Perfluoroalkyl Substances: Risk and Toxicity

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Perfluoroalkyl Substances

1 Group
PFAS Per- and Polyfluoroalkyl substances

2 Categories
Non-Polymers
Polymers

5 Classes
- Perfluoroalkyl Substances
  Compounds for which all hydrogens on all carbons (except for carbons associated with functional groups) have been replaced by fluorines
- Polyfluoroalkyl Substances
  Compounds for which all hydrogens on at least one (but not all) carbon have been replaced by fluorines

- Fluoropolymers
  Carbon-only polymer backbone with fluorines directly attached

- Polymeric Perfluoropolyethers
  Carbon and oxygen polymer backbone with fluorines directly attached to carbon

- Side-chain Fluorinated Polymers
  Variable composition non-fluorinated polymer backbone with fluorinated side chains

Adapted from Buck et al. 2011.
Integrated Environmental Assessment and Management 7:513.
Overview

- **Introduction to Risk**
- **Basis of EPA Drinking Water Health Advisories**
  - PFOS – Perfluorooctane Sulfonate
  - PFOA – Perfluorooctanoic Acid
- **Massachusetts Department of Environmental Protection (MassDEP) Considerations for PFAS Compounds of Interest**
- **Toxic Use Reduction Institute (TURI) PFAS Compound of Interest**
How is Risk Determined?

Exposure  
Toxicity
Sources of PFAS Exposure

- Food
- Indoor Dust
- Occupational
- Consumer Products
- Drinking Water
- Soil
- Air
U.S. Serum PFOS Levels

Toxicity – USEPA

- Toxicity evaluated and quantified by numerous agencies
- USEPA issued Health Advisories in 2016
  - PFOS
  - PFOA
- Quantified dose-response (toxicity) and exposure
PFOS – Non-cancer Effects

- Non-cancer endpoints identified in animals
  - Developmental effects
  - Nervous
  - Liver
  - Serum Lipids*
  - Immune*
  - Thyroid*
  * USEPA also notes supported by human studies

- Non-cancer endpoints identified in humans
  - Reproductive, fertility
PFOS Health Advisory

- The Health Advisory equals 70 ppt (0.07 μg/L)
- Based on Developmental effect endpoint – reduced pup weight in rats
- Assessed drinking water intake and body weight for a lactating woman
- Assumes a 20% Relative Source Contribution Factor
  - Other sources include food, dust, air, consumer and industrial product (textiles, rugs), soils, surface water
PFOA – Non-cancer Effects

- Non-cancer endpoints identified in animals
  - Liver*
  - Low birth weight*
  - Immune effects*
  - Developmental effects
  - Liver
  - Kidney
  - Thyroid
  - Fertility
  - Serum lipids

* USEPA also notes supported by human studies
PFOA – Cancer Endpoints

- Cancer endpoints identified in animals
  - Testicular*
  - Liver

*USEPA also notes supported by epidemiology
PFOA Conceptual Model

Source: USEPA Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA), May, 2016
PFOA Health Advisory

- The Health Advisory equals 70 ppt
- Based on Developmental and Immune endpoints
- Protective of potential cancer risk
- Assessed drinking water intake and body weight for a lactating woman
- Assumes a 20% Relative Source Contribution Factor
  - Other sources include food, air, dust, (incinerators, carpets, paint, textiles, furniture, other consumer products, precursors), soils, surface water
PFOA and PFOS

- Similar effects noted for both compounds
- Effects that serve as the basis of the Health Advisories are developmental
- Health Advisories are identical
- Because both RfDs based on development effects, where two chemicals co-occur, EPA recommends summing the concentrations for comparison to the Health Advisory of 70 ppt
## MassDEP Considerations

<table>
<thead>
<tr>
<th>Compound</th>
<th>Carbon chain length</th>
<th>In vivo toxicity vs. PFOA</th>
<th>In vitro toxicity vs. PFOA</th>
<th>Half-life (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFOA</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>1280</td>
</tr>
<tr>
<td>PFOS</td>
<td>8</td>
<td>1</td>
<td></td>
<td>1750</td>
</tr>
<tr>
<td>PFNA</td>
<td>9</td>
<td>&gt;= 1</td>
<td>1.2</td>
<td>NA</td>
</tr>
<tr>
<td>PFHpA</td>
<td>7</td>
<td>0.8</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>PFHxS</td>
<td>6</td>
<td>&gt;= 1</td>
<td>2670</td>
<td>30</td>
</tr>
<tr>
<td>PFBS</td>
<td>4</td>
<td>&lt;0.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## New England Drinking Water Health-Based Values

<table>
<thead>
<tr>
<th>State</th>
<th>Value</th>
<th>Application</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>70 ppt</td>
<td>ΣPFOA, PFOS, PFNA, PFHpA, PFHxS</td>
<td>Long half-lives, emerging toxicity</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>70 ppt</td>
<td>ΣPFOA, PFOS</td>
<td>USEPA HA</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>Pending</td>
<td>PFOA, PFOS, PFNA, PFHpA, PFHxS</td>
<td></td>
</tr>
<tr>
<td>Vermont</td>
<td>20 ppt</td>
<td>ΣPFOA, PFOS</td>
<td>Based on 0-1 year old</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>70 ppt</td>
<td>ΣPFOA, PFOS</td>
<td>USEPA HA</td>
</tr>
<tr>
<td>Maine</td>
<td>100 ppt</td>
<td>PFOA</td>
<td>Different RfD (liver), RSC = 60%</td>
</tr>
</tbody>
</table>
Toxic Use Reduction Institute

- PFOA/PFOS groundwater concerns
- Alternatives or their breakdown products may have similar properties
- TURI Science Advisory Board has been reviewing scientific literature for specific perfluoroalkyl substances:
  - PFOA – C8 – Perfluorooctanoic acid
  - PFOS – C8 – Perfluorooctane sulfonic acid
  - PFHxA – C6 - Perfluorohexanoic acid
  - PFHxS – C6 - Perfluorohexane sulfonic acid
  - PFBA – C4 - Perfluorobutyric acid
  - PFBS – C4 - Perfluorobutane sulfonic acid
- Tasked to evaluate hazard
# TURI SAB – Mammalian Toxicity Endpoints

<table>
<thead>
<tr>
<th>Organ or System</th>
<th>PFHxA</th>
<th>PFHxS</th>
<th>PFBA</th>
<th>PFBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developmental</td>
<td>*</td>
<td></td>
<td>*</td>
<td>✓</td>
</tr>
<tr>
<td>Thyroid</td>
<td>✓</td>
<td>✓</td>
<td>*</td>
<td>✓</td>
</tr>
<tr>
<td>Liver</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Immune</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Kidney</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nervous</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Blood</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Reproductive</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

✓ = identified mammalian toxic effect; * = some concerns for effect
Conclusions

- Exposure is an important aspect in determining risk and health-based concentrations
- Toxicity has been demonstrated, though results are mixed and selected endpoints and health-based drinking water concentrations vary
- Summing risk across compounds will reduce health-based concentrations
Questions?

Thank you!

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