# Appendix A - List of Documents Reviewed


1. U.S. EPA, Record of Decision for the Cannelton Ind. Site, September 30, 1992.
2. U.S. EPA, Habitat Survey, Cannelton Industries Site, August 1992
3. U.S. EPA, Statement of Work for Remedial Design at the Cannelton Ind. Site, March 24, 1993.
4. CRA, Remedial Design Pre-Design Studies Report, October 1994, Revised January 5, 1995.
5. CRA, HydroQual, Inc., Bioaccumulation Studies, Cannelton Industries Inc. Site, April 1995.
6. U.S. EPA, ERT, Ecological Risk Assessment for the Cannelton Industries, Inc. Site, January 1995.
7. U.S. EPA, Revised Proposed Plan, Cannelton Ind. Site, May 1996.
8. U.S. EPA, Declaration of Amended Record of Decision, Cannelton Ind. Site, September 27, 1996.
9. NOAA and EVS, Baseline Clam Monitoring Study report, September 1998.
10. MSU, Effects of Environmental Parameters on the Mobility of Chromium in Soils at the Cannelton Industries Site, October 1999.
11. CRA, Construction Completion Report, Cannelton Industries Site, December 1999.
12. CRA, Operation and Maintenance Plan (OMP), Cannelton Industries, Inc. Site, November 1999, Approved by U.S. EPA, June 2000.
13. CRA, Interim Remedial Action Report, Cannelton Industries Site, June 2002
14. HydroQual Inc. (Phelps Dodge), November 2002, Post-Baseline Clam Monitoring Study – Summer 2000-.

# Appendix B - Site Photos Documenting Site Conditions

# Appendix B

Site Current Conditions

Photographs Taken in June 2004

During Site Inspection

# Tannery Bay –Shoreline Protection- Looking East

# Tannery Bay –Shoreline Protection-Looking Southeast

# Tannery Bay -Shoreline Protection- Looking West

Tannery Bay –Southwest Corner –Looking West

# Western Shoreline Protection -Looking West-

# Shoreline Protection and Former Barren Zone (Zone B)

Former Barren Zone -Looking Northeast towards Wetlands area-

# Former Plant Area –Northwest corner-

# Former Plant Area (Zone E) –West Entrance Limit-

# Former Barren Zone -Looking Northwest-

Wetland Area -Western limit-

## **Appendix C -** Site Inspection CheckList

Please note that "O&M" is referred to throughout this checklist. At sites where Long-Term Response Actions are in progress, O&M activities may be referred to as "system operations" since these sites are not considered to be in the O&M phase while being remediated under the Superfund program.

## Five-Year Review Site Inspection Checklist (Template)

| I. SITE INFORMATION | |
|---|---|
| **Site name:** Cannelton Ind. | **Date of inspection:** June 8, 2004 |
| **Location and Region:** Sault Ste Marie, MI | **EPA ID:** |
| **Agency, office, or company leading the five-year review:** USEPA | **Weather/temperature:** Sunny Warm |

**Remedy Includes:** (Check all that apply)

- ☐ Landfill cover/containment
- ☒ Access controls
- ☒ Institutional controls
- ☐ Groundwater pump and treatment
- ☐ Surface water collection and treatment
- ☐ Other shore line protection
- ☐ Monitored natural attenuation
- ☐ Groundwater containment
- ☐ Vertical barrier walls

**Attachments:** ☐ Inspection team roster attached ☐ Site map attached

### II. INTERVIEWS (Check all that apply)

1. **O&M site manager** ______________________ ______________________ ______________
Name Title Date
Interviewed ☐ at site ☐ at office ☐ by phone Phone no. ____________
Problems, suggestions; ☐ Report attached ______________________________________

2. **O&M staff** ______________________ ______________________ ______________
Name Title Date
Interviewed ☐ at site ☐ at office ☐ by phone Phone no. ____________
Problems, suggestions; ☐ Report attached ______________________________________

3. **Local regulatory authorities and response agencies** (i.e., State and Tribal offices, emergency response office, police department, office of public health or environmental health, zoning office, recorder of deeds, or other city and county offices, etc.) Fill in all that apply.

Agency ______________________
Contact ______________________ ______________ ________ __________
Name Title Date Phone no.
Problems; suggestions; ☐ Report attached ______________________

Agency ______________________
Contact ______________________ ______________ ________ __________
Name Title Date Phone no.
Problems; suggestions; ☐ Report attached ______________________

Agency ______________________
Contact ______________________ ______________ ________ __________
Name Title Date Phone no.
Problems; suggestions; ☐ Report attached ______________________

Agency ______________________
Contact ______________________ ______________ ________ __________
Name Title Date Phone no.
Problems; suggestions; ☐ Report attached ______________________

4. **Other interviews** (optional) ☐ Report attached.

**III. ~~ON-SITE~~ DOCUMENTS & RECORDS VERIFIED** (Check all that apply)

1. **O&M Documents**

| | | | |
|---|---|---|---|
| ☒ O&M manual | ☒ Readily available | ☒ Up to date | ☐ N/A |
| ☐ As-built drawings | ☐ Readily available | ☐ Up to date | ☐ N/A |
| ☒ Maintenance logs | ☒ Readily available | ☒ Up to date | ☐ N/A |

Remarks Site Files - not needed on Site.

| | | | | |
|---|---|---|---|---|
| 2. | **Site-Specific Health and Safety Plan** | ☐ Readily available | ☒ Up to date | ☐ N/A |
| | ☐ Contingency plan/emergency response plan | ☐ Readily available | ☐ Up to date | ☐ N/A |
| | Remarks | | | |
| 3. | **O&M and OSHA Training Records** | ☐ Readily available | ☐ Up to date | ☐ N/A |
| | Remarks | | | |
| 4. | **Permits and Service Agreements** | | | |
| | ☐ Air discharge permit | ☐ Readily available | ☐ Up to date | ☒ N/A |
| | ☐ Effluent discharge | ☐ Readily available | ☐ Up to date | ☐ N/A |
| | ☐ Waste disposal, POTW | ☐ Readily available | ☐ Up to date | ☐ N/A |
| | ☐ Other permits | ☐ Readily available | ☐ Up to date | ☐ N/A |
| | Remarks | | | |
| 5. | **Gas Generation Records** | ☐ Readily available | ☐ Up to date | ☒ N/A |
| | Remarks | | | |
| 6. | **Settlement Monument Records** | ☐ Readily available | ☐ Up to date | ☒ N/A |
| | Remarks | | | |
| 7. | **Groundwater Monitoring Records** | ☒ Readily available | ☒ Up to date | ☐ N/A |
| | Remarks last round of sampling 12/03 | | | |
| 8. | **Leachate Extraction Records** | ☐ Readily available | ☐ Up to date | ☒ N/A |
| | Remarks | | | |
| 9. | **Discharge Compliance Records** | | | |
| | ☐ Air | ☐ Readily available | ☐ Up to date | ☒ N/A |
| | ☐ Water (effluent) | ☐ Readily available | ☐ Up to date | ☒ N/A |
| | Remarks | | | |
| 10. | **Daily Access/Security Logs** | ☐ Readily available | ☐ Up to date | ☒ N/A |
| | Remarks | | | |

## IV. O&M COSTS

| | | |
|---|---|---|
| 1. | **O&M Organization** | |
| | ☐ State in-house | ☐ Contractor for State |
| | ☐ PRP in-house | ☒ Contractor for PRP |
| | ☐ Federal Facility in-house | ☐ Contractor for Federal Facility |
| | ☐ Other | |

2. **O&M Cost Records**

☐ Readily available ☐ Up to date

☐ Funding mechanism/agreement in place

Original O&M cost estimate____________________ ☐ Breakdown attached

Total annual cost by year for review period if available

| | | | |
|---|---|---|---|
| From__________ (Date) | To__________ (Date) | __________ (Total cost) | ☐ Breakdown attached |
| From__________ (Date) | To__________ (Date) | __________ (Total cost) | ☐ Breakdown attached |
| From__________ (Date) | To__________ (Date) | __________ (Total cost) | ☐ Breakdown attached |
| From__________ (Date) | To__________ (Date) | __________ (Total cost) | ☐ Breakdown attached |
| From__________ (Date) | To__________ (Date) | __________ (Total cost) | ☐ Breakdown attached |

