Short chain PFAS: very persistent but maybe not so toxic or bioaccumulative - how can we make fair comparisons?

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Content

• Research context
• Substitution and chemicals alternatives assessment
• Results from our research so far and discussion about the models/methods
• Implications for further work
The project: Substitution in Practice

The aim of SUPFES is to help industry find alternatives that can replace fluorinated chemicals which are harmful to human health and/or the environment. Within the project a number of scientific and industrial partners collaborate to assess the risks with different chemicals and make sure that the new alternatives really provide desired functionality.

The project will test the hypothesis that emission of persistent fluorochemicals are generated as diffuse emissions and that textiles are an important source to these emissions.
The setting: substitution of hazardous PFAS in DWR

- Durable water repellent (DWR) – textile finishing to impart water (and oil) repellency, with three main chemistry types
- Long-chain per- and polyfluoroalkyl substances (PFAS) are being phased out

Chemicals alternatives assessment: principles

- Reduce Hazard
- Minimize Exposure
- Use Best Available Information
- Require Disclosure and Transparency
- Resolve Tradeoffs
- Take Action

# Chemicals alternative assessment

<table>
<thead>
<tr>
<th>I. Scope</th>
<th>1. Define goal and scope</th>
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<tbody>
<tr>
<td>II. Assessment</td>
<td>2. Characterize chemicals of concern</td>
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<tr>
<td></td>
<td>3. Identify/prioritize alternatives</td>
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<td></td>
<td>4. Assess comparative hazards</td>
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<td>5. Compare performance and consider impacts</td>
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<td>III. Selection and implementation</td>
<td>6. Select preferred alternative</td>
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<td>7. Implement adoption of the safer alternative</td>
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</table>

...assess the risks with different chemicals and make sure that the new alternatives really provide desired functionality.

*Geiser, K., et al. (2015).*
Reduce Hazard

Hazard classification per endpoint

<table>
<thead>
<tr>
<th>Substance</th>
<th>Human health</th>
<th>Ecotox</th>
<th>Fate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFOA</td>
<td>H  L  H  H  PEA  M  H  DG  L  L  vH  H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side-chain fluorinated polymers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFHxA</td>
<td>L  L  M  M  PEA  L  M  DG  L  L  vH  L</td>
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<td></td>
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<tr>
<td>PFBS</td>
<td>DG  L  L  L  PEA  L  L  DG  L  L  vH  L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicones</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Short-chain silanols</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMSD</td>
<td>DG  DG  DG  DG  DG  DG  DG  DG  DG  DG  DG  DG</td>
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<td></td>
</tr>
<tr>
<td>TMS</td>
<td>DG  L  DG  L  DG  M  M  DG  L  DG  DG  L*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D4</td>
<td>L  L  L  L  PEA  L  H  DG  L  vH  vH  vH</td>
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<td></td>
</tr>
<tr>
<td>D5</td>
<td>L  L  L  L  PEA  H  H  DG  L  vH  vH  vH</td>
<td></td>
<td></td>
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<tr>
<td>Hydrocarbons</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Paraffin Wax</td>
<td>L  L  vL*  vL*  DG  L  M  DG  L*  L*  L  L*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other chemistries (dendrimers, inorg. nano particles)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>DG  DG  DG  DG  DG  DG  DG  DG  DG  DG  DG  DG</td>
<td></td>
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</tr>
</tbody>
</table>
How do we capture PFAS risks?

Planetary boundaries could be one way

(i) persistence,
(ii) mobility across scales with consequent widespread distributions, and
(iii) potential impacts on vital Earth-system processes or subsystems.


Hazard assessment: weighted

<table>
<thead>
<tr>
<th>Group</th>
<th>$\gamma_c$ [mN/m]</th>
</tr>
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<tbody>
<tr>
<td>CF$_3$</td>
<td>6</td>
</tr>
<tr>
<td>CF$_2$</td>
<td>18</td>
</tr>
<tr>
<td>CH$_3$</td>
<td>22</td>
</tr>
<tr>
<td>CH$_2$</td>
<td>31</td>
</tr>
</tbody>
</table>

Minimize Exposure

- DWR contribution in relation to total flows
- The LCI (life cycle inventory) can be used to find hot spots
- Transformation of precursors will be a key issue

*The transformation of precursors might also occur in other environmental compartments

Figure from Holmquist et al. 2016
Resolve Trade-offs

• Potential **problem shifting** makes LCA relevant

• Has the potential to consider other options than drop-in substitutes

• **Holistic:**
  - More impact categories than only (eco)toxicity
  - Technical performance considered

• Focus on function: different **user protection needs**

*Figure from Holmquist et al. 2016*
Risk Assessment and LCA

Chemical risk assessment
Hazard and exposure: the probability of an unwanted event. Absolute effects on safeguard subjects.

