

Set-up of a Decision Support Tool for the remediation of contaminated sediments



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Interreg - Sullied Sediments

European program:

- Interregional cooperation within EU
- Information exchange
- Partners from the North Sea Region
- Belgium: OVAM
= Public Waste Agency of Flanders

Interreg
North Sea Region
Sullied Sediments
European Regional Development Fund



EUROPEAN UNION



Interreg - Sullied Sediments Goals

Improve:

1. Risk assessment of (emerging) contaminants in sediments
2. Treatment (*in situ* and *ex situ*) and possibilities for reuse of contaminated sediments
3. Prevention of sediment contamination by raising awareness

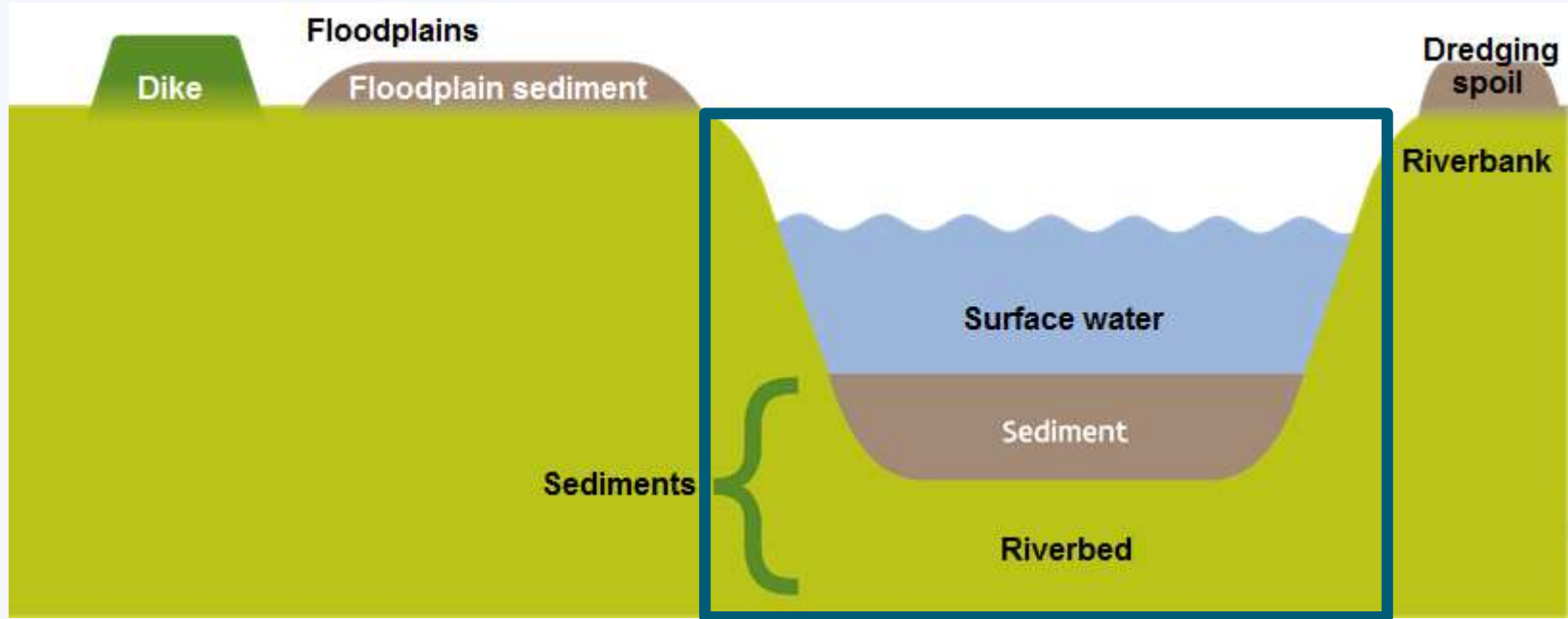
Objectives of the Decision Support Tool

- To create a central knowledge sharing platform on sediment remediation techniques
- To help choosing an optimal technique
- Updated frequently
- Users:
 - Soil/sediment remediation experts
 - Policy makers
 - Problem owners (e.g. industry)
 - Other stakeholders (e.g. waterway managers, etc.)