3. **Unanticipated or Unusually High O&M Costs During Review Period**

Describe costs and reasons: BioMonitoring performed by PRP was more expensive than one performed by NOAA

## V. ACCESS AND INSTITUTIONAL CONTROLS ☒ Applicable ☐ N/A

### A. Fencing

1. **Fencing damaged** ☐ Location shown on site map ☐ Gates secured ☐ N/A

Remarks________________________________________

### B. Other Access Restrictions

1. **Signs and other security measures** ☐ Location shown on site map ☐ N/A

Remarks Lock missing on gate for Zone E - former plant area

### C. Institutional Controls (ICs)

| | |
|---|---|
| 1. | **Implementation and enforcement**<br>Site conditions imply ICs not properly implemented ☐ Yes ☐ No ☒ N/A<br>Site conditions imply ICs not being fully enforced ☐ Yes ☐ No ☒ N/A<br><br>Type of monitoring (*e.g.*, self-reporting, drive by) ______<br>Frequency 1-2 per year<br>Responsible party/agency CRA<br>Contact Robert Bressan ______ ______ ______<br>Name Title Date Phone no.<br><br>Reporting is up-to-date ☐ Yes ☐ No ☒ N/A<br>Reports are verified by the lead agency ☐ Yes ☐ No ☒ N/A<br><br>Specific requirements in deed or decision documents have been met ☐ Yes ☒ No ☐ N/A<br>Violations have been reported ☐ Yes ☒ No ☐ N/A<br>Other problems or suggestions: ☐ Report attached |
| 2. | **Adequacy** ☒ ICs are adequate ☐ ICs are inadequate ☐ N/A<br>Remarks Deed Restriction have not been implemented & Recorded. However other ICs are adequate |
| **D. General** | |
| 1. | **Vandalism/trespassing** ☐ Location shown on site map ☒ No vandalism evident<br>Remarks ______ |
| 2. | **Land use changes on site** ☒ N/A<br>Remarks ______ |
| 3. | **Land use changes off site** ☒ N/A<br>Remarks ______ |
| **VI. GENERAL SITE CONDITIONS** | |
| **A. Roads** | ☒ Applicable ☐ N/A |
| 1. | **Roads damaged** ☐ Location shown on site map ☐ Roads adequate ☐ N/A<br>Remarks ______ |
| **B. Other Site Conditions** | |

Remarks ______________________________________________

## VII. LANDFILL COVERS ☐ Applicable ☒ N/A

**A. Landfill Surface**

1. **Settlement** (Low spots) ☐ Location shown on site map ☐ Settlement not evident
   Areal extent______________ Depth____________
   Remarks______________________________________________

2. **Cracks** ☐ Location shown on site map ☐ Cracking not evident
   Lengths____________ Widths___________ Depths__________
   Remarks______________________________________________

3. **Erosion** ☐ Location shown on site map ☐ Erosion not evident
   Areal extent______________ Depth____________
   Remarks______________________________________________

4. **Holes** ☐ Location shown on site map ☐ Holes not evident
   Areal extent______________ Depth____________
   Remarks______________________________________________

5. **Vegetative Cover** ☐ Grass ☐ Cover properly established ☐ No signs of stress
   ☐ Trees/Shrubs (indicate size and locations on a diagram)
   Remarks______________________________________________

6. **Alternative Cover (armored rock, concrete, etc.)** ☐ N/A
   Remarks______________________________________________

7. **Bulges** ☐ Location shown on site map ☐ Bulges not evident
   Areal extent______________ Height____________
   Remarks______________________________________________

8. **Wet Areas/Water Damage** ☐ Wet areas/water damage not evident
   ☐ Wet areas ☐ Location shown on site map Areal extent______________
   ☐ Ponding ☐ Location shown on site map Areal extent______________
   ☐ Seeps ☐ Location shown on site map Areal extent______________
   ☐ Soft subgrade ☐ Location shown on site map Areal extent______________
   Remarks______________________________________________

| | |
|---|---|
| 9. | **Slope Instability** ☐ Slides ☐ Location shown on site map ☐ No evidence of slope instability<br>Areal extent______________<br>Remarks______________________________________________________________ |
| **B. Benches** | ☐ Applicable ☒ N/A<br>(Horizontally constructed mounds of earth placed across a steep landfill side slope to interrupt the slope in order to slow down the velocity of surface runoff and intercept and convey the runoff to a lined channel.) |
| 1. | **Flows Bypass Bench** ☐ Location shown on site map ☐ N/A or okay<br>Remarks______________________________________________________________ |
| 2. | **Bench Breached** ☐ Location shown on site map ☐ N/A or okay<br>Remarks______________________________________________________________ |
| 3. | **Bench Overtopped** ☐ Location shown on site map ☐ N/A or okay<br>Remarks______________________________________________________________ |
| **C. Letdown Channels** | ☐ Applicable ☒ N/A<br>(Channel lined with erosion control mats, riprap, grout bags, or gabions that descend down the steep side slope of the cover and will allow the runoff water collected by the benches to move off of the landfill cover without creating erosion gullies.) |
| 1. | **Settlement** ☐ Location shown on site map ☐ No evidence of settlement<br>Areal extent______________ Depth____________<br>Remarks______________________________________________________________ |
| 2. | **Material Degradation** ☐ Location shown on site map ☐ No evidence of degradation<br>Material type_______________ Areal extent_____________<br>Remarks______________________________________________________________ |
| 3. | **Erosion** ☐ Location shown on site map ☐ No evidence of erosion<br>Areal extent______________ Depth____________<br>Remarks______________________________________________________________ |
| 4. | **Undercutting** ☐ Location shown on site map ☐ No evidence of undercutting<br>Areal extent______________ Depth____________<br>Remarks______________________________________________________________ |
| 5. | **Obstructions** Type_____________________ ☐ No obstructions<br>☐ Location shown on site map Areal extent______________<br>Size____________<br>Remarks______________________________________________________________ |

6. **Excessive Vegetative Growth** Type____________________
☐ No evidence of excessive growth
☐ Vegetation in channels does not obstruct flow
☐ Location shown on site map Areal extent______________
Remarks_______________________________________________

**D. Cover Penetrations** ☐ Applicable ☒ N/A

1. **Gas Vents** ☐ Active ☐ Passive
☐ Properly secured/locked ☐ Functioning ☐ Routinely sampled ☐ Good condition
☐ Evidence of leakage at penetration ☐ Needs Maintenance
☐ N/A
Remarks_______________________________________________

2. **Gas Monitoring Probes**
☐ Properly secured/locked ☐ Functioning ☐ Routinely sampled ☐ Good condition
☐ Evidence of leakage at penetration ☐ Needs Maintenance ☐ N/A
Remarks_______________________________________________

3. **Monitoring Wells** (within surface area of landfill)
☐ Properly secured/locked ☐ Functioning ☐ Routinely sampled ☐ Good condition
☐ Evidence of leakage at penetration ☐ Needs Maintenance ☐ N/A
Remarks_______________________________________________

4. **Leachate Extraction Wells**
☐ Properly secured/locked ☐ Functioning ☐ Routinely sampled ☐ Good condition
☐ Evidence of leakage at penetration ☐ Needs Maintenance ☐ N/A
Remarks_______________________________________________

5. **Settlement Monuments** ☐ Located ☐ Routinely surveyed ☐ N/A
Remarks_______________________________________________

**E. Gas Collection and Treatment** ☐ Applicable ☒ N/A

1. **Gas Treatment Facilities**
☐ Flaring ☐ Thermal destruction ☐ Collection for reuse
☐ Good condition ☐ Needs Maintenance
Remarks_______________________________________________

2. **Gas Collection Wells, Manifolds and Piping**
☐ Good condition ☐ Needs Maintenance
Remarks_______________________________________________

