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OLIVIA J. MITCHELL, LEIF H. OLSON, ROBERT W. NAIRN

Trace Metal Bioaccumulation in Planted Vegetation of a Mine Drainage Passive Treatment System and Potential Ecological Risk

GALLOGLY COLLEGE OF ENGINEERING
SCHOOL OF CIVIL ENGINEERING AND ENVIRONMENTAL SCIENCE
The UNIVERSITY of OKLAHOMA

CREW
Center for Restoration of Ecosystems and Watersheds
The University of Oklahoma

Overview

INTRODUCTION

HYPOTHESES

METHODS

RESULTS

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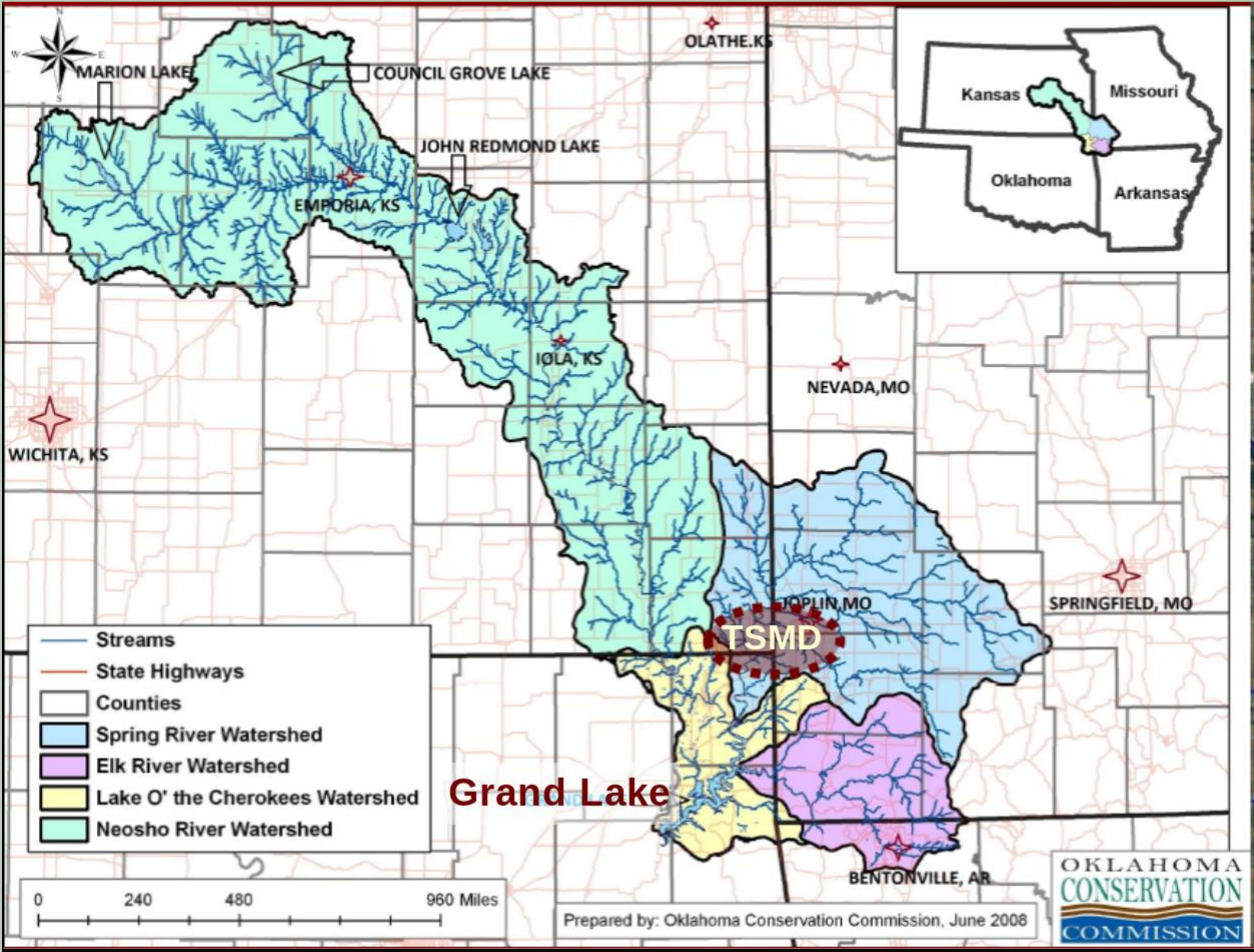
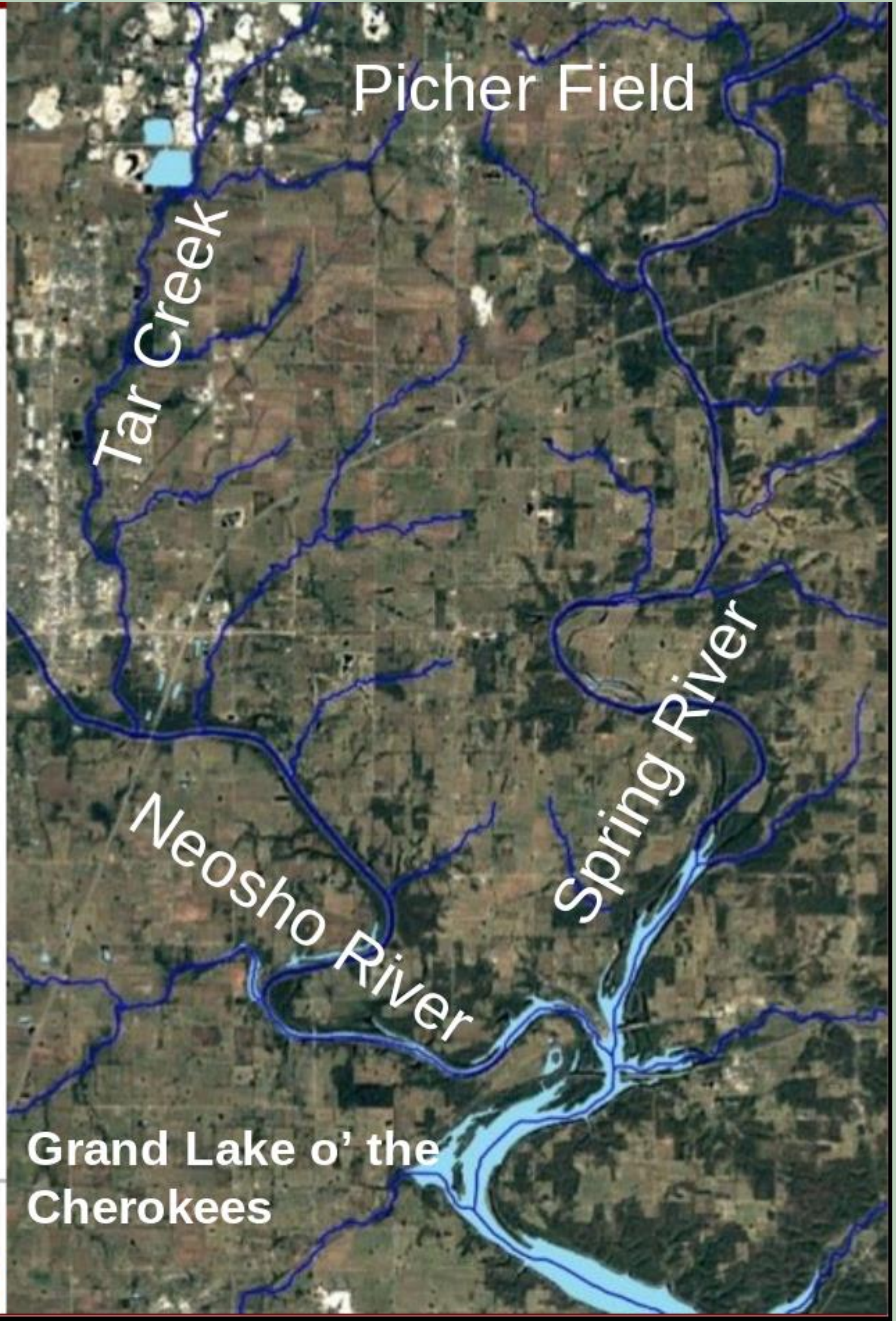
INTRODUCTION

Trace Metal Bioaccumulation in Planted Vegetation of a Mine Drainage Passive Treatment System and Potential Ecological Risk