Objectives of the Decision Support Tool

- Focus on technical feasibility of techniques
- First step in cost-benefit evaluations
- Applicable in Flanders (legally and technically)
- Experimental techniques are included
- Sediments \neq soil, but for now some proven techniques for soil remediation are also included

Sediments ≠ soil



Sediment vs. soil remediation

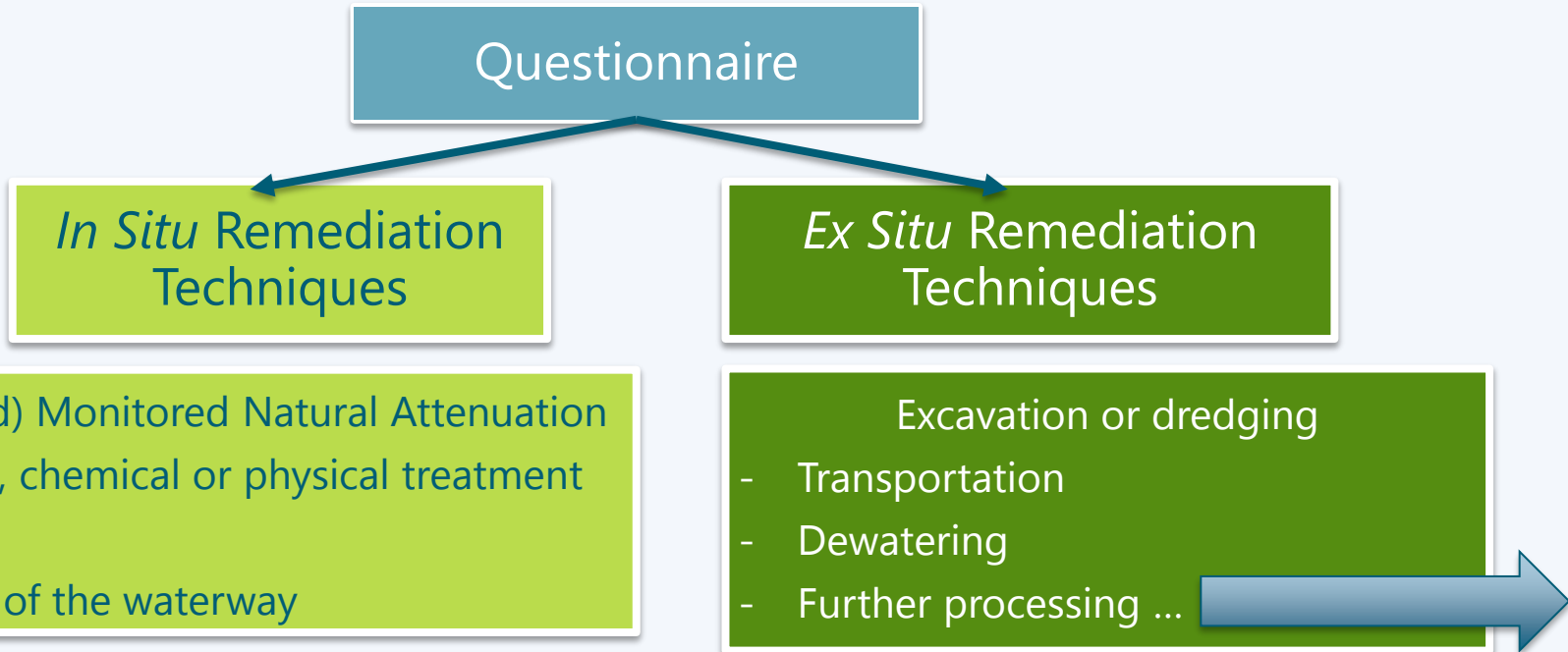
| | Sediments | Soil |
|--------------------------------|---|---|
| Grain size | Relatively small (clayey, loamy) | More varied |
| Water content | High (20-60% dry matter) | Low (>80% dm) |
| Organic content | Relatively high (>2%) | Limited organic content (<2%) |
| Contamination | Typical: heavy metals, mineral oils (>C14), PAHs | More varied |
| Degree of contamination | Relatively low | Relatively high |
| Volumes | Large | Usually smaller |
| Other | Occurrence of specific problem parameters such as TBT | Usually contains rocks, bricks, building- or demolition waste |