3. **Gas Monitoring Facilities** (*e.g.*, gas monitoring of adjacent homes or buildings)
☐ Good condition ☐ Needs Maintenance ☐ N/A
Remarks_______________________________________________

| | | | |
|---|---|---|---|
| **F. Cover Drainage Layer** | | ☐ Applicable | ☒ N/A |
| 1. | **Outlet Pipes Inspected**<br>Remarks________________ | ☐ Functioning | ☐ N/A |
| 2. | **Outlet Rock Inspected**<br>Remarks________________ | ☐ Functioning | ☒ N/A |
| **G. Detention/Sedimentation Ponds** | | ☐ Applicable | ☒ N/A |
| 1. | **Siltation** Areal extent________ Depth________<br>☐ Siltation not evident<br>Remarks________________ | | ☐ N/A |
| 2. | **Erosion** Areal extent________ Depth________<br>☐ Erosion not evident<br>Remarks________________ | | |
| 3. | **Outlet Works** ☐ Functioning ☐ N/A<br>Remarks________________ | | |
| 4. | **Dam** ☐ Functioning ☐ N/A<br>Remarks________________ | | |
| **H. Retaining Walls** | ☐ Applicable ☒ N/A | | |
| 1. | **Deformations** ☐ Location shown on site map<br>Horizontal displacement________ Vertical displacement________<br>Rotational displacement________<br>Remarks________________ | | ☐ Deformation not evident |
| 2. | **Degradation** ☐ Location shown on site map<br>Remarks________________ | | ☐ Degradation not evident |
| **I. Perimeter Ditches/Off-Site Discharge** | | ☐ Applicable | ☒ N/A |
| 1. | **Siltation** ☐ Location shown on site map<br>Areal extent________ Depth________<br>Remarks________________ | | ☐ Siltation not evident |
| 2. | **Vegetative Growth** ☐ Location shown on site map<br>☐ Vegetation does not impede flow<br>Areal extent________ Type________<br>Remarks________________ | | ☐ N/A |

3. **Erosion** ☐ Location shown on site map ☐ Erosion not evident
Areal extent______________ Depth____________
Remarks__________________________________________________________________________
_________________________________________________________________________________

4. **Discharge Structure** ☐ Functioning ☐ N/A
Remarks__________________________________________________________________________
_________________________________________________________________________________

**VIII. VERTICAL BARRIER WALLS** ☐ Applicable ☒ N/A

1. **Settlement** ☐ Location shown on site map ☐ Settlement not evident
Areal extent______________ Depth____________
Remarks__________________________________________________________________________
_________________________________________________________________________________

2. **Performance Monitoring** Type of monitoring__________________________
☐ Performance not monitored
Frequency_______________________________ ☐ Evidence of breaching
Head differential__________________________
Remarks__________________________________________________________________________
_________________________________________________________________________________

**IX. GROUNDWATER/SURFACE WATER REMEDIES** ~~☒ Applicable~~ ~~☐ N/A~~

**A. Groundwater Extraction Wells, Pumps, and Pipelines** ☐ Applicable ☒ N/A

1. **Pumps, Wellhead Plumbing, and Electrical**
☐ Good condition ☐ All required wells properly operating ☐ Needs Maintenance ☐ N/A
Remarks__________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________

2. **Extraction System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
☐ Good condition ☐ Needs Maintenance
Remarks__________________________________________________________________________
_________________________________________________________________________________

3. **Spare Parts and Equipment**
☐ Readily available ☐ Good condition ☐ Requires upgrade ☐ Needs to be provided
Remarks__________________________________________________________________________
_________________________________________________________________________________

**B. Surface Water Collection Structures, Pumps, and Pipelines** ☐ Applicable ☒ N/A

1. **Collection Structures, Pumps, and Electrical**
☐ Good condition ☐ Needs Maintenance
Remarks__________________________________________________________________________
_________________________________________________________________________________

2. **Surface Water Collection System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
☐ Good condition ☐ Needs Maintenance
Remarks__________________________________________________________________________
_________________________________________________________________________________

| | |
|---|---|
| 3. | **Spare Parts and Equipment**<br>☐ Readily available ☐ Good condition ☐ Requires upgrade ☐ Needs to be provided<br>Remarks______________________________ |
| **C. Treatment System** | ☐ Applicable ☒ N/A |
| 1. | **Treatment Train** (Check components that apply)<br>☐ Metals removal ☐ Oil/water separation ☐ Bioremediation<br>☐ Air stripping ☐ Carbon adsorbers<br>☐ Filters______________________________<br>☐ Additive (*e.g.*, chelation agent, flocculent)______________________________<br>☐ Others______________________________<br>☐ Good condition ☐ Needs Maintenance<br>☐ Sampling ports properly marked and functional<br>☐ Sampling/maintenance log displayed and up to date<br>☐ Equipment properly identified<br>☐ Quantity of groundwater treated annually______________________________<br>☐ Quantity of surface water treated annually______________________________<br>Remarks______________________________ |
| 2. | **Electrical Enclosures and Panels** (properly rated and functional)<br>☐ N/A ☐ Good condition ☐ Needs Maintenance<br>Remarks______________________________ |
| 3. | **Tanks, Vaults, Storage Vessels**<br>☐ N/A ☐ Good condition ☐ Proper secondary containment ☐ Needs Maintenance<br>Remarks______________________________ |
| 4. | **Discharge Structure and Appurtenances**<br>☐ N/A ☐ Good condition ☐ Needs Maintenance<br>Remarks______________________________ |
| 5. | **Treatment Building(s)**<br>☐ N/A ☐ Good condition (esp. roof and doorways) ☐ Needs repair<br>☐ Chemicals and equipment properly stored<br>Remarks______________________________ |
| 6. | **Monitoring Wells** (pump and treatment remedy)<br>☐ Properly secured/locked ☐ Functioning ☐ Routinely sampled ☐ Good condition<br>☐ All required wells located ☐ Needs Maintenance ☐ N/A<br>Remarks______________________________ |
| **D. Monitoring Data** | |
| 1. | Monitoring Data<br>☒ Is routinely submitted on time ☐ Is of acceptable quality |
| 2. | Monitoring data suggests:<br>☐ Groundwater plume is effectively contained ☒ Contaminant concentrations are declining |

**D. Monitored Natural Attenuation**

1. **Monitoring Wells** (natural attenuation remedy)

☒ Properly secured/locked ☒ Functioning ☐ Routinely sampled ☒ Good condition
☒ All required wells located ☐ Needs Maintenance ☐ N/A

Remarks ______________________________________________

## X. OTHER REMEDIES

If there are remedies applied at the site which are not covered above, attach an inspection sheet describing the physical nature and condition of any facility associated with the remedy. An example would be soil vapor extraction.

## XI. OVERALL OBSERVATIONS

**A. Implementation of the Remedy**

Describe issues and observations relating to whether the remedy is effective and functioning as designed. Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.).

Southern Shoreline – Rockwall in good physical condition

ZONE B (Barren ZONE)

✓ good physical condition of rock wall
✓ vegetation growth.
Early spring season – not completely green

No erosion evidenced.

**B. Adequacy of O&M**

Describe issues and observations related to the implementation and scope of O&M procedures. In particular, discuss their relationship to the current and long-term protectiveness of the remedy.

**C. Early Indicators of Potential Remedy Problems**

Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of unscheduled repairs, that suggest that the protectiveness of the remedy may be compromised in the future.

| D. | **Opportunities for Optimization** |
|---|---|

Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy.

# Appendix D
## Comments received from Support Agency (MDEQ) and Community Notification Information

State of Michigan
DEPARTMENT OF ENVIRONMENTAL QUALITY
Lansing

JENNIFER M. GRANHOLM
GOVERNOR

STEVEN E. CHESTER
DIRECTOR

July 29, 2004

Mr. Richard C. Karl
Acting Director, Superfund Division
United States Environmental Protection Agency
Region 5
77 West Jackson Boulevard (SR-6J)
Chicago, Illinois 60604

Dear Mr. Karl:

SUBJECT: Comments on the Draft Five-Year Review Report for the Cannelton Industries Superfund Site, Chippewa County, Michigan

Thank you for the opportunity to review and comment on the draft Five-Year Review Report (Review) for the Cannelton Industries Superfund site dated July 12, 2004, as well as earlier drafts. The Michigan Department of Environmental Quality (MDEQ) has completed its review and provides the following comments:

**Sediments**

We have reviewed all of the sediment investigation data for this site and summarize our findings on the various study types below.

