Assessing the effects of Lake Dredged Sediments on Soil Health: Agricultural and Environmental Implications in Northwestern Ohio

Angélica Vázquez-Ortega
avazque@bgsu.edu
Sep 15, 2020
Acknowledgements

Shannon Pelini
Zhaohui Xu
Russell Brigham, MS
Jyotshana Gautam, PhD

Undergraduate Students
Adam Swint
Emily Manner
Sara Honeck
Hannah Bebinger
Dredging in Lake Erie

- Poor management of dredging and disposal can adversely affect water quality and aquatic organisms.
- Increase suspended sediment concentrations.
- Disturbance of benthic habitats.
- 1.5 million tons of nutrient-rich sediment into Lake Erie every year (N, P, K, Ca, Mg)
- Most of the dredging occurs in the Toledo harbor
- An Ohio State Senate Bill, effective on July 2020, prohibits the open water dumping of dredged material and requires alternative beneficial uses of the dredged material
Dredged Material to Crop Fertilizer

Open Lake Disposal

Farm Amendment

Corn

Soybean

Wheat
Soil Health

Biological Health
- Microbial Biodiversity
- Macroinvertebrates Dynamics
- Nutrient Cycling
- Organic Matter Degradation
- Pesticide Detoxification
- Pathogen Suppression

Chemical Health
- pH
- Nutrients Content
- Cation Exchange Capacity
- Pollutants Immobilization
- Organic Carbon Content
  - Aromaticity
  - Recalcitrance

Physical Health
- Bulk Density
- Texture
- Porosity
- Compaction
- Water Holding Capacity
- Infiltration
Research Goals

Using a greenhouse approach…

1. Identify the appropriate native top soil to dredged material ratio to achieve the best crop yield.

2. Determine changes in soil health when a legacy P farm soil is amended with dredged material.

3. Determine nutrient and metal release into soil solution.

4. Determine metal and microcystin bioaccumulation in crop grains.
Material Collection

Farm Soil

Dredged Material
Greenhouse Experimental Setup

- No Plants
  - 100% soil
  - 10% dredged
  - 90% soil
  - 20% dredged
  - 80% soil
  - 100% dredged

- Soybean Plants
  - Quadruplets
  - 32 buckets
Materials and Methods

- Soil collection
  1. Dredged sediment from the Great Lakes Dredged Material Center for Innovation
  2. Farm soil from a farm in Oregon, Ohio – later identified as a legacy farm site

Greenhouse Setup

1. Dried farm soil and dredged sediment were mixed and placed into eight buckets each
   - 100% farm soil
   - 90% farm soil and 10% dredged sediment
   - 80% farm soil and 20% dredged sediment
   - 100% dredged sediment
2. Soybean was planted into four buckets of each treatment
3. Growing season lasted 123 days
4. Daily watering and 5 storm events
Sample Characterization

Greenhouse Experiments

Solid Characterization – initial and final

Soil – pH, IC, TOC, TN, TP, total cations and metals, bioavailable nutrients, microbial community composition

Grains – crop yield, TC, TN, TP, metal and microcystin bioaccumulation

Plant tissue - below biomass, TC, TN, TP

Percolated Solution - characterization during growing season

TOC, TN, TP, PO$_4^-$, NO$_3^-$, pH, EC, cations and metals
### Chemical characterization of dredged material from Toledo Harbor

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Optimal values (mg/kg)*</th>
<th>Dredged Material (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.3 to 7.0</td>
<td>7.9</td>
</tr>
<tr>
<td>Cation Exchange Capacity (CEC) (meq/100g)</td>
<td>21</td>
<td>35</td>
</tr>
<tr>
<td>P (Bray-1)</td>
<td>15 to 40</td>
<td>38</td>
</tr>
<tr>
<td>K</td>
<td>100 -200</td>
<td>259</td>
</tr>
<tr>
<td>Mg</td>
<td>50 to 1000</td>
<td>375</td>
</tr>
<tr>
<td>Ca</td>
<td>200 – 8000</td>
<td>6200</td>
</tr>
</tbody>
</table>

*Depending on CEC

Vitosh, et al. (1995)

