Geospatial Distribution of Soil Trace Metals Concentrations in a Mining Impacted Agricultural Watershed

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Introduction
Neosho River Bottoms

- ~25,000 acre floodplain and upland area

- Significant restoration opportunities
  - Bottomland hardwood forest
  - Oxbow lakes
  - Scrub shrub wetland
  - Eastern tall grass prairie

- GRDA acquired 3,600 acres along the Neosho River
Neosho River Bottoms

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The area of interest south of Superfund Site
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Elm Creek Watershed
Tar Creek Superfund Site
Neosho Bottoms
Neosho River
Elm Creek
Kansas
Oklahoma
Soil Trace Metals Detection

- Inductively coupled plasma optical emission spectrometry (ICP-OES)
- Inductively coupled plasma mass spectrometry (ICP-MS)
- X-ray fluorescence (XRF)
  - On-site fast screening method for soil metals
  - Cost effective when compared to ICP-OES
  - Viewed by the environmental community as an acceptable analytical approach for field applications
Objectives
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1. Evaluate soil lead, zinc, and cadmium concentrations in stream terraces and upland environments in this mining impacted agricultural watershed.

2. Generate a spatial perspective of the distribution of lead, zinc, and cadmium concentrations.
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2. Generate a spatial perspective of the distribution of lead, zinc, and cadmium concentrations.
Methods & Locations
The soil metal concentration in the floodplain were determined three different ways

Method 1: *In Situ*
Field Portable XRF Analyses (EPA 6200)
Bulk Sample
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Method 1: In Situ
Field Portable XRF Analyses (EPA 6200)
Bulk Sample

• Soil samples were collected using stainless steel shovel
  • 13 cm X 13 cm X 10 cm cuttings
  • Sealed tightly in 3 mil or thicker plastic bag

• Sample locations were recorded with GPS

• Transported back to laboratory
The soil metal concentration in the floodplain were determined three different ways

**Method 1:**
*In Situ*
Field Portable XRF Analyses (EPA 6200)
Bulk Sample

**Method 2:**
*Laboratory*
Field Portable XRF Analyses (EPA 6200)
Dried and < # 60 Sieve Fraction
The soil metal concentration in the floodplain were determined three different ways

Method 3:

Laboratory
Microwave HNO₃ digestion (EPA 3051)
Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) Analyses (EPA 6010)
Dried and < # 60 Sieve Fraction
The soil metal concentration in the floodplain were determined three different ways

**Method 1:** 
*In Situ*
Field Portable XRF Analyses (EPA 6200)  
Bulk Sample

**Method 2:** 
*Laboratory*
Field Portable XRF Analyses (EPA 6200)  
Dried and < # 60 Sieve Fraction

**Method 3:** 
*Laboratory*
Microwave HNO₃ digestion (EPA 3051)  
Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) Analyses (EPA 6010)  
Dried and < # 60 Sieve Fraction
Sampling Locations

- Elm Creek road crossings (intersecting the stream)
- Properties owned by GRDA
  - Elm Creek riparian zone
  - Neosho Bottoms uplands
Elm Creek Riparian Zone

- Samples taken from 15 locations
  - 7 sites at road crossings
  - 8 sites in GRDA properties

- Left and right side of creek
  - Top of Bank
  - Primary Terrace
  - Lower Terrace

- 106 soil samples
Elm Creek Riparian Zone

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  • Top of Bank
  • Primary Terrace
  • Lower Terrace

• 106 soil samples
Neosho Bottoms Upland Sites

• Series of transects
  • Total length of 13.2 miles
• Samples taken every 360 feet
• Locations entered on GPS before sampling
• Exact GPS locations taken in field
• 278 soil samples
Neosho Bottoms Upland Sites

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  - Total length of 13.2 miles
- Samples taken every 360 feet
- Locations entered on GPS before sampling
- Exact GPS locations taken in field
- 278 soil samples
Results & Conclusions
Elm Creek Riparian Zone Lead Concentrations

Laboratory [Pb] in <#60 Sieve Fraction (mg/Kg)

Stream Distance from Head Waters (km)

Left Bank

Right Bank

Top of Bank
Primary Terrace
Lower Terrace

Sediment Quality Guideline
Pb = 150 mg/kg
Elm Creek Riparian Zone Zinc Concentrations

Laboratory [Zn] in <#60 Sieve Fraction (mg/Kg)

Stream Distance from Head Waters (km)

Left Bank

Right Bank

Sediment Quality Guideline

Zn = 2100 mg/kg
Elm Creek Riparian Zone Estimated Cadmium Concentrations

Estimated [Cd] (mg/Kg)