Toxic and Bioaccumulative Characteristics: On page 19, the third paragraph, the Review states, "The results for sediment toxicity and bioaccumulation studies indicated that the sediments did not pose a significant threat to aquatic organisms due to chemical concentrations in soils and sediments in Tannery Bay." Yet, on page 35 the Review states, "There has not been sufficient data collected to make the determination for long-term protectiveness for the remedy selected in Tannery Bay." Perhaps some of the apparent disparity in evaluations derives from an attempt to distinguish between long and short term risks. If so, this could perhaps be clarified. The Remediation and Redevelopment Division (RRD) finds that the site's toxicity work on the sediments showed some indications of site-related toxicity, but the trends were of indeterminate significance, perhaps as much due to the small study size and limited statistical power of the studies, as to a lack of marked toxicity. Our evaluation of these toxicity studies is briefly summarized in our April 8, 2004, letter supporting use of Great Lakes Legacy (GLL) funding for sediment removal at this site.

Both of the bioaccumulation studies conducted to date were also indeterminate in light of mercury contamination of the initial study outset mussel tissues, as you note in the Review on page 26.

Geochemical Stability: Page 21 offers a very good discussion of the attempts by the potentially responsible parties (PRP) to characterize the stability of the organic/metal bonds which render the high metals concentrations nominally bioavailable. It mentions the relevance of the soil studies to the sediments. These discussions mention the shortcomings of not studying the effects of potential exposure to oxygen such as through erosion and other disturbances, and not studying the effects of exhausting the buffering capacity of the matrix.

Erosive Stability: On page 21 of the Review, second to last paragraph, it states that "…the potential for significant re-suspension of sediments is very low." However, our review of the storm erosion analysis indicated that in a 50-year storm event as much as 200 cubic yards of sediments might be eroded from the bay. The phenomenon of ice scouring as acknowledged in the 1996 Record of Decision (ROD) amendment should also be considered in evaluations of the protectiveness of the sediment remedy. One form of ice scouring which has not been mentioned but was observed by John Shauver, MDEQ, is that whereby the winter freeze extends through the ice and into the sediments, and then the high water of the spring melt carries these frozen sediments into the river in the form of ice floes. Granted, neither agency has quantitative criteria for acceptable erosion limits, but the RRD finds the erosive stability of the sediments to be questionable.

All the above factors need to be considered in the weight of evidence evaluation on the protectiveness of the sediment remedy. For purposes of the present Review we recommend language expressing continuing questions as to protectiveness of the sediment remedy. These questions could in part be answered by the planned 2005 mussel bioaccumulation study, or they could be obviated by the contemplated GLL removal. Our present leaning is toward an evaluation that the sediment remedy is not protective in the short or long term, which is why we have so strongly advocated their removal from the river, and offered cost-share monies for the GLL project.

**Wetlands**

The 1996 amended ROD calls for "…surface water, groundwater, sediment, wetland soils, and biological monitoring, including bioavailability studies for metals of concern (chromium, cadmium, mercury, arsenic, and lead)." While bioavailability studies are being done for sediments, they have yet to be done for wetland soils.

We also have some concerns about the metals exceedances in the last wetland pond monitoring round. It does seem likely they are attributable to the faulty sampling methods, but we will need to repeat the monitoring. All things considered, the RRD finds the need to recommend language being inserted in the Review that the protectiveness of the remedy for the wetlands remains uncertain.

The proposed GLL remedy calls for removal of wetland soils with high concentrations of mercury and chromium. If this proposal were to be carried out as planned it would largely obviate the need for bioavailability studies in the wetlands, but if it is not carried out the RRD recommends immediately pursuing bioavailability studies for wetland soils.

**Current Status – Zones A, B, E**

We recommend the fourth complete sentence be rewritten to read: "However, concurrence has been delayed pending a response from the PRP with their assertion that the site meets MDEQ land use closure criteria and related administrative requirements for closure." Similar wording would be appropriate on page 30, under Section VII - Technical Assessment, Question A.

If you have any questions regarding these comments, please contact Mr. Bruce VanOtteren at 517-373-8427, or you may contact me.

Sincerely,

Andrew W. Hogarth, Chief
Remediation and Redevelopment Division
517-335-1104

cc: ✓Ms. Rosita Clarke-Moreno, United States Environmental Protection Agency
Ms. Elizabeth M. Browne, MDEQ
Ms. Daria W. Devantier, MDEQ
Mr. Bruce VanOtteren, MDEQ/Cannelton File (O1)

# U.S. Environmental Protection Agency
# Region 5

### Cannelton Inc. Superfund Site
### Sault Ste. Marie, Mich.

## Public Meeting and Availability Session
## October 23, 2002

EPA will hold a public meeting followed by an availability session to discuss a proposed partial delisting and plans for the five-year review of the Cannelton Inc. Superfund Site. Representatives from the City of Sault Ste. Marie and the Michigan Department of Environmental Quality also will make presentations at the public meeting . Potential future uses of the Site and redevelopment will also be discussed. The availability session will allow people to discuss specific concerns. Representatives from Phelps Dodge, current property owner, will also be present to answer questions and for the availability session.

**Public Meeting**
5:30 - 6:30 p.m.

**Availability Session**
6:30 - 8 p.m.

Lincoln Elementary School
810 E 5th Ave.
Sault Ste Marie, Mich.

More information:

Rosita Clarke-Moreno
U.S. EPA Superfund Division (SF-6J)
77 West Jackson Blvd.
Chicago, IL 60604
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United States Environmental Protection Agency
Region 5
77 West Jackson Blvd.
Chicago, Illinois 60604
Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin

EPA

# Environmental NEWS RELEASE

CONTACT: Don de Blasio, (312) 886-4360
Rosita Clarke-Moreno, (312) 886-7251

FOR IMMEDIATE RELEASE No. 02-OPA XXX

## *EPA HOLDS MEETING ON CANNELTON SUPERFUND SITE PROGRESS AND RE-USE, OCT. 23, 5:30 P.M.*

*CHICAGO (Oct. 17, 2002)* — U.S. Environmental Protection Agency Region 5 will hold a public meeting followed by an availability session to discuss issues related to the completed cleanup and potential re-uses of the Cannelton, Inc., Superfund site, in Sault Ste. Marie, Mich., Wed. Oct. 23, at Lincoln Elementary School, 810 East 5th Ave.

The public meeting begins at 5:30 and includes presentations by EPA, Michigan Department of Environmental Quality and the city of Sault Ste. Marie. An informal availability session begins at 6:30, allowing residents to discuss specific concerns with officials one-on-one. Representatives from Phelps Dodge, the current site owner, will also be available.

The Cannelton cleanup, completed in October 1999, included the excavation and off-site disposal of 33,000 tons of contaminated soils and tannery waste, as well as efforts to landscape and stabilize portions of the St. Marys River shoreline.

# # #

# U.S. Environmental Protection Agency
# Region 5
## Cannelton Industries Inc. Superfund Site
## Public Meeting / Availability Session

Sault Ste. Marie, MI
October 23, 2002

**AGENDA**

| | |
|---|---|
| ` Introductions | Don de Blasio<br>Community Involvement Coordinator, EPA |
| ` Site Update/Partial Delisting Plans | Rosita Clarke-Moreno<br>Project Manager, EPA |
| ` State Involvement | Bruce Van Otteren<br>Michigan Department of Environmental Quality |
| ` City Involvement and Development Plans | City Officials |
| ` Potentially Responsible Parties Activities | Company Representatives |
| ` Question/Answer Session | Audience/Participants |

**Availability Session**

Adjourn: 8 p.m.

