Columbia Slough Sediment Study

DEQ Cleanup Program - Northwest Region
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Funded by EPA Grant #EM-96054601-0
Previous investigations provide baseline of data which was used and supplemented.

Previous Portland BES sediment data provides understanding of sediment contamination- 1994, 2005


Portland BES fish (carp) sampling in 2005
Objectives of Study

- Determine average concentrations of contaminants in slough sediment and developing new, updated estimates of baseline concentrations in the sampled segments

- Development of predictive relationships between sediment and fish tissue: DEQ’s 2009 work found good correlations between sediment and fish tissue.

- Validate DEQ’s bioaccumulation guidance using data specific to the Columbia Slough.

- Perform exploratory multivariate analyses and PCB source attribution.
Sampling Design

- **Incremental Sample** - Three 2-mile reaches of the Columbia Slough surrounding prior fish tissue collection areas. 50 incremental locations were evenly spaced and placed into three replicates to produce a statistically valid average.

- **Targeted Sites** - Four sites with 5-8 locations in each composite sample near possible elevated sediment concentrations.

- **Bioaccumulation** - Sediments collected at targeted sites to determine worm tissue uptake from Slough sediments in a controlled laboratory
COLUMBIA SLOUGH INCREMENTAL SAMPLE SCHEME

- Lower Slough 2009 IS sample
- Whitaker 2011 IS sample
- Upper Upper IS sites
- Upper Middle IS sites
- Lower Middle IS sites
- Slough Waterway
COLUMBIA SLOUGH INCREMENTAL SAMPLE SCHEME

Upper Upper Slough

- Incremental Sample Location
- Increment Sample A
- Increment Sample B
- Increment Sample C
- Targeted Sites

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Sediment Analyses Performed

- Focus on Bioaccumulative Analyses-
- Pesticide EPA 1699- *high resolution pg/g*
- PCB-Aroclor EPA 8082
- PCB Congener EPA 1668A- *high resolution ng/kg*
- grain size/TOC/solids
- Bio-accumulation **test** with *Lumbricus* worms*
  - Worm tissue analyzed for PCB Congeners and Pesticides

* Targeted sediment sites only.
Let the Sampling Begin!
Incremental Sampling Equipment
Aquatic Plants were constant companions!

I asked for Mud Pie, not Salad Greens!!
Bioaccumulation Sample-how many gallons of sediment do you need to grow 100g of worm tissue?
Triplicate Sediment Sample-QA review. Were samples less than 30% Relative Standard Deviation (RSD)?

<table>
<thead>
<tr>
<th>Location</th>
<th>Parameter</th>
<th>Relative Percent Difference</th>
<th>Pass QA?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Middle Columbia Slough</td>
<td>PCB Congeners Average of RSDs</td>
<td>32%</td>
<td>Just barely</td>
</tr>
<tr>
<td>Lower Middle Columbia Slough</td>
<td>Pesticide Average of RSDs</td>
<td>29 %</td>
<td>Yes</td>
</tr>
<tr>
<td>Upper Middle Columbia Slough</td>
<td>PCB Congeners Average of RSDs</td>
<td>26%</td>
<td>Yes</td>
</tr>
<tr>
<td>Upper Middle Columbia Slough</td>
<td>Pesticide Average of RSDs</td>
<td>24%</td>
<td>Yes</td>
</tr>
<tr>
<td>Upper Columbia Slough</td>
<td>PCB Congener Average RSDs</td>
<td>5%</td>
<td>Yes</td>
</tr>
<tr>
<td>Upper Columbia Slough</td>
<td>Pesticide Average of RSDs</td>
<td>17%</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Columbia Slough Sediment: Average Total Aroclor PCB and DDx Concentrations

![Total Aroclor PCBs and DDx Total Graph]

- **Y-axis**: ug/kg
- **X-axis**: Lower Slough, Whitaker, Lower Middle, Upper Middle, Upper Slough
- **Legend**:
  - Total Aroclors
  - DDx total
  - Log. (Total Aroclors)
  - Log. (DDx total)
Columbia Slough Sediment PCB Average Concentrations

The graph illustrates the average concentrations of PCBs in different locations of the Columbia Slough. The x-axis represents different sections: Lower Slough, Whitaker, Lower Middle, Upper Middle, and Upper Slough. The y-axis represents the concentration in ug/kg.