- Dredged sediments meet the optimal values as an amendment to farm soils.
- Organic carbon content in dredged sediments is 29,800 mg/kg (5.5%).
Chemical characterization of farm soil (P-legacy site) and dredged material at the time of collection.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Farm Soil (mg/kg)</th>
<th>Dredged Material (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.5</td>
<td>7.9</td>
</tr>
<tr>
<td>CEC (meq/100g)</td>
<td>21</td>
<td>35</td>
</tr>
<tr>
<td><strong>Bioavailable Concentrations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P (Bray-1)</td>
<td>110</td>
<td>38</td>
</tr>
<tr>
<td>K</td>
<td>349</td>
<td>259</td>
</tr>
<tr>
<td>Mg</td>
<td>550</td>
<td>375</td>
</tr>
<tr>
<td>Ca</td>
<td>3150</td>
<td>6200</td>
</tr>
<tr>
<td><strong>Total Concentrations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Carbon (TC)</td>
<td>27601</td>
<td>42179</td>
</tr>
<tr>
<td>Inorganic Carbon (IC)</td>
<td>0</td>
<td>12361</td>
</tr>
<tr>
<td>Organic Carbon (OC)</td>
<td>27601</td>
<td>29818</td>
</tr>
<tr>
<td>Freely extracted microcystin (ng/g)</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>P</td>
<td>1120</td>
<td>1033</td>
</tr>
<tr>
<td>N</td>
<td>5054</td>
<td>5281</td>
</tr>
<tr>
<td>Si</td>
<td>289436</td>
<td>245216</td>
</tr>
<tr>
<td>Al</td>
<td>70126</td>
<td>67956</td>
</tr>
<tr>
<td>Fe</td>
<td>35671</td>
<td>36230</td>
</tr>
<tr>
<td>Mn</td>
<td>364</td>
<td>651</td>
</tr>
<tr>
<td>Mg</td>
<td>10191</td>
<td>15860</td>
</tr>
<tr>
<td>Ca</td>
<td>10434</td>
<td>47598</td>
</tr>
<tr>
<td>Na</td>
<td>6083</td>
<td>4896</td>
</tr>
<tr>
<td>K</td>
<td>25652</td>
<td>22580</td>
</tr>
<tr>
<td>Ti</td>
<td>4411</td>
<td>3476</td>
</tr>
<tr>
<td>Cr</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Co</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Ni</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Cu</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Zn</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>As</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Pb</td>
<td>46</td>
<td>29</td>
</tr>
</tbody>
</table>
Effects of Dredged Sediment Amendment on Soil Health
Dredged sediments slightly increased soil pH, which can be beneficial for crops adapted to slightly alkaline soil pH conditions.
The addition of dredged sediments increased significantly SOC concentrations in farm soils (p<0.05).

High SOC benefits soil health by improving soil fertility, soil structure, water holding capacity, water percolation, soil resistance to erosion, nutrient retention, and crop productivity.
- Dredged sediments substantially increased cation exchange capacity (CEC) increasing macronutrient bioavailability.
- Mainly controlled by Ca content.
• The addition of dredged sediment to the farm soil induced a decrease in P in this legacy P farm soil.

• P levels decreased towards more agronomic values (dilution effect).
• Average bulk density showed a slight decrease with increasing dredged sediment ratios; however, the increase was not significant (p>0.05).

• Lower bulk density affects the function of the soil by allowing greater infiltration, increasing soil porosity and water capacity.
Results and Implications

Effects of Dredged Sediment Amendment on Crop Yield and Biomass
The amendment of farm soil with dredged sediments did not show any significant changes to soybean yields or root biomass.

However, the averages of these parameters slightly increased as the dredged sediment ratio increased.
Greater amounts of finer roots and root hairs.
Nutrient and Heavy Metals Loss into Waterways
- We observed a decreased in PO$_4$ loads at the soybean growth stage R3, indicating a potential larger used of these compounds as the plant is starting to produce pods. P is part of the DNA make up.
- We observed a large decrease in NO$_3$ loads at the soybean growth stage R3, indicating a potential larger used of these compounds as the plant is starting to produce pods. N is part of the DNA make up.

- Overall, amending farm soil with dredged sediments at various ratios did not significantly affect the export of nutrients (TP, PO$_4$, TN, NO$_3$, K, Mg, and Ca) into waterways.
• Arsenic and lead concentrations are above the recommended EPA drinking water standards. However, the concentrations are similar for that of the local soil.
• Cr, Cu, Ni, and Zn concentrations meet the recommended EPA drinking water standards.
<table>
<thead>
<tr>
<th>Element</th>
<th>Greenhouse Percolated water (mg/L)</th>
<th>EPA DWS (mg/L)</th>
<th>OEPA SWQC – Aquatic (mg/L)</th>
<th>OEPA SWQC – Agricultural use (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>&gt;6*</td>
<td>0.01</td>
<td>0.150</td>
<td>0.1</td>
</tr>
<tr>
<td>Cr</td>
<td>&gt;0.01</td>
<td>0.1</td>
<td>0.074</td>
<td>0.1</td>
</tr>
<tr>
<td>Cu</td>
<td>&gt;0.01</td>
<td>1.3</td>
<td>0.009</td>
<td>0.5</td>
</tr>
<tr>
<td>Pb</td>
<td>&gt;0.04*</td>
<td>0.015</td>
<td>0.0051</td>
<td>0.1</td>
</tr>
<tr>
<td>Ni</td>
<td>&gt;0.04</td>
<td>0.1</td>
<td>0.052</td>
<td>0.2</td>
</tr>
<tr>
<td>Zn</td>
<td>&gt;0.6</td>
<td>5.0</td>
<td>0.120</td>
<td>25</td>
</tr>
</tbody>
</table>