United States Environmental Protection Agency
Region 5
77 West Jackson Boulevard
Chicago, IL 60604
Illinois, Indiana
Michigan, Minnesota
Ohio, Wisconsin

EPA

# Partial Delisting Proposed

## 5-year Review Plan to Be Developed

# Cannelton Industries Inc. Superfund Site

Sault Ste. Marie, Mich. October 2002

The U.S. Environmental Protection Agency, is proposing to delist some parts of the Cannelton Industries Inc. Superfund Site, in Sault Ste. Marie, Michigan. EPA is also beginning to develop its five-year review of the cleanup carried out at the site.

Cannelton completed cleanup activities at the site in October of 1999. Cleanup activities included excavation and off-site disposal of 33,000 tons of contaminated soils and tannery- waste materials from the Barren Zone (Zone B), Western Shoreline (Zone A) and the Southern Shoreline of the Tannery Bay. Waste was disposed at 2 permitted off-site solid waste facilities. Cleanup activities also included regrading and landscaping of the western shoreline, backfilling and regrading as needed in the Barren Zone; seeding and mulching to revegetate the Western Shoreline and Barren Zone. Cannelton also constructed a stabilization berm to protect the shoreline from further erosion.

After two years of monitoring, EPA in consultation with MDEQ, has determined that cleanup goals for soils and groundwater have been met. This makes certain areas of the site eligible for removal from the National Priorities List, a list of nearly 1,300 Superfund sites nationwide. The eligible areas are Zones A, B, and E on the map.

## How Sites are Delisted from NPL

EPA may delist an NPL site if it determines that no further response is needed to protect human health or the environment. A site may be delisted where no further response is appropriate if EPA determines that one of the following criteria has been met:

- EPA, in conjunction with the State, has determined that responsible or other parties have implemented all appropriate response action required
- EPA, in consultation with the State, has determined that all appropriate Superfund-financed responses under CERCLA have been carried out and that no further response by responsible parties is appropriate
- a remedial investigation has shown that the release poses no significant threat to public health or the environment and remedial measures are not appropriate.

## Re Use and Future Redevelopment

The Cannelton Site sits in an area zoned for industrial use. The clean-up activities at the Site allows the site to be utilized for industrial uses and meets industrial standards. Others parts of the site meets residential and recreational standards. The City of Sault Ste. Marie is exploring with the current owner of the property about acquisition of the property and planning potential reuses for the Site.

## Meeting

## October 23, 2002 at

**Lincoln Elementary School, 810 East 5th Ave. 5:30 - 8:00pm. Representatives from agencies will be available from 6:30-8:00pm to answer questions.**

**Additional Information**

If you have questions about the **Cannelton Industries Inc. Site,** or would like to be added to the mailing list, please contact:

**Don DeBlasio**
Community Involvement Coordinator
(312) 886-4360 or
(800) 621-8431
deblasio.don@epa.gov

**Rosita Clarke-Moreno**
Project Manager
(312)886-7251
clarke.rosita@epa.gov

**More information on the Site can be found at:**

Bayliss Public Library
541 Library Drive
Sault Ste. Marie, Michigan 49783
(906)632-9331

A copy of this fact sheet and others can be downloaded from the EPA Region 5 web site at: http://www.epa.gov/region5/sites

Rosita Clarke/R5/USEPA/US
To: mripley@sault.com, JenniferManville/R5/USEPA/US, gzimmerman@gw.lssu.edu, dwights@itcmi.org, dtadgerson@saulttribe.net, pripple@bmic.net

05/12/2004 10:16 AM Subject Cannelton Industries Inc. Site, Five Year Review

Hello, U.S. EPA is currently conducting the Five Year Review for the Cannelton Industries Site and I plan on travelling to the Site the week of June 7th, 2004. I would like to meet with you (in groups or individually) to discuss the site and obtain your input regarding the Site's progress and the protectiveness of the remedy. At this time I can provide a status of activities and we can discuss and questions or concerns you may have.

Under CERCLA, Five Year Reviews are to evaluate the remedy implemented at sites and evaluate the effectiveness and protectiveness of that remedy. Community and Stakeholder interest is important to this process.

Please let me know (phone or email) your availability if you'd like to meet with me, for the days of June 7 - 9th.

I'd appreciate your response asap, so that I can appropriately plan my itenerary. I look forward to meeting each of you in person and discussiing the Cannelton Site.

Thank You.
Rosita Clarke-Moreno
U.S. EPA - Superfund
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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, ILLINOIS 60604

SR-6J

May 26, 2004

Re: Cannelton Industries, Inc. Superfund Site

Dear Resident/Community Member:

The U.S. Environmental Protection Agency (EPA) would like to provide you with a status of activities at the Cannelton Site.

Since 1999, when clean-up activities were completed, the property owner with oversight from EPA and Michigan Department of Environmental Quality (MDEQ) has been implementing the Long-Term Monitoring Plan at the site. Long term monitoring of the site include surface water and sediment sampling along Tannery Bay to ensure that remedy remains protective of human health and the environment. Results of the latest sampling, conducted in December of 2003, show no changes in chemical concentrations in surface water and sediments. Groundwater results show that no future groundwater sampling is necessary since clean-up goals have been met for groundwater, and this portion of the monitoring will be discontinued.

In October of 2002, U.S. EPA provided a Site update and presented to the community 3 ongoing activities for the site, in addition to the monitoring events: (a) EPA's proposal to delete 3 areas of the Site from the NPL; (b) City's proposal for future redevelopment of these future NPL delisted areas; and (c) the upcoming Five Year Review for the Site.

Status of these 3 activities:

(a) EPA's proposal for delisting areas of the site is still in process, some delays have occurred, but issues needing resolution for this to be accomplished, are being worked on by the property owner, MDEQ and EPA.
(b) The City's intent for future redevelopment and reuse of these areas are still on the table and will move forward once the first item (a) above is resolved.
(c) EPA is finalizing the Five Year Review and should complete this Report by mid-late June. A copy of the Report will be made available to the Community via EPA's website **http://www.epa.gov/region5/superfund/fiveyear/fyr_index.html**. A copy of the full report will also be available at the Bayliss Public Library, 541 Library Dr., Sault Ste. Marie, MI 49783 (906) 632-9331.

Five Year Reviews are conducted at Sites to ensure that the remedy implemented remains protective of human health and the environment. All past clean-up information for the site and any new relevant information is evaluated to ensure protectiveness. The community's input in this process was requested in October 2002, and any comments, questions or concerns are still welcome. If you'd like to provide input to EPA, please contact me, Rosita Clarke-Moreno, Project Manager for the Cannelton Site at (312)886-7251 or 800-621-8431. Email **clarke.rosita@epa.gov**.

Sincerely,

R Clarke Moreno

# Appendix E
# Literature Review of Metal Cycling by Cattails

# Literature Review of Metal Cycling by Cattails

**Prepared by**
**NOAA Coastal Protection and Restoration Division,**
**July 2004**

Metal contamination of sediment and water frequently occurs at sites around the Great Lakes. The bioavailability and toxicity of various metals have been well studied for a variety of organisms. The Cannelton Industries Superfund Site contains a thick stand of cattails along the western shore of Tannery Bay and in the adjacent wetland area. These cattails have been encroaching on the Bay over time. While this is a natural phenomenon, its potential impact on the Site must be evaluated as a part of the 5-year review.

### ***Typha*** **spp.**

*Typha* spp., commonly known as cattails, are distributed throughout North America. This genus is found in fresh water areas such as meadows, marshes, fens, ponds, lakes, rivers, and streams, but can also be found in slightly brackish marshes. Cattails are generally tolerant of continuous inundation and seasonal drawdowns, but prefer shallow water habitats.

Cattails can form dense, single species stands and floating mats. Each individual plant can spread extensively by rhizomes so that an acre of cattails may consist of only a few individuals. However, they also can occur in mixed stands with Bulrush (*Scirpus acutus*, *S. californicus*) and Maidencane (*Panicum hemitomon*). *Typha spp.* is often found down slope of the Common Reed (*Phragmites australis*), Reed Canarygrass (*Phalaris arundinacea*), and willows (*Salix* spp.). *Typha* spp. is a dominant component of early successional stages in wetlands. This is most likely due to its ability to rapidly colonize an area via wind and water dispersed seeds.