The graph shows two types of PCBs: Total Aroclors (represented by blue diamonds) and Total PCB Congeners (represented by red squares). The concentrations vary across different locations, with some locations showing higher concentrations than others.
Columbia Slough Average DDx Concentrations

![Graph showing DDx concentrations in different areas of Columbia Slough.

- Lower Slough
- Whitaker
- Lower Middle
- Upper Middle
- Upper Slough

- 4,4'-DDD
- 4,4'-DDT
- 4,4'-DDE
- DDD Baseline Value (6.1ug/kg)
- DDE Baseline Value (7ug/kg)
- DDT Baseline Value (2.5ug/kg) ]
Columbia Slough Average Pesticide Concentrations

Pesticides

- Lower Slough
- Whitaker
- Lower Middle
- Upper Middle
- Upper Slough

Concentrations measured in ug/kg:
- Aldrin
- Dieldrin
- trans-Chlordane (gamma)
- trans-Nonachlor
Targeted Site Sediment Results

<table>
<thead>
<tr>
<th>Analyte-</th>
<th>Pen 2 Levee</th>
<th>East of I-205</th>
<th>Wagner Mining</th>
<th>Fairview Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>ug/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total PCB Aroclors</td>
<td>7.7</td>
<td>15</td>
<td>29</td>
<td>3u</td>
</tr>
<tr>
<td>Total PCB Congeners</td>
<td>39</td>
<td>39</td>
<td>114</td>
<td>3</td>
</tr>
<tr>
<td>Total DDx</td>
<td>9.6</td>
<td>50</td>
<td>36</td>
<td>9.4</td>
</tr>
</tbody>
</table>
## Replicate Sample Results - PCBs (μg/kg)

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Congeners</th>
<th>RSD</th>
<th>Total Aroclors</th>
<th>RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Slough</td>
<td>37.8</td>
<td>11.7%</td>
<td>40.5</td>
<td>34.2%</td>
</tr>
<tr>
<td></td>
<td>33.5</td>
<td></td>
<td>29.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>42.4</td>
<td></td>
<td>59.1</td>
<td></td>
</tr>
<tr>
<td>Lower Middle</td>
<td>56.6</td>
<td>40.8%</td>
<td>14.8</td>
<td>53.6%</td>
</tr>
<tr>
<td></td>
<td>23.8</td>
<td></td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40.3</td>
<td></td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>Upper Slough</td>
<td>36.6</td>
<td>4.8%</td>
<td>15.6</td>
<td>8.9%</td>
</tr>
<tr>
<td></td>
<td>33.9</td>
<td></td>
<td>13.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>33.6</td>
<td></td>
<td>15.8</td>
<td></td>
</tr>
<tr>
<td>Upper Middle</td>
<td>67.6</td>
<td>36.1%</td>
<td>16.3</td>
<td>69.2%</td>
</tr>
<tr>
<td></td>
<td>51.7</td>
<td></td>
<td>43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>31.4</td>
<td></td>
<td>12.6</td>
<td></td>
</tr>
</tbody>
</table>
BSAFs are “standardized” ratios of tissue to sediment: used as a measure of bioaccumulation potential.

Calculated for each PCB congener detected in both sediment and Lumbriculus (worm) tissue.
For all PCB Congeners combined most BSAFs < 2
## Total PCB BSAFs by Method

