Toxicology and Risk Assessment Challenges with Evaluating Health Effects of PFAS

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State Toxicologist
Maine Center for Disease Control and Prevention
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• Quick primer on the risk assessment process

• How toxicity values for PFOS are derived (...and why do they differ so much)

• How drinking water guidelines/standards are derived (...and why do they differ so much)

• Soil Screening Levels (SSLs) for the soil-to-groundwater pathway

• Current work to investigate agronomic exposure pathways for PFOS
PFOS
(perfluorooctane sulfonic acid)

Carbon backbone

Octane

Acid Group

Perfluorooctane sulfonic acid (PFOS)
Risk Assessment

Toxicity Values
(EPA, ATSDR, FDA)
Derive our own

Toxicity

Concentration in Media

Contact / Intake Rate for Media

Exposure

Exposure Factors
(EPA, FDA, Literature)

Exposure Models
(EPA, FDA)

Risk

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Risk Assessment

Concentration in Media

Contact / Intake Rate for Media

Toxicity

Exposure

Risk
Available Toxicity Data for PFOS

**Human Studies**
- Liver damage*
- Thyroid hormone disruption*
- Decreased antibody response to vaccines*
- Lower birth weight (LBW)*
- Changes in cholesterol
- Hypertension during pregnancy
- Bladder, colon and prostate cancer

**Animal Studies**
- Increased liver size / liver damage*
- Thyroid hormone disruption*
- Changes in immune function*
- LBW and other developmental effects*
- Liver cancer
- Increased kidney weight
USEPA’s Derivation of a Toxicity Value for PFOS

100,000 ng/kg/day

No Observable Adverse Effect Level (Developmental Effects)

510 ng/kg/day

Human Equivalent Dose (equivalent serum levels)

20 ng/kg/day

Dose that is “safe” for sensitive members of the population

~200x

~30x

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## Differences in Toxicity Values for PFOS

<table>
<thead>
<tr>
<th>Agency</th>
<th>Endpoint</th>
<th>Species</th>
<th>Human equivalent dose (ng/kg/day)</th>
<th>Cumulative uncertainty factor</th>
<th>Reference dose (ng/kg/day)</th>
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<tbody>
<tr>
<td><strong>Federal</strong></td>
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<tr>
<td>EPA</td>
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<td>Rats</td>
<td>510</td>
<td>30</td>
<td>20</td>
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<tr>
<td>ATSDR</td>
<td>Developmental effects</td>
<td>Rats</td>
<td>515</td>
<td>300</td>
<td>2*</td>
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<tr>
<td>ME, VT, CT†</td>
<td>Developmental effects</td>
<td>Rats</td>
<td>510</td>
<td>30</td>
<td>20</td>
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<tr>
<td>MA</td>
<td>Developmental effects</td>
<td>Rats</td>
<td>510</td>
<td>100</td>
<td>5*</td>
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<tr>
<td>MN</td>
<td>Immune effects</td>
<td>Mice</td>
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<td>3</td>
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<tr>
<td>NH</td>
<td>Immune effects</td>
<td>Mice</td>
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<td>3</td>
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<tr>
<td>MI</td>
<td>Immune effects</td>
<td>Mice</td>
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<tr>
<td>NJ, NY, CA</td>
<td>Immune effects</td>
<td>Mice</td>
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<td><strong>States</strong></td>
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<td><strong>International</strong></td>
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<td>Health Canada</td>
<td>Liver effects</td>
<td>Rats</td>
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<td>25</td>
<td>60</td>
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<tr>
<td>EFSA</td>
<td>Changes in cholesterol</td>
<td>Humans</td>
<td>2</td>
<td>1</td>
<td>2</td>
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</tbody>
</table>

* Proposed/Draft. † ME, VT, CT all using EPA’s toxicity value (FDA is also using EPA’s toxicity value).
Deriving EPA’s Drinking Water Health Advisory

Toxicity Value 20 ng/kg/day

Water Intake Rate 0.054 L/kg/day

Drinking Water Exposure Limit 370 ng/L

Background Exposure (RSC) 20% Default 70 ng/L

Health Advisory

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# Other Drinking Water Guidelines for PFOS