Set-up of the Decision Support Tool

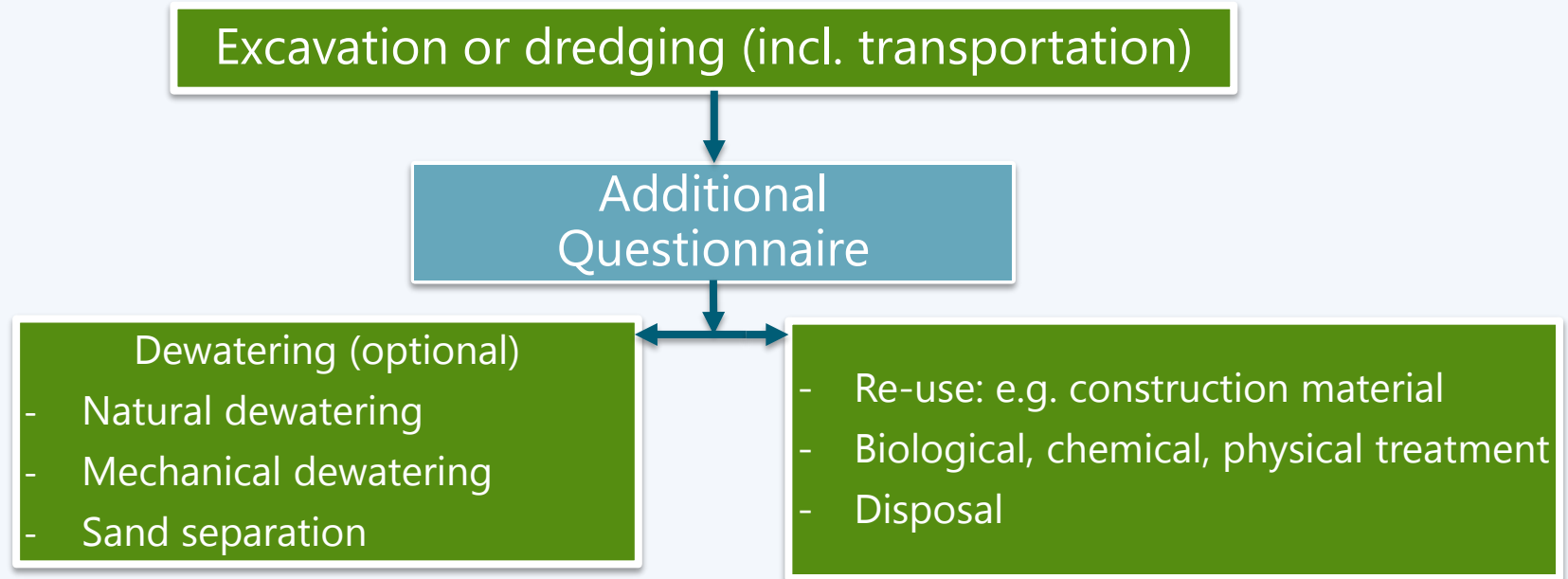
Based on:

- ITRC: Remedy Selection Tool for Contaminated Sediments
https://www.itrcweb.org/contseds_remedy-selection/
- EMIS-VITO: BOSS (BOdemsaneringsSelectieSysteem)*
<https://emis.vito.be/nl/boss-bodemsaneringsselectiesysteem>
- SedNet: Sustainable Management of Sediment Resources, Vol. 2 -
Sediment and Dredged Material Treatment

Decision Support Tool – Flow



Decision Support Tool – Flow: *Ex Situ* Techniques



Decision Support Tool – Questionnaire

Selection criteria – partially based on soil remediation:

- Remediation goals
- Timing
- Waterbody characteristics
- Sediment characteristics
- Contamination characteristics
- Accessibility, etc.

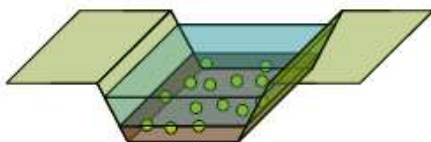
Decision Support Tool – step 1: input user

