Trace Metal Concentrations in Shallow Sediments from Grand Lake, OK

Shane Morrison†, Steve Nikolai†, Darrell Townsend†, Jason Belden†
†Department of Zoology, Oklahoma State University, Stillwater, Oklahoma, 74078, USA; †Grand River Dam Authority, Vinita, Oklahoma, 74301, USA

Abstract

The abandoned Tri-State Mining District (TSMD) is a historic superfund site that covers 4,500 square kilometers and three states (Kansas, Missouri and Oklahoma) and is the source for trace metal loading of sediments within Grand Lake O’The Cherokees (hereafter referred to as Grand Lake). Elevated concentrations of cadmium, lead and zinc have been documented in sediments collected along several lake transects that included muddy deep water and limited locations within the lake. The objective of this project is to develop a more complete metal distribution map with emphasis on shallow water areas (< 5 m depth) located in the northern reaches of Grand Lake where chances of sediment deposition from the TSMD is greatest. Previously established sediment quality guidelines (SQGs) were used to characterize the appropriate level of concern for each metal. Based on general water quality standards, sediment concentrations exceeded probable effect concentrations (PECs) for cadmium, lead and zinc at 10.6%, 1.5% and 40.6% of the 67 collected sediment samples, respectively. However, TSMD-PECs were only exceeded in 4.5% of samples for cadmium and 1.5% for lead and zinc. Trace metal distribution information is important because shallow areas are subject to disturbance events (e.g., boat traffic and dock construction) and have a higher chance of becoming dry during low water periods. Changes in water chemistry and oxidation state of trace metals during these disturbance events could cause greater availability resulting in toxicity, bioaccumulation, and greater lake impacts.

Background

- Grand Lake is a reservoir in Northeast Oklahoma that drains 6,500 square kilometers and three states (Kansas, Missouri and Oklahoma).
- The primary tributaries (Neosho and Spring Rivers) drain the abandoned Tri-State Mining District (TSMD) superfund site[1,2].
- Previous investigations measured trace metals (primarily cadmium, lead and zinc) in lake sediments, based on sparse lake transects with mostly deep water areas[1,2].
- No evidence of sediment toxicity to aquatic invertebrates has been observed in areas tested, despite elevated concentrations[1,2].

Objectives

- Develop a comprehensive metal distribution of shallow water areas (< 6 m) in the northern reaches of Grand Lake.
- Categorize the relative hazard posed to aquatic organisms based on established SQGs[3,4].
- Based on established SQGs, identify areas of greatest concern for metal mobilization following disturbance events.

Sediment Quality Guidelines (SQGs, Table 1)

- TEC – Threshold Effect Concentration. General concentration threshold below which represent a limited hazard.
- PEC – Probable Effect Concentration. General concentrations threshold above which indicate a probable hazard.
- TEC-PEC – Intermediate concentration range of undetermined hazard.
- TSMD-Specific PEC – Probable hazard threshold specific to the TSMD watershed.

Methods

- 113 sampling locations were randomly generated North of Sail Boat Bridge with the primary criteria being a water depth of ≤ 5 m based on lake contour maps.
- Sediments were collected via Ponar Dredge in accordance with USEPA sediment sampling guidelines[5,6].
- Analysis were conducted at GRDA Ecosystems and Education Center in accordance with USEPA method 3051A[7].
- General and TSMD-specific SQGs were used to categorize sediment hazards individually for cadmium, lead and zinc (Table 1).

Table 1: Sediment quality guidelines for cadmium, lead and zinc. Threshold concentrations in mg/kg.

<table>
<thead>
<tr>
<th>Trace Metal</th>
<th>General Thresholds</th>
<th>TSMD-Specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEC</td>
<td>PEC</td>
<td>PEC</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.99</td>
<td>4.98</td>
</tr>
<tr>
<td>Lead</td>
<td>35.8</td>
<td>128</td>
</tr>
<tr>
<td>Zinc</td>
<td>121</td>
<td>459</td>
</tr>
</tbody>
</table>

Table 2: Hazard classification of sediment samples (n=67) based on general and TSMD-specific sediment quality guidelines.

<table>
<thead>
<tr>
<th>Metal</th>
<th>General sediment quality guidelines</th>
<th>TSMD-Specific</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; TEC</td>
<td>&gt; PEC</td>
</tr>
<tr>
<td>Cadmium</td>
<td>10.45</td>
<td>4.98</td>
</tr>
<tr>
<td>Lead</td>
<td>77.6</td>
<td>20.9</td>
</tr>
<tr>
<td>Zinc</td>
<td>20.9</td>
<td>38.8</td>
</tr>
</tbody>
</table>

Results

- Cadmium, lead and zinc were detected in collected sediments, with higher concentrations distributed in the northern reaches of the lake (Figure 1).
- General PECs were most frequently exceeded for zinc (40.3%), followed by cadmium (10.5%) and then lead (1.5%) (Figure 1, Table 2).
- TSMD-specific PECs for cadmium were exceeded in 4.5% of sediments and 1.5% for both lead and zinc (Figure 1, Table 2).
- Cadmium, lead and zinc sediment concentrations are strongly correlated across all sediment samples (Figure 2).

Conclusion & Discussion

- Higher sediment concentrations of cadmium, lead and zinc are distributed in the northern reaches of Grand Lake.
- Although trace metal concentrations frequently exceeded general SQG-PECs, only a small percentage of the sites exceeded TSMD-specific PEC values.
- Although concentrations were measured that we would expect to cause adverse affects to aquatic organisms, previous toxicity investigations have not shown any significant adverse affects to aquatic organisms[8,9].
- Based on lake water chemistry, including pH, high hardness, and frequent anoxic sediments, bioavailability of the metals is expected to be low[10,11].
- Strong relationships between trace metals sediment concentrations imply that metal distribution is dependent on sediment particle suspension and deposition rather than movement of free metals.
- Disturbance and particle resuspension events in shallow water areas (< 6 m depth) are of greatest concern on the Neosho River.

Future Directions

- Disturbance events (e.g. boat traffic, wave action, dock construction and episodic drying) can induce localized changes in water chemistry.
- Changes in oxidation conditions and pH during resuspension of sediments can increase metal availability and thus toxicity[12].
- Bioavailability and accumulation tests need to be conducted under simulated disturbance conditions to manipulate changes in dissolved oxygen, pH and hardness.

References


Contact:
Shane Morrison (shane.morrison@okstate.edu) Oklahoma State University, 501 Life Sciences West