## Benefits

The addition of vascular plants can stabilize sediments and prevent erosion by reducing the surface water inflow. Cattails can minimize sediment resuspension and maximize the potential for recolonization (Wong 2003). The physical structure of cattails can also provide shade and shelter habitat for fish.

Biotoxicity can be reduced when wetland plants alter the metal form, in turn altering the metal bioavailability. Perhaps most importantly, wetlands can reduce Pb by 94%, Mn by 44%, Ni by 84%, Fe by 84%, and dissolved Cd, Cr, Cu and Zn by 98% (EPA 1992). Vascular plants can also accumulate Hg and B from sediments and water.

## Concerns

One concern with cattail proliferation at the Site is the potential for metals the cattails to extract metals from the system and then redistribute them. Seasonal cycles could be responsible for spreading the metals much farther than they had originally been distributed. In the fall, leaves of cattails senesce and can contribute significant quantities of organic matter via throughfall and litterfall. As a result, cattail stands tend to grow on sediments with high concentrations of organic matter in the surface layers.

## Uptake

*Typha* spp. can accumulate mercury from sediment, porewater, water, and air. Uptake in aquatic plants has been correlated with the concentration of mercury in the water (Lenka et al. 1990; Windom and Kendall. 1979). In aqueous laboratory experiments, 43.7 – 54.1% of mercury was removed by *Typha* (Krishnan et al. 1988). Similarly, Robichaud et al. (1995) found that common cattail (*Typha latifolia*), burr reed (*Sparganium minimum*), and *Menyanthes trifoliata* roots readily absorb mercury from aqueous solutions. Furthermore, the hydrophilic parts of the roots accumulated significantly more mercury than did the hydrophobic parts (Robichaud et al. 1995).

Foliar uptake of metals by C3 species (e.g. *Typha* spp.) can be five times greater than that of C4 species (e.g. other wetland species) (Patra and Sharma 2000). Metal uptake rates can vary depending on the metal and tissue type. Vascular plants accumulate both inorganic and methylmercury from sediment and water in root, stem, and leaf sections (Alberts et al. 1990; Boudou et al. 1991). Metal uptake of Pb and Hg in dried roots of *Typha* were 42 and 76 mg/g-hr, respectively (Robichaud 1996). Metal uptake of Zn, Cu, Pb, and Cd in shoots of *Typha* were 85, 11, 0.2, and 2.2 mg/m$^2$, respectively (Dunbabin and Bowmer 1992).

### *Factors Affecting Uptake*

Factors affecting plant uptake include the size, duration, and timing of contamination; oxide and carbonate content; redox potential; sediment organic carbon; and oxygen content.

Breteler et al. (1981) examined factors which would affect the uptake of mercury by *S. alterniflora*. They found that redox potential was not a significant influence for mercury at this site. However, Davies and Jones (1988) determined that redox potential is a significant influence on iron uptake since it dictates the solubility of iron in soil. Zn is more available at higher Eh (Davies and Jones 1988).

Other factors such as pH and organic matter can affect uptake. Mn availability and toxicity are often affected by pH since Mn is more available at low pH (acidic) environments(Davies and Jones 1988). Cu is more readily complexed (and less available) in soils with high organic matter content and/or acidic environments(Davies and Jones 1988). Additionally, Breteler et al. (1981) demonstrated that roots more readily accumulated mercury in soils with lower organic matter.

## Partitioning

A summary of *Typha* uptake concentrations is presented in Table 1. Most research (Cardwell et al. 2002; Debusk et al. 1996; Mays and Edwards 2001; Sriyaraj and Shutes 2001; Ye et al. 1997), indicates that metal concentrations follow the general order roots > rhizomes > shoots/leaves. However, when shoots were divided into subcategories metals were fractioned in the following order: roots > rhizomes > mature fruit > shoot tip > shoot midsection > shoot base (Taylor and Crowder 1983). The ability of vascular plants to transfer metals varies depending on the species. For example,*Juncus effusus* transfers metals to stems much more efficiently than *Typha latifolia* (Shutes et al. 1993).

Some evidence suggests that sediment concentrations do increase coinciding with the senescence of cattail stands. In other words, when cattails drop their leaves, sediment concentrations are elevated. Throughfall and litterfall have been shown to play a significant role in the cycling and deposition of mercury in the watershed of Lake Champlain (Rea et al. 1996). However, it is important to consider that the concentrations of metals in leaves are often an order of magnitude less than those in roots (Mays and Edwards 2001). Therefore, limited ability to transfer metals within the plant will ultimately dictate the concentration of metals that are reintroduced to the system due to litterfall. The shoot and leaf tissue concentrations are dependent upon several factors including the potential binding of the metal to the root surface, the transport of the metal into the root, and the metal translocation from the root to the shoot (Chaney and Giordano 1977; Wild 1988).

## Toxicity

Overall, *Typha* sp. are very tolerant of metal-rich environments (Wong 2003). Tolerance is usually specific to one particular metal; however, *Typha* seems to be tolerant to a wide variety of individual metals and their mixtures. This tolerance, despite the uptake of metals, indicates that there are no observable adverse affects (Wong 2003). Lim et al. (2003) observed that metal uptake could lead to a potential inhibition of nitrogen uptake. Specifically, Lim et al. found that increased metal loadings (Zn, Pb, and Cd) decreased the ammoniacal nitrogen removal efficiency of the cattails.

There are a number of potential mechanisms that would prevent metal toxicity to cattails. Phytochelatins in plants and fungi prevent toxicity by binding the metal so that it is no longer bioavailable. Cattails may also sequester the metals by compartmentalizing the toxic compounds (Patra 2000). Regardless of the mechanism, the tolerance of *Typha* to metals allows it to flourish in an environment that may be toxic to other species.

## Biomass

*T. latifolia* in a constructed wetland may take about two years to reach maximum biomass (Groudeva et al. 2001). An average biomass estimate for roots, rhizomes, and leaves was 60.4, 1077.6, and 838.1 $g/m^2$, respectively (Zhang et al. 1990). Seasonal variations in biomass can be indicative of high productivity.

Metal uptake in cattails is impressive based on tissue concentrations alone, but when normalized for biomass, the metals only account for 1-2% of the total metal loadings. It seems that while cattails do have the ability to uptake metals, their total impact on a site may be low due to low biomass in relation to the mass of the contaminated sediment.

### *Metals*

*Arsenic*

Mays and Edwards (2001) performed an arsenic uptake study with *T. latifolia* in natural wetlands (Table 1). There were no significant differences between uptake in the spring versus that in the fall. Arsenic concentrations in roots and shoots were relatively low (3.9-8.6 and 0.03-0.06 ug/g, respectively) in wetlands with low aqueous arsenic concentrations (<0.4 - 0.85 ug/L) and sediment (1.43 – 3.44 ug/g). However, in natural wetlands with elevated arsenic concentrations in water (100 ug/L) and sediment (7.5 – 32 ug/g), root and shoot concentrations were higher (21.1 – 28.8 and 0.7 – 1 ug/g, respectively).

*Cadmium*

Cadmium uptake appears to be variable. In a study by Mays and Edwards (2001), Cd concentrations in water and sediment were below detection limits; however, root concentrations ranged from 1.7 to 6 ug/g. Ye et al. (1997) found that Cd concentrations were much more variable in roots than in shoots. In a system with Cd sediment concentrations ranging from 1.4 to 26 ug/g, root concentrations varied from 1 to 17 ug/g, however shoot concentrations were much less variable (ranging from 0.2 to 0.8 ug/g). This indicates that the variability in Cd concentrations may be due to unequal binding to roots. However, in a natural wetland and greenhouse study by Zhang et al. (1990), the rhizome Cd fraction exceeded that in roots and shoots.

*Chromium*

Mays and Edwards (2001) have illustrated seasonal variability in Cr uptake. In both constructed and natural wetlands, Cr concentrations were much higher in the spring than the fall (13-37 and 2.3 – 3.9 ug/g, respectively). Shoot concentrations demonstrated the same order of magnitude decrease in fall versus the spring.