<table>
<thead>
<tr>
<th>Agency</th>
<th>Reference dose (ng/kg/day)</th>
<th>Receptor</th>
<th>Drinking water intake (L/kg/day)</th>
<th>Relative source contribution (%)</th>
<th>Drinking water guideline (ng/L)</th>
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<td>0.054</td>
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<td>70</td>
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<tr>
<td>ATSDR</td>
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<td>Infant, birth to 1 yr</td>
<td>0.143</td>
<td>No RSC</td>
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<tr>
<td>VT</td>
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<td>Bottle-fed infant</td>
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<td>20</td>
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<tr>
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<td>Lactating woman</td>
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<td>20</td>
<td>20*</td>
</tr>
<tr>
<td>MI</td>
<td>3</td>
<td>Breastfed infant</td>
<td>0.047</td>
<td>50</td>
<td>16*</td>
</tr>
<tr>
<td>MN</td>
<td>3</td>
<td>Breastfed infant</td>
<td>0.047</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>NH</td>
<td>3</td>
<td>Breastfed infant</td>
<td>0.047</td>
<td>50</td>
<td>15*</td>
</tr>
<tr>
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<td>0.029</td>
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<td>13*</td>
</tr>
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<tr>
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<tr>
<td>Health Canada</td>
<td>60</td>
<td>Adult</td>
<td>0.021</td>
<td>20</td>
<td>600</td>
</tr>
</tbody>
</table>

* Proposed / Draft
Based on Chapter 418 risk standard of 0.5 HI, USEPA RSL tap water model modified with use of SESOIL soil to groundwater model, and USEPA RfD.
Stoneridge Farm

PFOS levels for milk and water in nanograms / liter:
- Milk: 1400 ng/L
- Ground Water: 100 – 130 ng/L
- Hay: 9.6 µg/kg, dw

Kowalczyk et al. 2013.

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PFOS Levels for Stoneridge Farm

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Soil / Hay µg/kg, dw</th>
<th>Water / Milk ng/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>ND</td>
<td>98.2</td>
<td>42</td>
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<tr>
<td>151</td>
<td>69.6</td>
<td>1.8</td>
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<td>759</td>
<td>110</td>
<td>62.7</td>
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<td>878</td>
<td>51.1</td>
<td>98.2</td>
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<tr>
<td>ND</td>
<td>62.7</td>
<td>4.7</td>
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<tr>
<td>1.8</td>
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<tr>
<td>22.4</td>
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<tr>
<td>79.0</td>
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<tr>
<td>51.1</td>
<td></td>
<td></td>
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<tr>
<td>130</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ND</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1400</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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PFOS Soil Screening Levels for Residential Soil Exposure Pathway - 2017

Based on USEPA RfD of 20 ng/kg/day, 95th percentile incidental soil ingestion rate for a 1-6 year old child, 150 days / year.

PFOS

2700 µg/kg, dw
What would be a PFOS soil screening level for the dairy farming scenario?

Soil → Hay/Corn → Cow → Milk → Child
USEPA PRGR Soil Screening Level Equation

Agronomic Pathway

\[ SL_{soil} = \frac{C_{milk}}{TF_{milk} \times \left[\left(I_{fodder} \times F_{on site-f} \times F_{year-f} \times (TF_{plant} + MLF)\right) + (I_{soil} \times F_{on site-g} \times F_{year-g})\right]} \]

Source:

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Deriving a Milk Action Level for “adulterated” Milk

Toxicity Value
20 ng/kg/day

Relative Source Contribution
80%

Milk Exposure Limit
270 ng/L

90th Percentile Milk Intake
0.074 L/kg/day

Action Level
210 ng/L

1-2 year old

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PFOS Milk Transfer Factor ($TF_{milk}$)

**PFOS in Milk**

- Calculated $TF_{milk} = 0.005$
- Modeled $TF_{milk} = 0.02$ to $0.08$

Source:
PFOS Hay Transfer Factor ($TF_{plant}$)

$TF_{hay} = 0.07$

$TF_{hay} = 0.1$

$TF_{hay} = 0.5$

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PFOS Corn Transfer Factor ($TF_{plant}$)