Stream Distance from Head Waters (km)

Left Bank
Right Bank

Top of Bank
Primary Terrace
Lower Terrace

Sediment Quality Guideline
Cd = 11.1 mg/kg

Cd = 11.1 mg/kg
Elm Creek East and West Branches

Laboratory XRF in <#60 Sieve Fraction (mg/kg)

- **Pb**
  - SQG Pb = 150 mg/kg
  - E30: 300 mg/kg
  - E40: 200 mg/kg
  - E50: 100 mg/kg

- **Zn**
  - SQG Zn = 2100 mg/kg
  - E30: 2100 mg/kg
  - E40: 2000 mg/kg
  - E50: 1900 mg/kg

- **Cd**
  - SQG Cd = 11.1 mg/kg
  - E30: 10 mg/kg
  - E40: 9 mg/kg
  - E50: 8 mg/kg

Estimated [Cd] (mg/Kg)

West Branch
- E30
- E40
- E50

East Branch
- E30
- E40
- E50
Upland Frequency Distribution

- **Pb = 500 mg/kg**
  - Remedial Goal
  - Frequency Distribution:
    - 0-49: 214
    - 50-99: 49
    - 100-149: 10
    - 149-200: 5

- **Zn = 1100 mg/kg**
  - Remedial Goal
  - Frequency Distribution:
    - 0-199: 188
    - 200-399: 51
    - 400-599: 21
    - 600-799: 7
    - 800-999: 4
    - 1000-1099: 1
    - >1100: 7

- **Cd = 10 mg/kg**
  - Estimated
  - Frequency Distribution:
    - 0.49: 254
    - 5.99: 15
    - >10: 7
Legend
- GRDA Properties
- Soil Sampling Location
- Exceeding RG
- Elm Creek
<table>
<thead>
<tr>
<th>Location</th>
<th>Zn (mg/kg)</th>
<th>Cd (mg/kg)</th>
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<tr>
<td></td>
<td>XRFS</td>
<td>ICP Estimated</td>
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<tr>
<td>1</td>
<td>1260 1070</td>
<td>10.9 9.80</td>
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<tr>
<td>2</td>
<td>1766 1440</td>
<td>15.2 16.5</td>
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<td>12.7 12.8</td>
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<td>7</td>
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</tr>
</tbody>
</table>

Legend
- GRDA Properties
- Soil Sampling Location
- Exceeding RG
- Elm Creek
Concentration Distribution Interpolation

Lead

Zinc

Lab XRF Readings

Lead
Zinc

RG

RG

0 0.38 0.76 1.5 2.25 3
Kilometers

mg/kg
Concentration Distribution Interpolation

Cadmium

Zinc

Lab XRF Readings

Cadmium
Zinc

RG
10
1100
RG

0
5
10
14
18

0
500
1000
1500
2000

0
0.38
0.76
1.5
2.25
3
Kilometers

mg/kg
Cluster and Outlier Analysis

Lead

Nearest Neighbor Radius (300 m)

Zinc

- High-High Cluster
- Low-Low Cluster
- Low-High Outlier
- High-Low Outlier
- Not Significant
Cluster and Outlier Analysis

Cadmium

Zinc

Nearest Neighbor Radius (300 m)
Hot Spot Analysis

Lead

Zinc

- Cold spot – 99% confidence
- Cold spot – 95% confidence
- Cold spot – 90% confidence
- Not Significant
- Hot spot – 90% confidence
- Hot spot – 95% confidence
- Hot spot – 99% confidence
Hot Spot Analysis

Cadmium

Zinc

- Cold spot – 99% confidence
- Cold spot – 95% confidence
- Cold spot – 90% confidence
- Not Significant
- Hot spot – 90% confidence
- Hot spot – 95% confidence
- Hot spot – 99% confidence
Hot Spot Analysis

Cadmium

Zinc

- Cold spot – 99% confidence
- Cold spot – 95% confidence
- Cold spot – 90% confidence
- Not Significant
- Hot spot – 90% confidence
- Hot spot – 95% confidence
- Hot spot – 99% confidence
Conclusions

• Elm Creek riparian area
  • Decreasing trend in trace metals concentrations as distance downstream increases
  • Trace metals influence from Tar Creek Superfund Site

• Upland concentration distribution
  • Elevated trace metals influence from gravel roads
  • Elevated concentrations are likely due to upstream source materials being transported downstream

• Cleanup of source material!
Acknowledgements

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- Aaron Roper, GRDA
- OU CREW
  - Thank you to everyone who helped with field sampling, laboratory analysis, and data reduction!
- Darren Shepherd
Questions?