Step 1 - preconditions

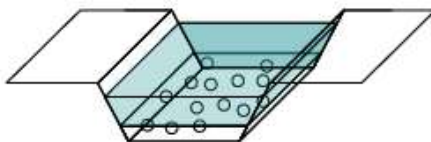
Step 2 - screening

Step 3 - detailed evaluation

1. Remediation goal



2. Characteristics of the waterbody



| Criteria | Definition |
|--|---|
| Based on the results from the Descriptive soil investigation, it is determined on the basis of the contamination situation whether there is a remediation need based on a human risk, risk of dispersion and / or ecological risk. | <input type="radio"/> source control <input type="radio"/> the removal of the risk of dispersal <input checked="" type="radio"/> control of distribution by the water body <input type="radio"/> specific remediation value <input type="radio"/> remediation to the remediation standards <input type="radio"/> preventing physical contact with pollution <input type="radio"/> usage restrictions / advice for use: e.g. no fishing, no swimming, etc. |
| Criteria | Definition |
| Type of waterbody | <input type="checkbox"/> navigable <input checked="" type="checkbox"/> non-navigable <input checked="" type="checkbox"/> canal <input type="checkbox"/> dock <input type="checkbox"/> tidal river |

Behind the scenes: example for MNA

Evaluation by the tool

| Essential criteria | | | MNA |
|-----------------------------------|-----------------------------|--|-------|
| Remediation goal | | Removal to guide value | no |
| | | Removal to risk limit value | * |
| | | Control spreading | maybe |
| | | User advise / limitation | yes |
| Timing | | 0-1 year | no |
| | | 1-5 years | no |
| | | 5-30 years | yes |
| Type(s) of contaminant | Mineral oil fractions < C14 | Biological degradation | yes |
| | | Mobility and ab- and adsorption potential | yes |
| | | No harmful degradation products | yes |
| | | Relatively low concentrations | yes |
| | | Removal to risk limit value | yes |
| | Other... | ... | ... |
| Spreading of contamination | | Contaminants present in groundwater or risk of spreading towards groundwater | no |
| | | Risk of spreading to surface water | no |
| Waterway characteristics | | Navigable / maintenance dredging necessary | no |
| | | Susceptible to erosion | no |

If user answers YES

Decision Support Tool – Step 2: Evaluation

Remediation technologies
Remediation technologies – ex-situ

Step 1 - Input
Step 2 - Evaluation
Step 3 - Input
Step 4 - Evaluation

Technologies

| # | Remediation technology | Result | Criteria | Your selection | Matches? |
|---|----------------------------------|--------|----------------------|--|----------|
| 1 | Biological treatment | yes > | 1. Remediation goal | Remediation to the remediation standards | ✔ |
| 2 | Chemical treatment | yes > | 2. Timing | 0-1 years | ✘ ⓘ |
| 3 | Physical treatment | yes > | 3. Parameters | | |
| 4 | Conventional capping | no > | 3.1 Mineral oil | Remediation to the | |
| 5 | Amended capping | no > | fractions < C14 | | |
| 6 | Monitored Natural Recovery (MNR) | no > | 4. Contamination | | |
| 7 | Enhanced MNR | no > | 4.1 Contamination to | yes | |
| 8 | Excavation (dry) | no > | surface water? | | |
| 9 | Dredging (wet) | no > | | | |

Monitored Natural Recovery (MNR)

[View more →](#)

Required answer:
5-30 years

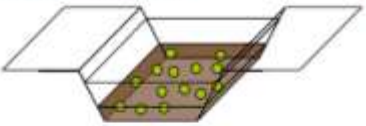
Description:
Description about why this is the required answer.

Decision Support Tool – Step 3: Additional input user for *ex situ* techniques

Remediation technologies
Remediation technologies – ex-situ

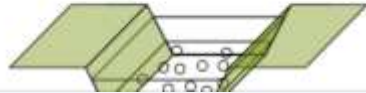
Step 1 - Input
Step 2 - Evaluation
Step 3 - Input
Step 4 - Evaluation

4. Contamination



| Criteria | Definition |
|----------------------------|---|
| Mineral oil fractions + CM | <input type="checkbox"/> Biodegradability / precipitation <input type="checkbox"/> Mobility / ad / absorption <input checked="" type="checkbox"/> No damaging breakdown products <input type="checkbox"/> Concentrations below maximum <input checked="" type="checkbox"/> Remediation to the remediation standards |
| Heavy metals | ✘ no |
| PAHs | ✔ yes |

5. Boundary conditions



| Criteria | Definition |
|----------|--|
| Timing | <input type="radio"/> 0-1 jaar <input checked="" type="radio"/> 1-5 jaar <input type="radio"/> 5-30 jaar |

