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

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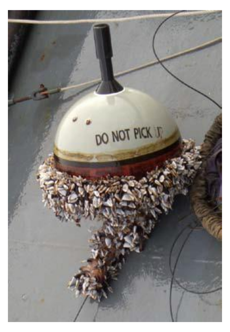
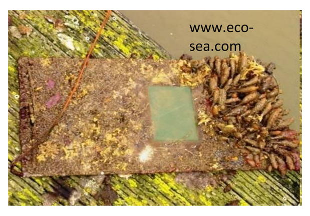
Background

- 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 environs 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

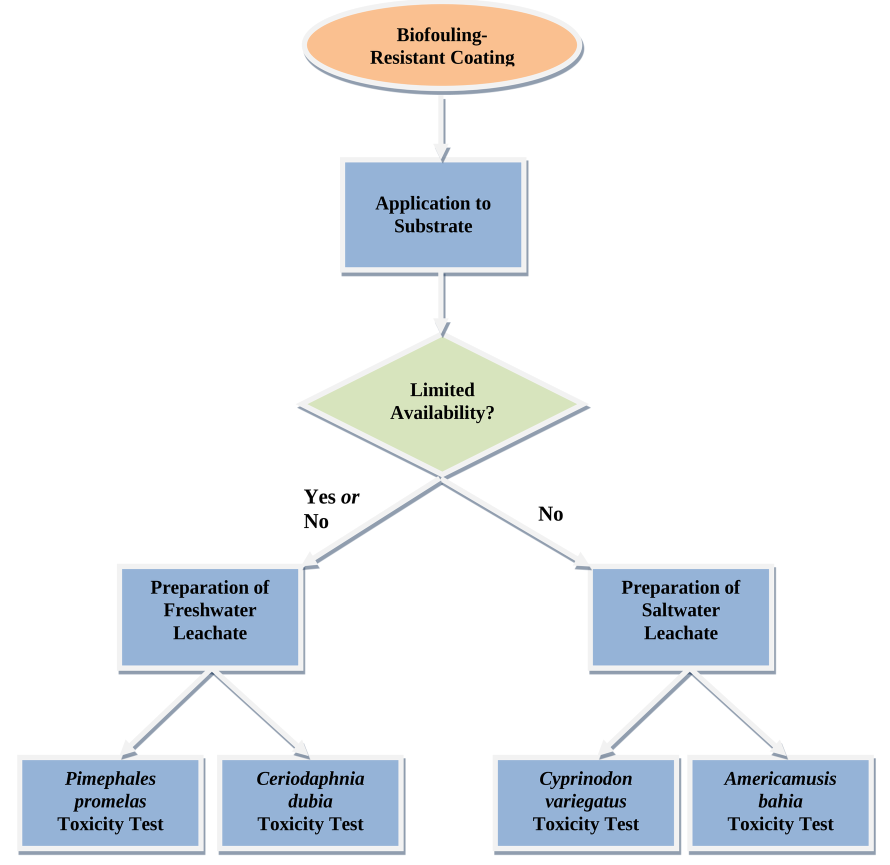




PROJECT OBJECTIVES

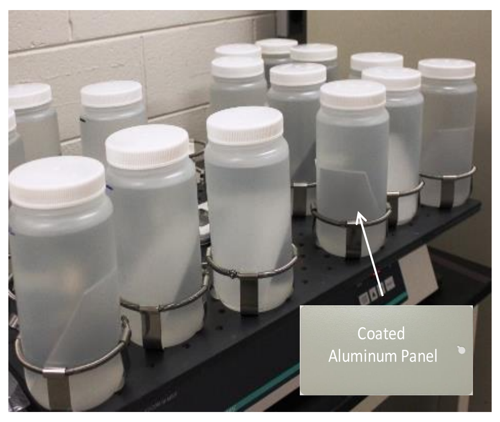
- Evaluate the current status of knowledge concerning the toxicity of anti-biofouling coatings or agents
- Identify significant data gaps relevant to HK energy devices, particularly with regard to the freshwater toxicity of anti-biofouling coatings
- Propose and evaluate approaches to addressing data gaps
- Address selected data gaps through laboratory testing of representative anti-biofouling coatings either currently commercially available for use with HK devices or under active development

Methods



Flowchart of process used in evaluating the toxicity of anti-biofouling coatings for potential use on HK devices

- 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)



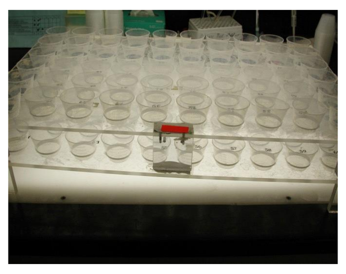
Leaching procedure
(with opaque cover removed)

