Evaluation of Intrinsic Biodegradation and Amendments to Support Enhanced Monitored Natural Recovery of Sediments

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Outline

- Sediment Remedies
- Monitored Natural Recovery (MNR) Processes
- Enhanced MNR (EMNR) Processes
- Treatability Testing to Understand EMNR
- Sorption / Sequestration
- Biodegradation
Sediment Remedies

- Dredging / Removal
- Isolation Capping
- MNR

- EMNR
  - Thin Layer Capping
  - *In Situ* Treatment
  - Active Capping
  - Combinations of all of the above
Monitored Natural Recovery (MNR)

- Natural processes that reduce concentrations, toxicity, bioavailability or exposure over time
- Key mechanisms are:
  - degradation or conversion to less toxic form,
  - sorption or sequestration,
  - reduction of exposure through deposition of new clean sediment, or
  - reduction of concentrations through dispersion or dilution
EMNR Processes

- **Physical**
  - Thin layer cap

- **Chemical**
  - Sorption of PAH, PCB and mercury
  - Sequestration/precipitation of mercury

- **Biological**
  - Anaerobic reductive dechlorination of chlorinated compounds (CB, PCBs)
  - Aerobic biodegradation (PAH, BTEX)
Implementing EMNR

- Understanding how natural processes (MNR) act to reduce risks and using this knowledge to:
  - predict future concentrations and risks
  - understand how to enhance these processes (EMNR)

- Enhancing these processes may involve amendments to:
  - sorb or sequester target compounds
  - address nutrient or microbial limitations
Examples of Treatability Testing

- biodegradation of chlorinated organics
- biodegradation of BTEX and PAH
- sorption of PAHs with activated carbon
- sorption / sequestration of PCBs and Hg & MeHg with activated carbon and other sorbents

Site Water

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Sorption / Sequestration Processes
Hydrophobic Organic Compounds (HOCs) (such as PAH & PCB) and metals can be sorbed onto many different forms of carbon in sediment.

Porewater concentrations of HOCs in un-amended sediment will be a function of the fraction of organic carbon ($f_{oc}$).

Amendment with activated carbon or similar materials can reduce porewater concentrations, mobility, bioavailability, and risk.
Activated Carbon and Other Sorbents

- Direct addition of bulk activated carbon
  - granular activated carbon (GAC)
  - powdered activated Carbon (PAC)
- Activated carbon incorporated into products such as Sedimite, AquaBlok or AquaGate
- Biochar (less expensive form of carbon)
Case Study of Treatability Testing for PAH in Sediment

- Evaluation of remedial options for PAH impacted sediments adjacent to historical MGP site
- Treatability testing conducted to evaluate natural and enhanced processes for PAHs:
  - Anaerobic + aerobic biodegradation
  - Sequestration via activated carbon addition
Test results indicated that:

- Intrinsic aerobic biodegradation of PAHs in Site sediment was possible
- Activated carbon addition (1%) reduced porewater PAH levels to non-detect
- Test results support use of MNR and use of carbon amendment if MNR will not achieve objectives in necessary time frame
Amendment with activated carbon or other sorbents can reduce Hg and MeHg porewater concentrations through sorption.

Research suggests other amendments can reduce Hg and MeHg – mechanisms may include co-precipitation and reduced bioavailability to Hg methylating bacteria.

Treatability testing can demonstrate site specific impacts of different amendments.
Biodegradation Processes
Biological Reductive Dechlorination

- **Chlorinated Solvents (PCE, TCE, TCA)**
  - Anaerobic reductive dechlorination process
  - *Dehalococcoides (Dhc)*, *Dehalobacter (Dhb)*, *Dehalogenimonas (Dhg)*, *Geobacter*
  - Common practice for groundwater remediation

- **Chlorinated Benzenes (TCB, DCM, MCB)**
  - Same processes and bacteria as for chlorinated solvents

- **Polychlorinated Biphenyl (PCBs)**
  - Same processes and bacteria but complicated by 209 difference PCB congeners
Biodegradation of Chlorobenzenes (CB)

Anaerobic: TCB → DCB → MCB → benzene

Aerobic:
Microcosm Test Results for Chlorobenzenes

Anaerobic with No Amendments

Also biodegrade under aerobic conditions
PCB in Sediments

- Stability of PCBs in industrial applications also makes them stable in the environment
- Activated carbon and other sorbents can reduce bioavailability
- Biological reductive dechlorination also demonstrated but seldom incorporated into sediment management plans
Specific pathways of anaerobic reductive dechlorination of PCBs have been identified

*Dehalococcoides (Dhc)*, and related *Chloroflexi* have been identified in the processes

Field evidence from Hudson River and other sites demonstrates that dechlorination is occurring

Anaerobic processes produce mono-, di- and tri- Cl PCB which are:

- More soluble in water & less bioaccumulative
- Lower toxicity
- More likely to biodegrade under aerobic conditions
Benefits of Understanding Biological Processes for PCBs

- Analysis of PCB homologs or congeners can identify the extent to which reductive dechlorination has occurred:
  - data can be used to understand the characteristics of PCBs present and potential risks
  - predict what changes may happen in the future

- Treatability testing can further demonstrate the site specific potential for reductive dechlorination (intrinsic and enhanced) and help:
  - better predict what changes may happen in the future
  - assess the potential benefits of enhancing biodegradation
EMNR can be used to mitigate risks associated with impacted sediment but requires:

- understanding natural physical, chemical and biological processes
- demonstrating through site specific lab and pilot testing how these processes can be enhanced to provide greater or faster risk mitigation
- implementing and monitoring
Questions