Decision Support Tool – Step 4: Evaluation *ex situ* techniques

| Remediation technologies | | | Remediation technologies – ex-situ | | | |
|--------------------------|------------------------------------|---------------------|------------------------------------|--|----------|-----------------------------|
| Step 1 - Input | | Step 2 - Evaluation | | Step 3 - Input | | Step 4 - Evaluation |
| Technologies | | | Bioreactor | | | View more → |
| # | Remediation technologies – ex-situ | Result | Criteria | Your selection | Matches? | |
| | Re-use | | 3. Parameters | | | |
| 1 | Geowall | yes | 3.1 Mineral oil fractions < C14 | No damaging breakdown products, Remediation to the remediation standards | ✓ | |
| 2 | USAR | yes | 3.4 Heavy metals | no | ✓ | |
| 3 | Durme-river | yes | 3.5 PAHs | yes | ✓ | |
| 4 | Bricks | no | 5. Timing | 1-5 years | ✓ | |
| 5 | Artificial basalt | no | | | | |
| | Ex-situ treatment | | | | | |
| 6 | Thermal treatment | yes | | | | |
| 7 | Bioreactor | yes | | | | |
| 8 | Landfarming | no | | | | |
| 9 | BioGenesis | no | | | | |

Technical info pages: example for MNA

Case studies

[Enhanced] Monitored Natural Recovery (EMNR)

Monitored Natural Recovery (MNR) is a passive remediation technique that relies on natural processes to protect the environment from exposure to contaminants (EMR). Its primary goal is to reduce the amount of contaminants on the sediment surface and/or the physical bioavailability of the remaining contamination.

With MNR, contaminated sediments are left in place and monitored for ongoing physical, chemical and biological processes that transform, immobilize, volatilize, or remove contaminants and may no longer pose a risk. Natural processes that contribute to MNR may include sediment burial, sediment erosion or dispersion, and contaminant sorption or degradation, for example precipitation, adsorption, or transformation.

MNR Monitoring the process of sediment burial and/or adsorption reduce the amount of contaminants on the sediment surface which is bioavailable.

Physical processes (burial and dispersion)

Burial and dispersion of contaminated sediments can be achieved or accelerated by natural dissipation of suspended particles, turbulence spreading, and sediment transport events such as TSS events. All these processes generally decrease the amount of contaminated sediments on the soil surface, where it usually poses the greatest risk of chemical exposure. However, high contamination levels in the surface layer combined with low erosion rates increase retention of toxic substances on the sediment surface and release a large amount of contamination. Which is why this technique is preferred for low level contaminated sites.

Chemical processes (precipitation, precipitation, degradation and sedimentation)

Sediment precipitation, degradation and sedimentation can all reduce the bioavailability and/or toxicity of a contaminant. With adsorption, dissolved contaminants bind themselves onto or in the soil sediment matrix while precipitation usually causes which specific particles which a certain point of saturation, thus reducing its bioavailability. Changing conditions can however cause the contaminated particles to go back into solution.

Degradation is the transformation of a toxic component into a less toxic component. Reductive dehalo also causes a loss in toxicity, depending on the half-life of the occurring contaminants. However, transformation may also cause a loss in toxicity, depending on the half-life of the occurring contaminants. However, transformation may also cause a loss in toxicity, depending on the half-life of the occurring contaminants. However, transformation may also cause a loss in toxicity, depending on the half-life of the occurring contaminants.

Biological processes

Microbial activity in sediments has an influence on the contaminant concentration, depending on the type of microorganism and the environmental conditions. Microbial activity can lead to the degradation of contaminants.

Besides that, bioturbation caused by burrowing or sediment-dwelling organisms also plays a role in the bioavailability of contaminants.

In order to successfully use these remediation techniques, it is important to have a thorough understanding of the contamination source and to (predict) interaction with the environment. Careful and continuous monitoring of the remediation process is a vital part of this technique.

Enhanced Monitored Natural Recovery (EMNR) follows the same principles, with the addition of an active technique which increases and/or accelerates the natural recovery process. This can for example be the application of a thin-layer cap on the top layer of activated carbon into the contaminated soil.

The main purpose of this active layer is not to completely isolate the contaminated sediments from its surroundings, but to reduce the amount of surface chemicals in order to create a suitable environment for recovery. Additionally, it also accelerates the natural physical restoration process.

EMNR: Enhanced MNR is in essence used to accelerate the natural recovery process, for example adding another layer of sand and addition of an activated charcoal.

Both physicochemical effects, as combined with biological processes, increase sorption and causing it easier to achieve the required remediation goals.

