td>GRP part (R1)</td>
<td>4 min</td>
<td>19000</td>
</tr>
<tr>
<td></td>
<td>8 min</td>
<td>35700</td>
</tr>
<tr>
<td>Ceiling over seats (R1)</td>
<td>4 min</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>967</td>
</tr>
<tr>
<td>Ceiling over gangways (R1)</td>
<td>4 min</td>
<td>16500</td>
</tr>
<tr>
<td></td>
<td>8 min</td>
<td>20000</td>
</tr>
<tr>
<td>Foam of seats (R20)</td>
<td>4 min</td>
<td>14200</td>
</tr>
<tr>
<td></td>
<td>8 min</td>
<td>15800</td>
</tr>
</tbody>
</table>
Conclusion – Smoke Gas Toxicity

• In general CIT and individual toxic concentrations in line
• In one case, the Hydrogen Cyanide concentration approaches values for fatality (and CO after 30-60 minutes)
  • after 10 min (4 min burning test)
  • less than 10 min (8 min burning test)
• In another case, CO is fatal after ~ 30 – 60 min

• At this stage, it is still unclear whether the CIT value is a good criterion for bus materials
• **What is a good criterion for smoke gas toxicity on busses?**
• **Is a new criterion needed?**
• **Is a tailored test for the bus sector more appropriate?**
Upcoming Research

Identification of appropriate criterion to limit smoke gas toxicity in busses
→ Identification of smoke gas toxicity from current materials
→ Identification of relevant materials
→ Identification of relevant smoke gas components
→ Definition of a simplified test procedure
→ Derivation of threshold values for simplified test procedure

Project will last 10 month, has not started as of now. Input from BMFE still possible. Intermediate results could be provided to BMFE.
Recent Severe Fire (July 2017)

- Bus (2013) impacts stationary truck with 60-70 km/h impact speed
- Damaged tank, pneumatic reservoir contribute to quick fire spread, 18 fatalities,
- Vehicle fully compliant with regulations applicable at that time, i.e. NOT equipped with AEBS!
- Today’s AEBS: - 20 km/h on stationary tgt.
- German proposal to increase requirements (GRVA)
  - No impact up to 70 km/h
  - Impact ≤25 km/h from 80 km/h
  - Impact ≤40 km/h from 90 km/h
  - Impact ≤55 km/h from 100 km/h
  - Impact ≤65 km/h from 110 km/h
Summary

- Bus fires typically start in the engine compartment (>75%)
- Bus fire safety has been improved
- Improved standards not all effective as of now (for new busses!)
- Smoke gas toxicity not yet limited
- Criterion for smoke gas toxicity under investigation
- Severe bus fires typically after severe accidents
- Improvement of AEBS → German proposal at GRVA
- Improvement of crash safety → GRSP activities
- High potential to address catastrophic bus fires with additional measures!
Thank you for your attention!

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