Relative Toxicity of Protective Coatings for Use in Controlling Biofouling on Hydrokinetic Energy Devices

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Background

- Biofouling by aquatic organisms on hydrokinetic (HK) energy devices, if uncontrolled, would result in significantly decreased efficiency and increased maintenance and/or replacement costs
- Many current anti-biofouling coatings used on ships and static structures in aquatic environments still rely extensively on toxic additives (ex. copper, herbicides)
- Use of some effective but particularly toxic coatings have either been restricted (tributyl tin-based coatings) or are subject to increasing regulatory scrutiny (copper-based coatings)
- Environmental-friendliness of newer coating technologies is often more assumed than documented
- There is a relative shortage of data concerning the potential toxicity of many anti-biofouling coatings in freshwater situations

Methods

- Literature and database reviews assessed commercially-available and/or experimental anti-biofouling coatings of potential use on HK devices
- Data gaps were identified and prioritized
- Representatives of coating classes with data gaps were applied to metal panels (steel or aluminum) for leaching process
- Volatile constituents were removed by an initial 24-h immersion in either freshwater or saltwater
- Coated panels were subjected to leaching at 22°C in the dark with 30 rpm agitation for 14-d
- Leachates were tested for toxicity to freshwater and saltwater organisms (the latter if sufficient leachate available) at a 37.5 cm²/L surface area to volume ratio
- Toxicity tests were conducted according to standard US EPA test protocols (Methods 1000.0, 1002.0, 1004.0, 1007.0, 2000.0, 2002.0, 2004.7, and 2007.0)

Results

Example of toxicity test results
(Ultra® 3669 cuprous oxide-based coating)

<table>
<thead>
<tr>
<th>Test species</th>
<th>Test media</th>
<th>48-h IC₅₀</th>
<th>NOEC</th>
<th>IC₂₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fathead minnow (Pimephales promelas)</td>
<td>Freshwater</td>
<td>70%</td>
<td>&lt;15%</td>
<td>35%</td>
</tr>
<tr>
<td>Water flea (Ceriodaphnia dubia)</td>
<td>Freshwater</td>
<td>80%</td>
<td>25%</td>
<td>45%</td>
</tr>
<tr>
<td>Zebra mussel (Dreissena polymorpha)</td>
<td>Saltwater</td>
<td>60%</td>
<td>10%</td>
<td>40%</td>
</tr>
<tr>
<td>Mytilus (Mytilus edulis)</td>
<td>Saltwater</td>
<td>80%</td>
<td>25%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Lower values = Higher toxicity

SUMMARY OF ORNL-CURRATED TOXICITY TESTS

Relative toxicity of anti-biofouling agents in current tests

- Fluoropolymers
- Other fluorocarbons
- Superoxophosphatic Si₅O₇
- Superoxophosphatic Diatomaceous Earth
- Dimethyl silicone
- Silicons
- Zwitterionic polymers

Significantly Toxic
Moderately Toxic
Relatively Non-Toxic

Conclusions

- A variety of anti-biofouling coatings and approaches are currently available for use with submerged surfaces of HK energy devices
- New anti-biofouling technologies based on innovative and relatively non-toxic mechanisms are under active development
- Commercially-available foul-release coatings (ex. Smart Surface® and Intersleek 900®) which work by slick surface technology were non-toxic in current tests, are relatively efficient and environmentally-friendly based on literature review, and suitable for use in high water flow locations (i.e. turbine blades and/or where water currents or turbulence are high)
- Copper-based coatings, although more toxic and potentially subject to greater regulatory scrutiny than other classes of protective coatings, may still be the current choice for immediate protective use on HK devices where water flow doesn’t support foul-release coatings
- Goal should be to eventually eliminate toxic agents with known environmental risks from anti-biofouling coating use at HK device installations


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