State of the soil and sediment

EMNR has been used as a successful technique on full scale in the United States. Effectiveness and recovery time largely depend on the type and extent of the contamination.

Environmental impacts: Bioremediation

This technique is non-invasive and does not disturb or disrupt biologically active zones, which can be useful in sensitive habitats. It also avoids contaminant reemission. It does, however, often take a long time before remediation goals are met and is preferably used on sites where contamination levels are already relatively low.

Disadvantages

The process of natural recovery takes a relatively long time, during which continuous monitoring is needed since there are still uncertainties between model predictions and reality. Besides that, there also needs to be control of the interaction with natural groundwater and/or surface water discharge.

If appropriate for the site conditions, EMNR is a relatively easy, low-cost, low-risk option that provides a high level of effectiveness and durability.

State of the soil

Contamination is left in place for some time, which is often met with resistance from the public. Under certain circumstances, substantial might be generated into the environment. Substances should be made aware. However, the general public is often not aware of the risks associated with contamination from a sediment site (EMR).

Table: Tuckahoe Creek-Lake Farmstead, Warren County, VT (EMR)

| Question | Response/Yes |
|--|--|
| Site | 22.5 acre parcel located at Tuckahoe Creek and 1.50 km of the Tuckahoe-Mile Creek arm of Lake Farmstead. |
| Contaminants of concern | PCBs |
| Have metals/pesticides ever been analyzed? | No |
| Soil types | EMNR in Tuckahoe-Mile Creek arm of Lake Farmstead |
| Depth of recovery zone | 12 feet |
| Cost | |
| EMNR selected vs. other? | No |
| Site description | The primary focus of the contamination is a company owned large-scale livestock feed (EMR) from 1985 to 1971. It is estimated that 2% of the yearly average amount of PCBs (total approximately 200,000 lbs) passed, including being discharged into Tuckahoe Creek, which is a tributary to Tuckahoe-Mile Creek arm of Lake Farmstead. |
| Contaminant description | Estimated PCB concentrations in a 12.5 acre parcel located at Tuckahoe-Mile Creek, were originally measured between 1-10 ppm or the surface and higher in deeper sediments. In some locations concentrations up to 50 ppm PCBs were found. The affected area in Lake Farmstead covers approximately 375 sq. yds with a total estimated volume of 18 million cu. yd. of PCB contaminated sediments. At EMR-EMR, maximum PCB concentrations measured in sediment core samples from the upper stratum of Lake Farmstead showed concentrations of 1-12 ppm PCBs measured in sediment in the lower part of the core were typically 1-3 ppm. |
| Remedial objectives | The selected target cleanup standard for sediment was 2 ppm PCBs, based on technical feasibility. For the upper stratum, the goal was set at 10 ppm PCBs, also based on technical feasibility. This amount was modified to be achievable within 12 years of the EMR. |
| Remedial approach | Sediment cores were collected in Lake Farmstead and provided data used to determine the vertical profile of PCBs in the sediment column. These data indicated that higher PCBs were being buried beneath sediment surface with over 100 cm of sediment. Sediment transport modeling predicted that sediment accumulation in the water is 1 to 2.5 cm/yr. A water quality model was developed to determine the fate of PCBs in the system over time, and results of this model indicated that PCB concentrations in the water column and sediments of Lake Farmstead would generally decrease over time even in the absence of any active remediation. The primary mechanism for PCB reductions over time were boundary transport and burial. |
| Monitoring | Annual three and sediment monitoring occurred in the spring of each year since 1998, including surface sediment sampling at 12 locations in Tuckahoe-Mile Creek and Lake Farmstead and shallow three analyses in Lake Farmstead. Sediment cores from EMR indicated that typical sediment PCB concentrations in Tuckahoe-Mile Creek have remained stable since 1998 due to ongoing physical processes such as burial, re-suspension, and PCB biodegradation. However, PCB concentrations in fish are not necessary as much. |
| Conclusions | In 2006 it was decided that two of the three sites on the Tuckahoe-Mile Creek arm of Lake Farmstead had to be decontaminated in order to enhance the ongoing natural remediation of lake sediments. However, in the absence of the PCB contaminated |

Pros/cons

Detailed description

Tool = work in progress

- More practical experience is needed
- Next phase: stakeholders will be involved
- Techniques will be updated (added / deleted) frequently
- Suggestions are always welcome!

Thank you for your attention