Freshwater test organisms

Ceriodaphnia Fathead minnow

Saltwater test organisms

Mysid Sheepshead minnow



Ceriodaphnia **reproduction and survival toxicity test set-up (left); fathead minnow chronic larval growth and survival test (right)**

Results

Example of toxicity test results

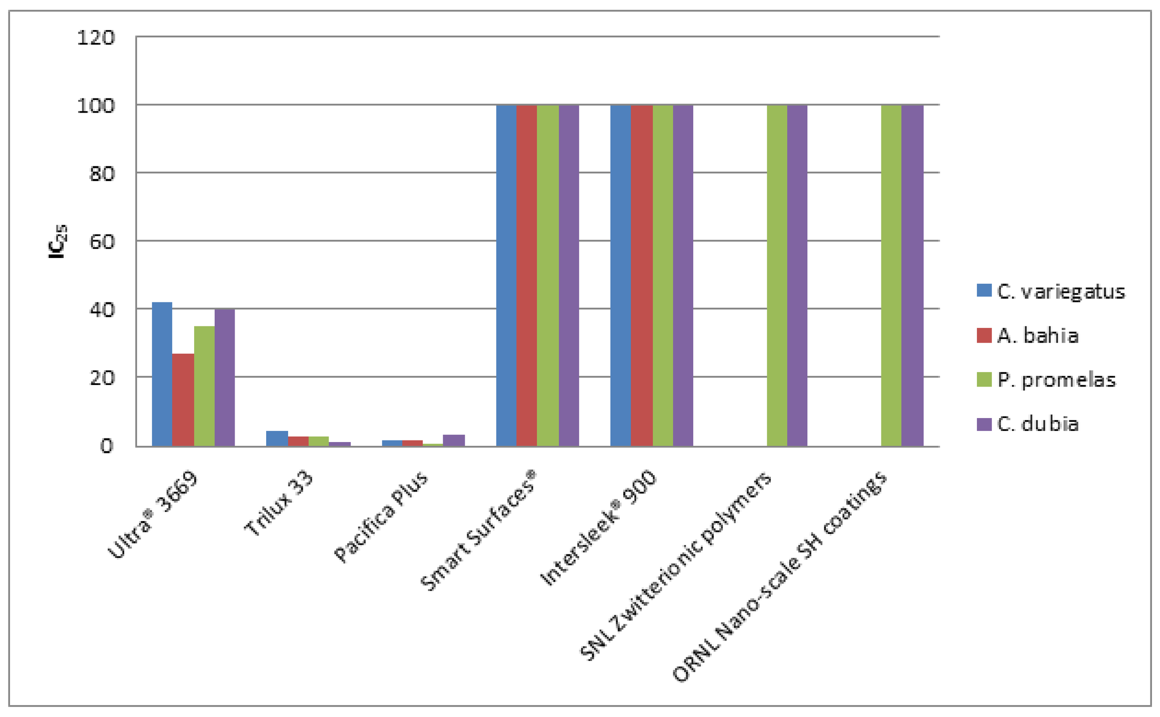
(Ultra® 3669 cuprous oxide-based coating)

Lower values = Higher toxicity

Test species	Test media	48 hr-LC_{50}	NOEC	IC_{25}
Fathead minnow *Pimephales promelas*	Freshwater	75%	<50%	35%
Water flea *Ceriodaphnia dubia*	Freshwater	30%	25%	40%
Sheepshead minnow *Cyprinodon variegatus*	Saltwater	32%	50%	42%
Mysid *Americamysis bahia*	Saltwater	32%	25%	27%

LC_{50} = Lethal concentration at which 50% of test organisms are expected to die.
NOEC = No-observed-effect concentration.
IC_{25} = Inhibition concentration at which a 25% reduction in a measured endpoint is expected.

Summary of ORNL-conducted toxicity tests



Relative toxicity of anti-biofouling agents in current tests

Significantly Toxic		Moderately Toxic		Relatively Non-Toxic
Econea®	>	*Cuprous oxide*	>	*Fluoropolymers*
Copper Thiocyanate				*Other fluorocarbons*
				Superhydrophobic SIO_2
				Superhydrophobic Diatomaceous Earth
				Dimethy Siloxane
				Silicones
				Zwitterionic polymers

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 Surfaces® 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

Collaborators

Kitty McCracken (Oak Ridge National Laboratory) provided assistance in conducting leaching and toxicity test procedures. Commercial test materials were provided by Charles Fisher, Fujifilm Smart Surfaces, LLC (Smart Surfaces® coating), Jim Seidel, International Paint LLC (Ultra® 3669, Trilux® 33, and Pacifica Plus coatings), and Shane Stafslien, North Dakota State University (Intersleek® 900). Experimental coatings were provided by Michael Hibbs and Bernadette Hernandez, Sandia National Laboratory (various polymer coatings) and John Simpson, Oak Ridge National Laboratory (various nanoscale superhydrophobic formulations).

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