INTRODUCTION

- Fluorotelomer alcohols (FTOHs) have recently been identified as a potentially significant source of global perfluorinated acid (PFCAs) contamination.
- FTOHs degrade through biotic and abiotic processes in the environment to the saturated (s-) and unsaturated (u-) fluorotelomer carboxylic acids (FTCAs).
- Lower relative volatility and higher water solubility compared with the FTOHs indicates that surface waters are a likely final repository for the FTCAs.
- Scientific and regulatory concern over PFCAs has resulted in a great deal of research on the environmental concentrations, fate, and toxicity of the PFCAs, but no such information exists for the FTCAs.
- We address this knowledge gap by determining acute and chronic laboratory toxicity thresholds for the 4:2, 6:2, 8:2, and 10:2 s- and u-FTCAs with the pelagic microcrustacean, Daphnia magna, the benthic macroinvertebrate, Chironomus tentans, and the floating aquatic macrophyte Lemna gibba.

METHODS & MATERIALS

- Standard laboratory assays conducted in a triple-tier design whereby lower tiers served as screening tools to determine the compounds, concentrations, and species to be tested in the next tier.

Acute Assays

- Daphnia magna
  - < 24-hour-old neonates exposed for 48 hours
  - 250 mL polypropylene test vessels containing 200 mL FTCA solutions
  - 10 animals/replicate, 5 replicates/treatment, 9 treatments/assay
  - Endpoints measured: Immobility and survival

Chironomus tentans

- 10-day-old larvae exposed for 10 days
- 250 mL polypropylene test vessels containing 50 mL sand with overlying FTCA solutions (total volume = 240 mL)
- Static renewal of test solutions every 48 hours
- 10 animals/replicate, 5 replicates/treatment
- 9 treatments/assay
- Endpoints: Growth and survival

Lemna gibba

- 7-day exposures
- 10 mL FTCA solutions in 60 x 15 mm polypropylene petri dishes
- 8 fronds/replicate, 3 replicates/treatment, 9 treatments/assay
- Static renewal of test solutions every 48 hours
- Endpoints: Growth as frond number and dry weight

RESULTS

Chronic Assays

Daphnia magna
- Same conditions as for acute assays, but with 21-day exposures
- 4 animals/replicate, 5 replicates/treatment, 6 treatments/assay, not including controls
- Endpoints: Survival, time to first brood, number of young/female reproduction day

Chironomus tentans
- Same conditions as for acute assays, but exposed for 60 days
- 10 animals/replicate, 12 replicates/treatment, 7 treatments/assay, not including controls
- Endpoints measured: Growth and survival at 20 days, emergence, reproduction

Statistical Analyses

- LC(x, y = 10, 25, 50) values calculated using probit analysis (SAS, 8.2)
- EC(x, y = 10, 25, 50) values calculated using nonlinear regression techniques
- Linear interpolation method used where data were not amenable to nonlinear regression

DISCUSSION & CONCLUSIONS

- FTCAs toxicity is species-dependent and is influenced by fluorocarbon chain length and saturation of the α-β carbon bond.
- All species were more sensitive to FTCAs with chain lengths ≥ 8 fluorocarbons (FCs).
- Lemna gibba was the most sensitive species to FTCAs with FC chain lengths ≥ 8, while Daphnia magna was the most sensitive species to FTCAs with FC chain lengths > 8.
- Saturated FTCAs are more toxic than their unsaturated counterparts.
- FTCAs generally more toxic (1-4 orders of magnitude) to aquatic organisms than corresponding PFCAs that are the focus of current scientific and regulatory concern.
- Critical need for environmental concentration data must be addressed before potential risks of FTCAs to aquatic ecosystems can be adequately evaluated.

ACKNOWLEDGEMENTS

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REFERENCES

Benoit, T.M. 2002. Toxicological evaluation of perfluorinated organic acids to selected freshwater primary and secondary trophic levels under laboratory and semi-field conditions, Master’s Thesis, Department of Environmental Biology, University of Ghent.

AQUATIC TOXICITY OF FLUOROTELOMER ACIDS

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Table 1. Acute toxicity (EC50) of eight saturated (s-) and unsaturated fluorotelomer carboxylic acids (FTCAs) to Daphnia magna, Chironomus tentans, and Lemna gibba for ash-free dry weight, and dry weight, respectively. Most sensitive thresholds are highlighted in blue.

<table>
<thead>
<tr>
<th>FTCA</th>
<th>Daphnia magna</th>
<th>Chironomus tentans</th>
<th>Lemna gibba</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LC50 (mg/L)</td>
<td>EC50 (mg/L)</td>
<td>LC50 (mg/L)</td>
</tr>
<tr>
<td>4:2 u-FTCA</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>4:2 s-FTCA</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>6:2 u-FTCA</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>6:2 s-FTCA</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>8:2 u-FTCA</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>8:2 s-FTCA</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>10:2 u-FTCA</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>10:2 s-FTCA</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
</tr>
</tbody>
</table>

Table 2. Chronic toxicity (EC50) of the 10:2 saturated (s-) and unsaturated (u-) fluorotelomer carboxylic acids (FTCAs) to Daphnia magna, and the 8:2 s-FTCA to Chironomus tentans. Results analyses are (correctly) underway.

<table>
<thead>
<tr>
<th>FTCA</th>
<th>Mortality</th>
<th>Time to 1st brood</th>
<th>Young/female reproductive day</th>
<th>Growth</th>
<th>Total Emergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:2 u-FTCA</td>
<td>2.61 (0.44, 1.66)</td>
<td>1.25 (0.38, 0.52)</td>
<td>Not conducted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:2 u-FTCA</td>
<td>&gt; 2.61</td>
<td>&gt; 1.25</td>
<td>Not conducted</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Relative toxicity (EC50) of saturated (s-) and unsaturated fluorotelomer carboxylic acids (FTCAs) to Chironomus tentans, Daphnia magna, and Lemna gibba for ash-free dry weight, immobility, and dry weight, respectively. Error bars denote 95% confidence intervals. Arrows indicate toxicity thresholds > highest concentration tested.

Figure 2. Sublethal chronic responses (growth, emergence) of Chironomus tentans to the 8:2 saturated fluorotelomer acid and Daphnia magna (time to first brood), young/female reproductive day to the 10:2 saturated (s-) and unsaturated (u-) fluorotelomer acids (FTCAs). D. magna concentrations are nominal values (residue analyses underway). Error bars = 95% confidence limits. Reproductive results for C. tentans were inconclusive.