Life cycle assessment
Emissions and raw material use over the whole life cycle of a product/service. Relative effects on safeguard subjects.

Is it safe?

Which is the better choice?

**Technical scope:** standard shell jacket

- Fabrics
- Accessories
- DWR

Flowchart:
1. Confectioning
2. Reimpregnation
3. Use phase
4. Wash
5. End of life

**Basic scenario**
- Life length: 10 years
- Wash: 2 times/year
- Reimpregnation: After 10 washes

There is potential for problem shifting

- Increased frequency of **washing** (10X) has **moderate effect** (2X on GWP), if effects of wash on the life length is not considered
- An increased frequency of **re-impregnations** (10X) has **marginal effects** (<10%, with some additional uncertainty for the Si-system)
- Change in **life length** will however have **large effects** on the total potential impact

Preliminary results
Cannot differentiate between alternatives

- A comparison of the DWR types show that the potential environmental impacts for GWP and (eco)toxicity do not differ between the alternatives
- But, current version of USEtox does not capture PFAS hazards

Functional unit: warm and dry for 10 years (1 jacket)

Normalised to the impacts of the FC8 alternative; basic scenario; potential impacts characterised with CML2001 (GWP) and USEtox 2.01 ((eco)tox), the Si high impacts are associated with high uncertainty
How do the PFAS fit into LCA?

- The (ILCD) recommended method is USEtox
- USEtox model scope and algorithms may not be suitable for PFAS
  - Accumulation in the oceans, but only accounting for freshwater ecotoxicity
  - Accumulation processes described based on Kow
- UNEP-SETAC ecotoxicity and human toxicity task force for model improvement
Which are the suitable methods?

- Reduce Hazard
- Minimize Exposure
- Resolve Tradeoffs

**Focus chemicals**

<table>
<thead>
<tr>
<th>Global</th>
<th>Local</th>
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<tbody>
<tr>
<td>Hazard assessment, Planetary boundaries as weighting basis?</td>
<td>Hazard assessment, Classic PBT/vPvB weighting?</td>
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<table>
<thead>
<tr>
<th>Stressor</th>
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<tr>
<th>Other chemicals</th>
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<tbody>
<tr>
<td>LCA is inevitable, but can (eco)toxicity effects be fairly assessed?</td>
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<tr>
<td>Local effects generally not considered, but an LCA hot spot analysis could potentially identify risk areas?</td>
</tr>
</tbody>
</table>
(Eco)toxicity in LCA

- Also other substances potentially problematic to model, e.g. metals
- The USEtox model is sensitive to choice of data source
- Published characterization factors, albeit many, cover only a fraction of the total amount of chemicals in use
- New characterization factors can be calculated but it can be resource intensive

Holmquist et al., manuscript

Preliminary results
How much effort can be put into one chemical (group)?

In our LCA model with C6 it is arsenic, mercury and lead that are the major toxicity contributors. Organic substances contribute with less than 1%. PFAS contribute to a negligible extent. Is it worthwhile to calculate the characterization factors?

Maybe there is not one model to fit all cases

• It is not realistic to expect one LCA model to fit all substances and all safeguard subjects

• Simplified risk assessment approach, with a life cycle perspective? Or simplified LCIA (LCA impact assessment) model?

• Can full mixture toxicity be captured and is it relevant?
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Conclusions

• **Long term and global perspective** essential to capture PFAS effects - *the risks connected to “vPvM’s” should be highlighted*

• **Life cycle thinking**, including full garment, is necessary in the substitution assessment to avoid problem shifting - *further guidance is needed*

• **What DWR to select**, based on results so far?
  – The longest garment life length
  – Consider the intrinsic hazard of the chemicals
  – Functionality category as needed, but not more
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