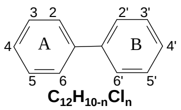
In-Situ Remediation of PCB-Contaminated Sediments using Polymeric Absorption System

Purpose of Study

- Investigate various polymers capacity for PCB absorption/removal
- Investigate effect of solvent interior on PCB-removal capacity
- Investigate feasibility of 1-step versus 2-step remediation treatment options
- Develop technology capable of removing PCBs from contaminated sediments
- Design prototype system capable of demonstrating capabilities of technology on larger scale

Overview of PCBs

- Polychlorinated Biphenyls
- Synthetic, 209 Congeners
- Heavy Industrial Use
- Possible Carcinogens



- Bioaccumulate and Concentrate in Fatty Tissue
- TSCA Regulated Since 1976
- Environmentally Persistent due to Stability
- Difficult to remediate from sediments due to variety of factors

Previous Remediation Technologies for Sediments

- Dredging and incineration
  - Contaminated sediments removed and destroyed
  - High risk of re-releasing the PCBs into the water table during the dredging process
    - Allows PCBs to become available to benthic population
  - Transport and incineration of PCB-contaminated wastes is a costly process
  - Incineration requires high-temperature facilities to avoid dioxin formation
- Sediment Capping
  - Impermeable capping material used to seal contaminated sediments in place
  - Does not treat source of contamination
  - Possibility of cap failure; re-introduction of contaminants into local water table
- Monitored Natural Recovery (MNR)
  - Contaminated sediments left in place
  - Natural processes allowed to reduce contamination through weathering processes, biodegradation, natural capping (clean sediment)
  - Requires long time periods
  - Not as effective as more aggressive techniques

Initial Research Results

- Initial studies focused on determining various polymers affinities for PCB absorption
  - PCB-spiked sediment vial experiments carried out over a period of several months
  - Polymers exposed to contaminated sediments, extracted/analyzed at various times during experiment
  - Certain polymers (Butyl Rubber, Norprene, Gum Rubber/Foam) showed higher removal capacities over the 4 month study

Sample ID	PCB Removal		
	3 Weeks	7 Weeks	17 Weeks
Black Norprene Tubing	5.73%	7.96%	10.63%
White Norprene Tubing	2.15%	4.54%	4.60%
Latex Glove	0.93%	3.14%	4.14%
Thick Nitrile Glove	0.95%	0.31%	1.59%
Abrasion Resistant Gum Rubber (5/8")	1.03%	3.43%	1.86%
Natural Gum Foam	3.04%	14.17%	20.26%
Abrasian Resistant Gum Rubber (1/16")	3.02%	5.42%	8.27%
Weather Resistant Butyl Rubber	3.44%	7.14%	18.46%
Weather Resistant Butyl Rubber	3.85%	9.02%	9.87%
Viton Mat	4.22%	7.30%	6.03%
Black Viton Tubing	1.89%	0.94%	2.76%
White Viton Tubing	0.99%	0.63%	0.91%
Butyl Rubber (glove)	3.99%	3.48%	4.10%
ABS	2.95%	4.71%	3.89%

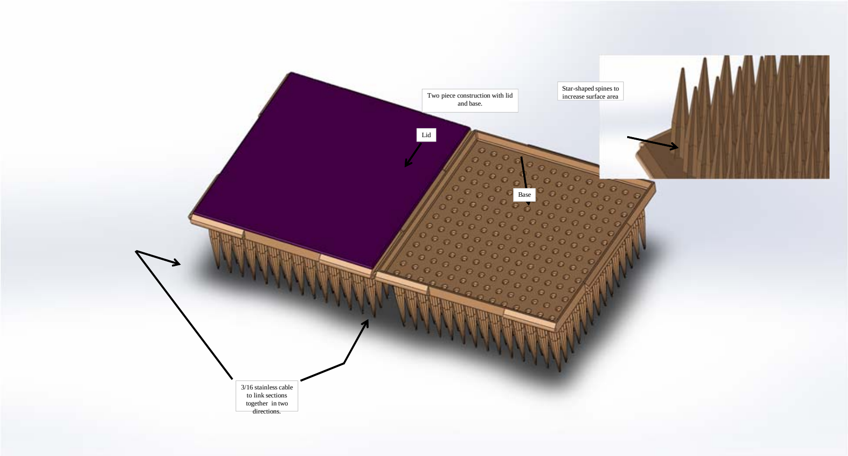
- Follow-up studies were conducted to determine if PCB removal from contaminated sediments could be increased through the use of an interior solvent
  - Would provide a concentration gradient which would allow for increased PCB transport across polymer as well as to open polymer lattice for easier transport

Sample ID	% PCB Removal	
	3 Weeks	7 Weeks
Thick Nitrile Glove (w/EtOH)	19.19%	66.13%
Ethanol Interior	4.99%	2.47%
Thick Nitrile Glove (w/EtOH)	24.18%	68.61%
Thick Nitrile Glove (w/EtOH)	19.42%	70.13%
Ethanol Interior	4.34%	2.49%
EtOH Interior + Glove	23.76%	72.62%

- Nitrile used due to convenience; polymer filled with acidified ethanol for testing
- Both polymer and solvent interior were extracted and analyzed
- ~70% of PCBs were recovered using this method

Conceptual Prototype Blanket Design

- Produced via industrial manufacturing process such as injection molding, plastic extruder, 3-D printing, etc…
- Produced in individual segments
  - A failure/leak in one segment will be localized; will prevent failure from affecting entire blanket and causing loss of entire solvent reservoir
  - Each segment will be capable of being pumped for easy solvent removal/replacement for re-use or recycling purposes, or to allow for remediation of the solvent using activated magnesium



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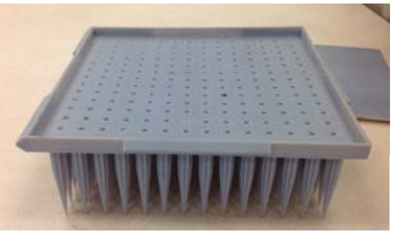
Demonstration Unit



- Small-scale demo unit produced via 3-D printing
- Will be used in the next set of scaled-up experiments for proof-of-concept

2-Step Process

- Preliminary lab work has shown that a 2-step process will be most effective in the field..
- Step 1 will be to use the Polymer Blanket to remove as many PCBs as possible from the contaminated sediments.
- Step 2 will be to extract the PCBs (*ex-situ*) from the polymer blanket and the interior solvent using a combination of ultrasound/solvents, then exposing the extract to activated zero-valent metal (AMTS) and allowing the PCBs to degrade.
- The Polymer blanket (now cleaned) can be refilled and re-used until the contaminated area has reached its target goal.

Summary

- Various polymers tested for ability to remove PCBs from contaminated sediments
- Butyl Rubber, Norprene, Gum Rubber/Foam showed highest removal capacities
- Interior solvent studies showed marked increase in PCB removal capacity when combined with polymers
- Polymer blanket designed for use in feasibility studies
- Small-scale demonstration unit produced for testing

Future Directions

- Test demonstration unit's ability/feasibility to remove PCBs from contaminated sediments in a laboratory scale test
- Evaluate re-usability of both blanket and interior solvent
  - Test effectiveness of removal capability of PCBs over multiple removal cycles
  - Test extraction efficiency from polymer blanket
- Evaluate capability of combining polymer blanket with AMTS technology for degradation of PCBs removed /extracted from contaminated sediments