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In-Situ Bioremediation of Polychlorinated Biphenyls in Sediments

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How Bioaugmentation of PCBs Works

Aroclor 1260

Aerobic Degradation

Anaerobic Dechlorination

CO₂ + H₂O

#RemTEC
Why Natural Attenuation of PCBs is Slow

- PCB dechlorination follows 1st order rate kinetics
- Low cell numbers due to high $k_{ow}$ of PCBs
- Increasing cell numbers increases the dechlorination rates

Lombard et al. 2014 ES&T 48 (8), pp 4353–4360
Technology/Methodology Description

1) Required biocatalysts are available including an anaerobic halorespirer and an aerobic degrader.

2) Chemical/molecular methods were developed for monitoring treatment and bioamendments.

3) Biomass scale-up methods were developed for bioamendments.

4) An system was developed for in situ deployment of bioamendments on GAC using the SediMite delivery system.
Bioamended Activated Carbon

- SediMite™ with biofilm of PCB transforming microorganisms

Application of Bioamended AC
- Abraham’s Creek is an 8 acre/32,000 m² watershed outflow
- Original contaminant likely A1260
- Currently contaminated with an average 5 ppm PCB
- Treatments in four 400 sq. m plots
  Load rate = 1 ton SediMite + $10^{12}$ cells/400 sq. m
Treatability Study

- Bioamending with $10^5$ cell/g yielded greatest reduction of PCBs after 375 days
- DF1 and LB400 were most robust bioamendments
- Addition of carbon source only slightly stimulated PCB degradation
- Mono- to nona-chlorobiphenyls were reduced = anaerobic & aerobic activity
Abraham’s Creek VA – Field Results

Payne et al., 2019. ES&T: 10.1021/acs.est.8b05019
Conclusions – *In Situ* Treatment

- 52% reduction in total mass of PCBs after 409 days
- 80% reduction in total mass of coplanar PCBs
- 95% reduction in dissolved PCBs
- All homolog groups dechlorinated or degraded
- Monitoring will continue
In Situ Treatment of High PCB Concentrations

- Waste Water Emergency Overflow Pond primary treatment until mid-70’s
- Area 6 acres/24,000 m²
- Aroclor 1248 (<17,000 ppm) from glass fabric production
- Adjacent to Roanoke River
- Site is currently in VA DEQ voluntary remediation program
Treatment Goals

- VA DEQ voluntary remediation program requires reduction of PCBs to <50 PPM

- Of currently accepted technologies: dredging is expensive and does not eliminate liability; capping does not remove or reduce levels of PCBs at site

- *In situ* treatment with Bioamended Activated Carbon:
  - Cost-effective for town
  - Reduction of PCB mass
  - Negates requirement for extensive waste management
  - Maintains function of WWTP as an emergency overflow basin
In Situ Study - Deployment
Treatability Study - Results

- **Caisson Top Layer +/- Bioactive Sediment**
  - Inside Caisson (+BA Sediment)
  - Outside Caisson (Untreated)
  - Initial PCB: 50 ppm
  - Final PCB: 50 ppm
  - Change: -288 ppm

- **Caisson Bottom Layer +/- Bioactive Sediment**
  - Inside Caisson (+BA Sediment)
  - Outside Caisson (Untreated)
  - Initial PCB: 1400 ppm
  - Final PCB: 819 ppm
  - Change: -581 ppm
PCB Depth Profile

PCB Conc increases with depth

ca. 10-100 PPM

12-18 in

14-16 in

ca. 100-1000 PPM

4-6 in

Rinaugmentation Treatment

Caisson 4 Top

Day 0

Day 519 total PCB 66 PPM

Day 992 total PCB 49 PPM

Caisson 4 Bottom

Day 0

Day 519 total PCB 775 PPM

Day 992 total PCB 761 PPM
Conclusions – In Situ Test

2.5 years after initial treatment

- PCBs in upper 14 inches of sediment degraded below 50 PPM
- PCBs in 0-4 inch bottom layer of sediment reduced 45%
- Mixing sediments during application increases activity
Pilot-Scale Field Study

- Four - 80 sq. ft (7.4 sq. m.) caissons
- PCB levels 500 – 1500 PPM
Deployment of BAC

18 March 2015
Deployment of BAC

- Applied approximately 1200 lbs bioamended SediMite
- Sump pump used to homogenize sediments
10 Ft Caisson - Results

![Graph showing the results of PCB levels in four caissons. Caisson 1 Mixed: No bioamendment. Caisson 2 Mixed: Bioamendment AC/Nutrients. Caisson 3 Mixed: Bioamendment AC. Caisson 4 Mixed: Nutrients.](image-url)
Conclusions – High PCB Pilot Study

• Mixing alone has some stimulatory effect (Caisson 1)

• Treatments with bioamendment continue to degrade PCBs

• Treatments without bioamendment leveled off after 1 year

• Monitoring will continue
Full-Scale Treatment - Approaches

Approach I - Tilling in Bioamended SediMite to access PCBs at bottom

Approach II - Mix Bioamended SediMite with circulation pumps
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Questions

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