<table>
<thead>
<tr>
<th>Location</th>
<th>Parameter</th>
<th>Sediment (oc norm)</th>
<th>Invert Tissue (lipid norm)</th>
<th>BSAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMCS-Pen-2</td>
<td>Total Aroclor</td>
<td>356,481</td>
<td>1,554,278</td>
<td>4.36</td>
</tr>
<tr>
<td></td>
<td>Total PCB (Congener Sum)</td>
<td>2,133,987</td>
<td>1,554,278</td>
<td>0.73</td>
</tr>
<tr>
<td>UMCS-I-205</td>
<td>Total Aroclor</td>
<td>407,557</td>
<td>1,654,018</td>
<td>4.06</td>
</tr>
<tr>
<td></td>
<td>Total PCB (Congener Sum)</td>
<td>1,470,715</td>
<td>1,654,018</td>
<td>1.12</td>
</tr>
<tr>
<td>US-WgnrM</td>
<td>Total Aroclor</td>
<td>856,716</td>
<td>2,697,833</td>
<td>3.15</td>
</tr>
<tr>
<td></td>
<td>Total PCB (Congener Sum)</td>
<td>4,211,406</td>
<td>2,697,833</td>
<td>0.64</td>
</tr>
</tbody>
</table>
**Sediment v. Water (SPMD)**

**Buffalo Slough-Deep**

![Graph showing the relationship between Ln Sediment Concentration and Ln SPMD Concentration](image)

**Table: Correlation and P-Value**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Correlation (CORR)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEARSON'S R</td>
<td>0.20</td>
<td>0.19</td>
</tr>
<tr>
<td>SPEARMAN'S RHO</td>
<td>-0.003</td>
<td>0.98</td>
</tr>
<tr>
<td>KENDALL'S TAU</td>
<td>-0.007</td>
<td>0.96</td>
</tr>
</tbody>
</table>

**Chlorination**

- 2
- 3
- 4
- 5
- 6
- 7
Sediment vs. Carp
All Reaches Select PCB Congeners

Graph showing the relationship between LN Sediment (ng/Kg) and Ln Carp Tissue (ng/Kg) for various PCB congeners. The graph includes data points for LMCS, Lower, UMCS, and Whitaker locations, with different markers and colors for each location. The x-axis represents LN Sediment (ng/Kg) ranging from 7 to 13, and the y-axis represents Ln Carp Tissue (ng/Kg) also ranging from 5 to 13.
SPMD, Sediment, Carp Interactions
Predictive Modeling

- How to relate correlation between sediment (or SPMDs) to acceptable levels in Carp tissue?

- Since relationships between sediment and Carp tissue appear nearly linear, regression approach selected.

- Using reach-specific models, and assuming the Carp concentration at DEQ risk-based levels (for Aroclor 4.7 ug/kg-wet); predict corresponding sediment concentration.
Predictive Modeling-Results

<table>
<thead>
<tr>
<th>PCB Congener</th>
<th>Lower Slough</th>
<th>Upper Middle Slough</th>
<th>Lower Middle Slough</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB-77</td>
<td>0.037</td>
<td>0.66</td>
<td>1.0</td>
</tr>
<tr>
<td>PCB-81</td>
<td>0.012</td>
<td>0.17</td>
<td>0.33</td>
</tr>
<tr>
<td>PCB-105</td>
<td>0.13</td>
<td>3.0</td>
<td>3.7</td>
</tr>
<tr>
<td>PCB-114</td>
<td>0.13</td>
<td>3.0</td>
<td>3.7</td>
</tr>
<tr>
<td>PCB-118</td>
<td>0.13</td>
<td>3.0</td>
<td>3.7</td>
</tr>
<tr>
<td>PCB-123</td>
<td>0.13</td>
<td>3.0</td>
<td>3.7</td>
</tr>
<tr>
<td>PCB-126</td>
<td>0.0000026</td>
<td>0.00012</td>
<td>0.00077</td>
</tr>
<tr>
<td>PCB-156</td>
<td>0.13</td>
<td>3.01</td>
<td>3.7</td>
</tr>
<tr>
<td>PCB-157</td>
<td>0.13</td>
<td>3.01</td>
<td>3.7</td>
</tr>
<tr>
<td>PCB-167</td>
<td>0.13</td>
<td>3.01</td>
<td>3.7</td>
</tr>
<tr>
<td>PCB-169</td>
<td>0.0000093</td>
<td>0.00053</td>
<td>0.0027</td>
</tr>
<tr>
<td>PCB-189</td>
<td>0.13</td>
<td>3.0</td>
<td>3.7</td>
</tr>
<tr>
<td>Total PCB TEQ</td>
<td>0.000002</td>
<td>0.0001</td>
<td>0.0006</td>
</tr>
<tr>
<td>Total PCB as Aroclor</td>
<td>0.034</td>
<td>0.59</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Total PCB guidance default = 0.39 ug/kg
Predictive Modeling- Interpretation

- Predicted Sediment Concentrations for Total PCB (as Aroclor) in lower and middle upper slough are similar to existing DEQ PCB sediment screening levels for human health.