$TF_{corn} = < 0.08$

$TF_{corn} = 0.04$

$TF_{corn} = 0.16$
Plant Soil Mass Loading Factor (MLF)

Processes for transfer of soil to plant surface
• Rain splash
• Wind erosion
• Soil disturbance by mechanical equipment

USEPA PRGR Defaults
• Default = 0.25, range 0.001 to 0.5
• Geometric mean of 11 studies* = 0.034
  (pasture plants only)

\[ MLF = 0.034 \]

Source:
Example Soil SL Calculation for Hay

\[ SL_{soil} = \frac{C_{milk}}{TF_{milk} \times \left[ (I_{fodder} \times F_{onsite-f} \times F_{year-f} \times (TF_{plant} + MLF)) + (I_{soil} \times F_{onsite-g} \times F_{year-g}) \right]} \]

13,800 ng/kg dw (13.8 µg/kg dw)

204 ng/kg

\[
\begin{align*}
0.02 & \text{ day/kg} \\
6.5 & \text{ kg/day} \\
1 & \\
1 & \\
0.07 & \\
0.034 & \\
1 & \text{ (kg/day)} \\
0.13 & \\
0.5 & \\
0.68 \text{ kg/day} & \\
0.065 \text{ kg/day} & \\
\end{align*}
\]

Source:

Maine Department of Health and Human Services
Example Soil SL Calculation for Corn Silage

\[
\text{SL}_{\text{soil}} = \frac{C_{\text{milk}}}{TF_{\text{milk}} \times \left( I_{\text{fodder}} \times F_{\text{onsite-f}} \times F_{\text{year-f}} \times (TF_{\text{plant}} + MLF) \right)}
\]

5,900 - 31,300 ng/kg dw (5.9 - 31.7 µg/kg dw)

204 ng/kg

0.02 day/kg

8.7 kg/day

1

1

0.036 - 0.165

0.0014 - 0.034

0.32 - 1.73 kg/day

Source:

Maine Department of Health and Human Services
Example Soil Screening Levels for Dairy Farm Scenarios

EPA “Subsistence Dairy Farm”
• Diet: Hay (65%)  Corn (20%)  Grain (15%)

SSL = 4 – 6 µg/kg, dw

Average Maine Dairy Farm
• Diet: Hay (28%)  Corn (37%)  Grain (35%)

SSL = 4 – 10 µg/kg, dw
PFOS Levels for Stoneridge Farm

<table>
<thead>
<tr>
<th>Soil / Hay in µg/kg, dw</th>
<th>Water / Milk in ng/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>ND</td>
<td>11.0</td>
</tr>
<tr>
<td>151</td>
<td>0.7</td>
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<td>878</td>
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<tr>
<td>759</td>
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<td>79.0</td>
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<td>130</td>
<td>5.4</td>
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<td>ND</td>
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<tr>
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<td>4.6</td>
<td></td>
</tr>
<tr>
<td>3.6</td>
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</tr>
</tbody>
</table>

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Model Estimated PFOS Milk Levels based on Stoneridge Farms Soil Levels

<table>
<thead>
<tr>
<th>Stoneridge Farms PFOS site-wide soil level estimates (ug/kg dry weight)</th>
<th>Model estimated PFOS milk (ng/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>123 (arithmetic average)</td>
<td>4,100</td>
</tr>
<tr>
<td>25 (geometric mean)</td>
<td>840</td>
</tr>
</tbody>
</table>

Initial average measured PFOS milk levels at Stoneridge Farms = 1,117 ng/L
Next Steps

Soil-to-Corn PFOS Uptake Study (DEP, MECDC, DACF)

- Identified biosolid amended soils with elevated PFOS levels for a plant uptake study
- Confirmed soils are being used to grow corn
- Collect matched soil and silage corn samples for PFOS analysis
- Analyze to derive a transfer factor

Review

- ATSDR, USDA, FDA, other states
- Monitoring / evaluating new literature / reports
- Looking for more farms to test model against
Two Big Questions to End With:

- Should Maine continue to rely on EPA toxicity values?

- What about other PFAS (e.g., PFOA, PFHxS, PFHxA, PFNA, etc)?
Questions?

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