*Exceeding standards, but comparable to the farm soil values.
Contaminants Bioaccumulation
Heavy Metal Bioaccumulation in Soybean Grains

- Overall, no apparent preferential bioaccumulation of heavy metals in the grains.
Collection time – soil and dredged sediments

**GreenWater Laboratories**
205 Zeagler Drive
Suite 302
Palatka FL 32177
Ph: (386) 328-0882
Fax: (386) 328-9646

---

**Bowling Green State University**

**MICROCYSTINS/NODULARINS RESULTS**

<table>
<thead>
<tr>
<th>Sample ID/ [Extract]</th>
<th>Date Collected</th>
<th>Sample Weight (g)</th>
<th>Assay Value, ng/mL</th>
<th>Dilution Factor</th>
<th>Avg. LPB Recovery</th>
<th>Avg. LFSM Recovery</th>
<th>Final Concentration (ng/g)</th>
<th>Average ppb (ng/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS100A0702</td>
<td>1/2/2019</td>
<td>0.50</td>
<td>0.17</td>
<td>1</td>
<td>94%</td>
<td>100%</td>
<td>1.7</td>
<td>1.6F</td>
</tr>
<tr>
<td>(100% Farm Soil)</td>
<td></td>
<td></td>
<td>0.14</td>
<td>1</td>
<td>1.4</td>
<td>&lt;15</td>
<td>&lt;15</td>
<td></td>
</tr>
<tr>
<td>DM100A0702</td>
<td>1/2/2019</td>
<td>0.50</td>
<td>0.34</td>
<td>1</td>
<td>94%</td>
<td>103%</td>
<td>3.4</td>
<td>3.8</td>
</tr>
<tr>
<td>(100% Dredged)</td>
<td></td>
<td></td>
<td>0.41</td>
<td>1</td>
<td>4.1</td>
<td>&lt;15</td>
<td>&lt;15</td>
<td></td>
</tr>
</tbody>
</table>

**LOD/LOQ** = 1.5 ng/g
LFB = 1.0 ng/mL MCLR
ND = Not detected above LOD/LOQ
LFSM = 100 ng/g MCLR

Submitted by: Amanda Foss, M.S.
Date: 1/25/2019

Submitted to: Dr. Angélica Vazquez
Bowling Green State University
1001 E. Wooster, 110 Oxnerman
Bowling Green, OH 43403
(419) 372-9385
avazquez@bgsu.edu

---

Contact:
markaubel@greenwaterlab.com
amandafoss@greenwaterlab.com
### Summary of Results

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Total Adda MCs/NODs (MMPB) ng/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>(100% Farm)</td>
<td></td>
</tr>
<tr>
<td>S0508SMC</td>
<td>ND</td>
</tr>
<tr>
<td>(10% DM: 90% FS)</td>
<td></td>
</tr>
<tr>
<td>S1316SMC</td>
<td>ND</td>
</tr>
<tr>
<td>(20% DM: 80% FS)</td>
<td></td>
</tr>
<tr>
<td>S2124SMC</td>
<td>ND</td>
</tr>
<tr>
<td>(100% Dredged)</td>
<td></td>
</tr>
<tr>
<td>S2932SMC</td>
<td>ND</td>
</tr>
</tbody>
</table>

**MRL (ng/g):** 5.0  
**Analyst Initials:** AF  
**Date Analyzed:** 11/15/19

### Interpretations:
Total Adda MCs/NODs were not detected in the submitted samples above 5 ng/g (ppb).

---

- No preferential bioaccumulation of microcystin in the grains.
Agricultural Implications

• Increasing the dredged sediment ratio showed proportional increases in total organic carbon, cation exchange capacity (CEC), calcium and pH.

• Conversely, the increase in dredged sediment decreased phosphorous in this P legacy farm.

• Average bulk density decreased with increasing dredged sediment ratios.

Environmental Implications

• Dredged sediments can be a viable fertilizer source.
  • The use of synthetic (e.g., urea, monoammonium phosphate) and organic (e.g., manure, biosolids) fertilizers can improve crop growth but also induce unintended detrimental effects to the water quality of freshwater systems.

• Dredged sediment amendment did not increase the nutrient export into waterways.
Thanks!

Questions

Angélica Vázquez-Ortega
avazque@bgsu.edu