- Predicted risk-based sediment levels for lower slough 10x lower than existing DEQ sediment criteria, inconsistent with carp tissue ATLS. Lower Slough Carp PCBs ~ 200 ug/kg.

- Both Sediment and SPMDs appear to be related to tissue concentrations, limited tissue data prevents further consideration of whether water or sediment is more important for tissue loadings.
Sediment levels for congeners exceeding on the order of 10x. However, excluding the lower slough Aroclor exceeds by approximately a factor of 100x.

Concentration reduction of 10x (i.e., 90%) could reduce dioxin like risks to acceptable levels, but:

If Aroclor based criteria are the relevant then 100x (99%) reduction would be required to reach risk-based levels.

Predictive Modeling- Interpretation
Source Attribution

- Since PCB levels in sediment and tissue appear stable and not declining, what are the sources?; and can they be controlled?

- Approach: Use mathematical “unmixing” algorithm.

- Method also termed receptor modeling has been used in air pollution monitoring.
Source Attribution

- PCB Congener Data from multiple regional sources compiled in a single database, including Columbia River, Puget Sound, Lower Willamette River and the Columbia Slough.

- Data processed to create a single consistent database of approximately 85 congeners. Non-detections replaced with model estimated values.

- Data analyzed using commercial software with unmixing algorithm.
Source Attribution- Four Profiles
First pattern appear consistent with Atmospheric Transport, associated with low concentration (<3 ug/kg) and remote locations.

Third pattern consistent with weathered recalcitrant residual material.
Second and fourth patterns consistent with Aroclor 1248/42 and 1254 as original sources. Approximately equal mix and consistent with other literature.
Source Attribution- Unaddressed Questions

- Which congeners/homologues are most significant in terms of differentiating between Lower Willamette and Columbia Rivers?

- Of the Aroclor patterns identified, where are /did they come from? (stormwater, point sources)? Can they be controlled?

- What is loading fish tissue? Is weathered component in sediment significant? Complete congener data in tissue needed to assess.
Did we meet our Objectives?

- Objectives of Study
  - Determine average concentrations of contaminants in slough sediment and developing new, updated estimates of baseline concentrations in the sampled segments -
    - Yes- Updated five(5) Slough segments with individual estimates of baseline concentrations in sediments for PCBs and Pesticides
  - Development of predictive relationships between sediment and fish tissue: DEQ’s 2009 work found good correlations between sediment and fish tissue.
    - Yes- three of four sediment vs tissue slopes were similar. Likely another unknown factor influencing tissue concentrations-possibly stormwater?
Did we meet our Objectives?

- **Validate DEQ’s bioaccumulation guidance using data specific to the Columbia Slough.**
  - Yes - Two of Three segments within ‘ball park’ of DEQ guidance for PCBs. Pesticides not calculated.

- **Perform exploratory multivariate analyses and PCB source attribution.**
  - Yes - Found four (4) distinct types of PCB signatures –
    - Air deposition/background
    - Weathered and recalcitrant PCBs
    - Two types consistent with Aroclor 1248/42 and Aroclor 1254 as original sources
Overall Summary

- ISM sampling effective in determining average concentrations in sediment. ISM data appears useful to assess bioaccumulation, at least in some cases.

- Model predicted sediment concentrations appear to validate default screening levels for PCBs of <1 ppb.

- High quality congener data useful for assessing sources. Needed in all matrices including tissue to address most effective control strategies, assess sources to tissue.
Any Questions?
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Sarah Miller-503-299-5040
http://www.deq.state.or.us/lq/cu/nwr/columbiaslough