*Lead*

In some natural wetlands, rhizomes have higher concentrations than both roots and shoots (Zhang et al. 1990, Ye et al. 1997). Since rhizomes have much more biomass than roots, this indicates that more Pb could be extracted than other metals which tend to partition to the roots. In a study of natural wetlands by Ye et al. (1997), root Pb concentrations (25 to 3628 ug/g) increased with increasing sediment Pb concentrations (26 to 18,894 ug/g).

*Mercury*

Mercury uptake and toxicity is highly influenced by its form/speciation. Methyl mercury is produced by bacterial decomposition of elemental or inorganic mercury. Higher sediment organic carbon content can increase microbial production, which would decrease available $O_2$, increasing the methylation rate of mercury (Beckvar et al. 1996). Breteler et al. (1981)demonstrated that an increased mercury methylation rate decreased the mercury uptake rate in *Spartina*. Organic mercury has been reported to be 200 times more potent than inorganic mercury. This form is so toxic because mercuric cations bind to sulphydryl (-SH) groups which can be found in almost all proteins (Clarkson 1972). Methylmercury can biomagnify up a food chain, which means that even small concentrations of methyl mercury in Typha could pose a serious threat to higher trophic levels (Meagher and Rugh 1997).

The fraction of mercury retained in the roots is about 20 times that observed in the shoots and is closely related to the $NH_4OAc$-extractable mercury in the soils (Lindberg et al., 1979). Patra and Sharma (2000) explained that there is a tendency for mercury to accumulate in roots, indicating that the roots serve as a barrier to mercury uptake. They further state that the mercury concentrations in aboveground plant tissues appear to depend on foliar uptake of mercury that has volatilized from the soil. Mercury concentrations in the plants (stems and leaves) are always greater when the metal is introduced in organic form (Patra and Sharma 2000).

## Conclusion

Metals can be taken up by *Typha* directly from sediment, porewater, surface water, and air. In cattails, metals tend to follow similar partitioning patterns; roots tend to have the greatest metal concentration followed by rhizomes, then, shoots and leaves, respectively. While roots do extract a significant metal fraction, the relatively smaller biomass of the roots (vs. leaves and the contaminated sediment) limits the extraction impact on the contaminated site. Limited transfer of metals from the cattail roots also limits the potential for metal redistribution via leaf senescence or animal dissemination.

Table 1. Metal uptake in roots, rhizomes, and shoots of common cattails (NR= not reported, n.d. = not detected)

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Cardwell et al. 2002 | *Typha orientalis* | Field natural wetland | Pb, Zn, Cu, Cd mixture | Cd | NR | 0.03 | 0.13 | NR | 0.17 |
| Cardwell et al. 2002 | *Typha domingensis* | Field natural wetland | Pb, Zn, Cu, Cd mixture | Cd | NR | 0.07 - 1.53 | 1.47 - 2.57 | NR | n.d. - 0.20 |
| Cardwell et al. 2002 | *Typha domingensis* | Field natural wetland | Pb, Zn, Cu, Cd mixture | Cu | NR | 17.6 - 38.3 | 53.5-127.4 | NR | 3.37 - 14.9 |
| Cardwell et al. 2002 | *Typha orientalis* | Field natural wetland | Pb, Zn, Cu, Cd mixture | Cu | NR | 5.1 | 4.1 | NR | 2.37 |
| Cardwell et al. 2002 | *Typha orientalis* | Field natural wetland | Pb, Zn, Cu, Cd mixture | Pb | NR | 14.9 | 0.2 | NR | 0.07 |
| Cardwell et al. 2002 | *Typha domingensis* | Field natural wetland | Pb, Zn, Cu, Cd mixture | Pb | NR | 12.9 - 77.2 | 21.1 - 201.6 | NR | 1.57-4.53 |
| Cardwell et al. 2002 | *Typha domingensis* | Field natural wetland | Pb, Zn, Cu, Cd mixture | Zn | NR | 93.4 - 514.1 | 355.5 - 1030 | NR | 21.4 - 83.4 |
| Cardwell et al. 2002 | *Typha orientalis* | Field natural wetland | Pb, Zn, Cu, Cd mixture | Zn | NR | 29.7 | 13.3 | NR | 20.2 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Debusk et al. 1996 | *Typha domingensis* | 14 month microcosm | leachate, spiked with 396 ug/L Pb and 105 ug/L Cd | Cd | 52 | 42-61 | 600 | 55 | 5.25 |
| Debusk et al. 1996 | *Typha domingensis* | 14 month microcosm | leachate, spiked with 396 ug/L Pb and 105 ug/L Cd | Pb | 196 | 198-295 | 1200 | 150 | 90 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Spring | Metals | As | < 0.4 | 1.43 | 3.9 | NR | 0.03 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Fall | Metals | As | < 0.4 | 1.47 | 8.6 | NR | 0.06 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP)- Spring | Metals | As | 0.85 | 3.2 | 3.5 | NR | 0.06 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP) - Fall | Metals | As | 0.85 | 3.44 | 3.8 | NR | 0.04 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)- Spring | Metals | As | 100 | 32 | 28.8 | NR | 0.07 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)- Fall | Metals | As | 100 | 7.5 | 21.1 | NR | 1 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Spring | Metals | Cd | < 6 | < 0.006 | 1.7 | NR | < 0.006 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Fall | Metals | Cd | < 6 | < 0.006 | 2.2 | NR | 0.06 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP)-Spring | Metals | Cd | < 6 | < 0.006 | 2.7 | NR | < 0.006 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP) - Fall | Metals | Cd | < 6 | < 0.006 | 6 | NR | 0.1 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Spring | Metals | Cd | 20 | < 0.006 | 2.4 | NR | < 0.006 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Fall | Metals | Cd | 20 | < 0.006 | 5.6 | NR | 0.4 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Spring | Metals | Cr | < 0.005 | < 0.005 | 13 | NR | 3.3 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Fall | Metals | Cr | < 0.005 | 0.53 | 3.9 | NR | 0.7 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP)-Spring | Metals | Cr | < 0.005 | < 0.005 | 37 | NR | 12 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP) - Fall | Metals | Cr | < 0.005 | 0.78 | 3.1 | NR | 0.4 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Spring | Metals | Cr | < 0.005 | < 0.005 | 24 | NR | 6.2 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Fall | Metals | Cr | < 0.005 | 0.38 | 2.3 | NR | 0.5 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Spring | Metals | Cu | NR | 0.9 | 6.5 | NR | 6.3 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Fall | Metals | Cu | NR | 1.13 | 5.4 | NR | 1.8 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP)-Spring | Metals | Cu | NR | 0.49 | 6.5 | NR | 1.2 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP) - Fall | Metals | Cu | NR | 1.22 | 1.2 | NR | 1 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)- Spring | Metals | Cu | NR | 1.3 | 3.3 | NR | 3.6 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)- Fall | Metals | Cu | NR | 1.22 | 4.1 | NR | 2.5 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Spring | Metals | Fe | 1.29 | 314 | 8820 | NR | 363 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Fall | Metals | Fe | 1.29 | 372 | 9121 | NR | 253 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP)- Spring | Metals | Fe | 44 | 350 | 7427 | NR | 349 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP) - Fall | Metals | Fe | 44 | 448 | 28660 | NR | 327 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Spring | Metals | Fe | 205 | 240 | 13077 | NR | 381 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Fall | Metals | Fe | 205 | 217 | 27322 | NR | 1739 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Spring | Metals | Mn | 0.2 | 66 | 442 | NR | 751 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Fall | Metals | Mn | 0.2 | 56 | 617 | NR | 821 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP)-Spring | Metals | Mn | 5.9 | 241 | 1786 | NR | 1752 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP) - Fall | Metals | Mn | 5.9 | 277 | 2012 | NR | 2076 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Spring | Metals | Mn | 7.4 | 123 | 121 | NR | 527 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Fall | Metals | Mn | 7.4 | 59 | 144 | NR | 549 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Spring | Metals | Ni | < 0.029 | 0.85 | 8.5 | NR | 2.9 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Fall | Metals | Ni | < 0.029 | 0.73 | 4 | NR | 1.2 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP)-Spring | Metals | Ni | < 0.029 | < 0.03 | 18.1 | NR | 6.2 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP) - Fall | Metals | Ni | < 0.029 | 0.96 | 1.5 | NR | 0.7 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Spring | Metals | Ni | < 0.029 | 0.69 | 10.7 | NR | 3.3 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Fall | Metals | Ni | < 0.029 | 0.9 | 0.5 | NR | 0.3 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Spring | Metals | Pb | < 2 | 1.3 | 17.9 | NR | < 0.09 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Fall | Metals | Pb | < 2 | 2.1 | 9.9 | NR | 0.7 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP)-Spring | Metals | Pb | < 2 | 1 | 4.7 | NR | < 0.09 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP) - Fall | Metals | Pb | < 2 | 1.8 | 6.1 | NR | 0.6 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Spring | Metals | Pb | 2.2 | 2 | 6 | NR | 1.1 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Fall | Metals | Pb | 2.2 | 1.8 | 8.2 | NR | 0.8 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Spring | Metals | Zn | < 9 | 3.7 | 34 | NR | 38 |
| Mays and Edwards 2001 | *Typha latifolia* | Field natural wetlands - Fall | Metals | Zn | < 9 | 2.9 | 34 | NR | 12 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP)-Spring | Metals | Zn | < 9 | 1.4 | 41 | NR | 16 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (IMP) - Fall | Metals | Zn | < 9 | 2.6 | 23 | NR | 7.5 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Spring | Metals | Zn | 30 | 2.5 | 16 | NR | 16 |
| Mays and Edwards 2001 | *Typha latifolia* | Field constructed wetlands (WC)-Fall | Metals | Zn | 30 | 2.6 | 23 | NR | 12 |
| Siyaraj and Shutes 2001 | *Typha latifolia* | Field natural wetland | Cd, Pb, Cu, Zn | Cd | 0.4 - 1.65 | 1.14 - 44.39 | ~10 | ~2 | ~1 |
| Siyaraj and Shutes 2001 | *Typha latifolia* | Field natural wetland | Cd, Pb, Cu, Zn | Cu | 0.05 - 2.43 | 5.78 - 41.50 | ~15 | ~5 | ~2 |
| Siyaraj and Shutes 2001 | *Typha latifolia* | Field natural wetland | Cd, Pb, Cu, Zn | Pb | 2.80 - 5.65 | 9.71 - 95.45 | ~18 | ~5 | ~2 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Siyaraj and Shutes 2001 | *Typha latifolia* | Field natural wetland | Cd, Pb, Cu, Zn | Zn | n.d. - 13.15 | 48.46 - 239.81 | ~42 | ~22 | ~15 |
| Taylor and Crowder 1983 | *Typha latifolia* | Field natural wetland near smelters | Metals | Ca | NR | 8292 | 1781 - 11574 | 1209 - 6726 | 2793 - 23129 |
| Taylor and Crowder 1983 | *Typha latifolia* | Field natural wetland near smelters | Metals | Cu | NR | 3738 | 13 - 265 | n.d. - 37 | n.d. - 11 |
| Taylor and Crowder 1983 | *Typha latifolia* | Field natural wetland near smelters | Metals | Fe | NR | 24258 | 777 - 57138 | 105 - 17162 | 21 - 333 |
| Taylor and Crowder 1983 | *Typha latifolia* | Field natural wetland near smelters | Metals | Mg | NR | 6841 | 882 - 5542 | 745 - 2782 | 276 - 2410 |
| Taylor and Crowder 1983 | *Typha latifolia* | Field natural wetland near smelters | Metals | Mn | NR | 573 | 16 - 901 | 16 - 552 | 21 - 808 |
| Taylor and Crowder 1983 | *Typha latifolia* | Field natural wetland near smelters | Metals | Ni | NR | 9372 | n.d. - 388 | n.d. - 80 | n.d. - 24 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Taylor and Crowder 1983 | *Typha latifolia* | Field natural wetland near smelters | Metals | Zn | NR | 343 | 24 - 572 | 6 - 65 | 5 - 33 |
| Ye et al. 1997 | *Typha latifolia* | Laboratory | 0.05 ug/ml Cu and 0.10 ug/ml Ni for 72 days | Cu | 50 | NR | 435 - 493 | NR | 44 |
| Ye et al. 1997 | *Typha latifolia* | Laboratory | 0.05 ug/ml Cu and 0.10 ug/ml Ni for 72 days | Ni | 100 | NR | 317 - 561 | NR | 66 - 92 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (FS) | Metals | Zn | NR | 86 ± 14 | 46 ± 4.6 | 36 ± 3.4 | 22 ± 1.1 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (FS) | Metals | Pb | NR | 26 ± 26 | 25 ± 8.2 | 40 ± 36 | 19 ± 9.8 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (FS) | Metals | Cd | NR | 1.4 ± 0.3 | 2.1 ± 0.5 | 1.7 ± 0.9 | 0.6 ± 0.3 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (SH) | Metals | Zn | NR | 909 ± 280 | 58 ± 8.0 | 43 ± 9.7 | 23 ± 3.8 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (SH) | Metals | Pb | NR | 434 ± 58 | 35 ± 7.4 | 2.0 ± 0.5 | 4.7 ± 0.8 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (SH) | Metals | Cd | NR | 9.4 ± 3.0 | 1.0 ± 0.2 | 0.8 ± 0.1 | 0.2 ± 0.02 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (CM) | Metals | Zn | NR | 1327 ± 52 | 684 ± 70 | 376 ± 63 | 29 ± 2.2 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (CM) | Metals | Pb | NR | 18894 ± 3390 | 3628 ± 804 | 414 ± 107 | 32 ± 8.2 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (CM) | Metals | Cd | NR | 26 ± 1.9 | 17 ± 6.3 | 1.1 ± 0.4 | 0.8 ± 0.3 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (SG) | Metals | Zn | NR | 3009 ± 78 | 946 ± 137 | 456 ± 66 | 122 ± 24 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (SG) | Metals | Pb | NR | 5686 ± 621 | 1108 ± 149 | 354 ± 69 | 40 ± 11 |
| Ye et al. 1997 | *Typha latifolia* | Field natural wetland (SG) | Metals | Cd | NR | 20 ± 0.3 | 1.5 ± 0.1 | 1.6 ± 0.6 | 0.6 ± 0.09 |
| Zhang et al. 1990 | *Typha latifolia* | Field natural wetland (Welsh Harp flood storage reservoir) | Metals | Cd | 8.9 | 12.4 | 6 | 72 | 28 |
| Zhang et al. 1990 | *Typha latifolia* | Field natural wetland (Welsh Harp flood storage reservoir) | Metals | Cu | 53.4 | 220.1 | 67 | 1580 | 840 |

| Paper | Species | Type of test | Contaminant | Metal | Water Concentration (ug/l) | Surface Sediment Concentration (ug/g) | Root Concentration (ug/g) | Rhizome Concentration (ug/g) | Shoot Concentration (ug/g) |
|---|---|---|---|---|---|---|---|---|---|
| Zhang et al. 1990 | *Typha latifolia* | Field natural wetland (Welsh Harp flood storage reservoir) | Metals | Pb | 36.2 | 841.2 | 112 | 504 | 224 |
| Zhang et al. 1990 | *Typha latifolia* | Field natural wetland (Welsh Harp flood storage reservoir) | Metals | Zn | 136.6 | 778.9 | 164 | 540 | 434 |
| Zhang et al. 1990 | *Typha latifolia* | Greenhouse | Metals | Cd | 10000 | 286 | 662 | 1669 | 613 |
| Zhang et al. 1990 | *Typha latifolia* | Greenhouse | Metals | Cu | 10000 | 187 | 190 | 1188 | 329 |
| Zhang et al. 1990 | *Typha latifolia* | Greenhouse | Metals | Pb | 10000 | 168 | 242 | 976 | 532 |
| Zhang et al. 1990 | *Typha latifolia* | Greenhouse | Metals | Zn | 10000 | 294.8 | 689 | 1800 | 512 |

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