Tri-State Mining District





Tri-State Mining District

Mid-19th Century

Lead (Pb) and
Zinc (Zn) Production;
Underground Workings

Tri-State Mining District

Mid-19th Century

Lead (Pb) and
Zinc (Zn) Production;
Underground Workings

Mid-20th Century

Mine Water Discharges, Waste Pile Runoff, Leachate with Ecotoxic Contamination

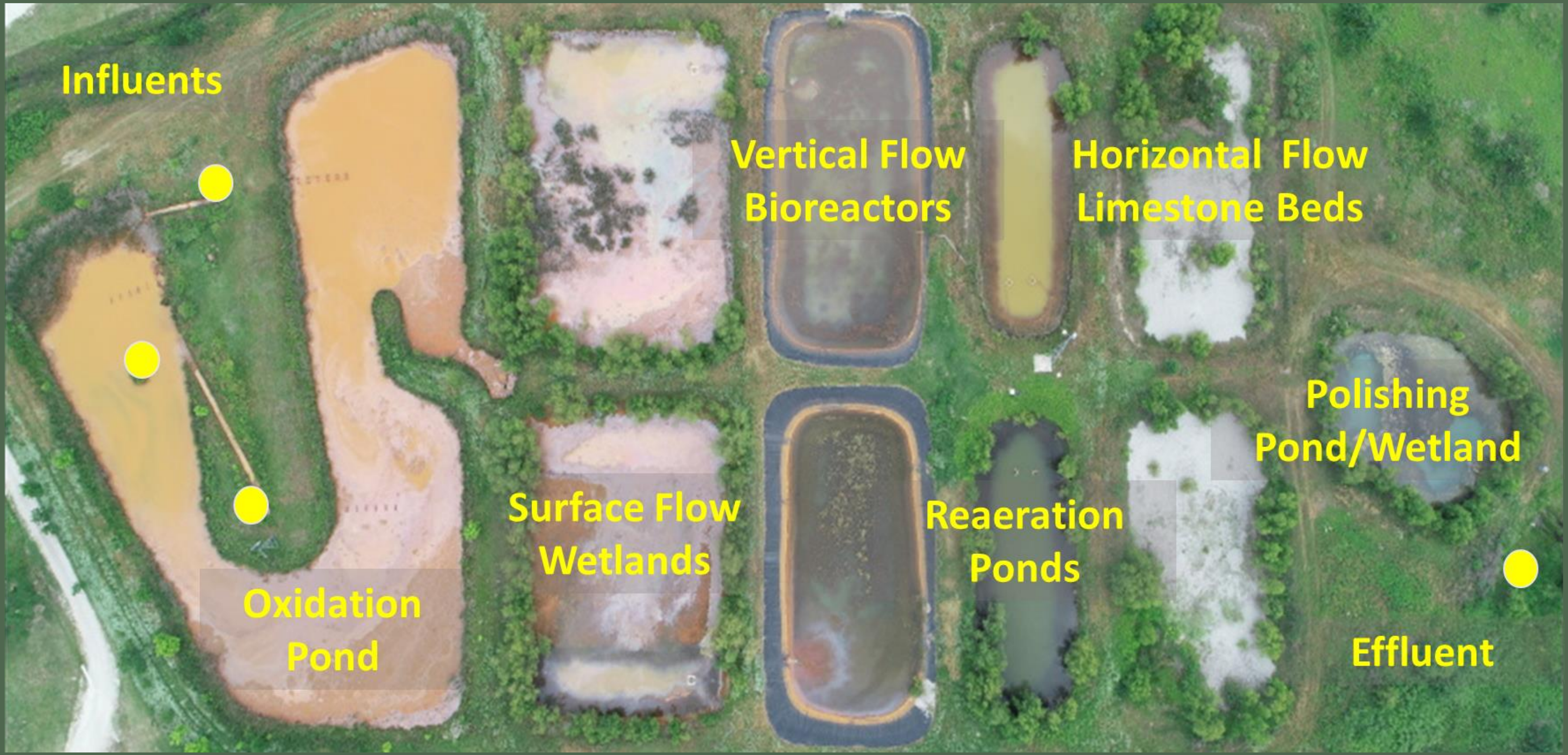

“IMPACTS TO (SURFACE WATERS) ARE DUE TO IRREVERSIBLE MAN-MADE DAMAGES RESULTING FROM PAST MINING OPERATIONS AT THE SITE” - EPA

Is it True?

After Over 40 Years of Unabated Mine Water Flows?


Passive Treatment System (PTS)

Mayer Ranch Passive Treatment System

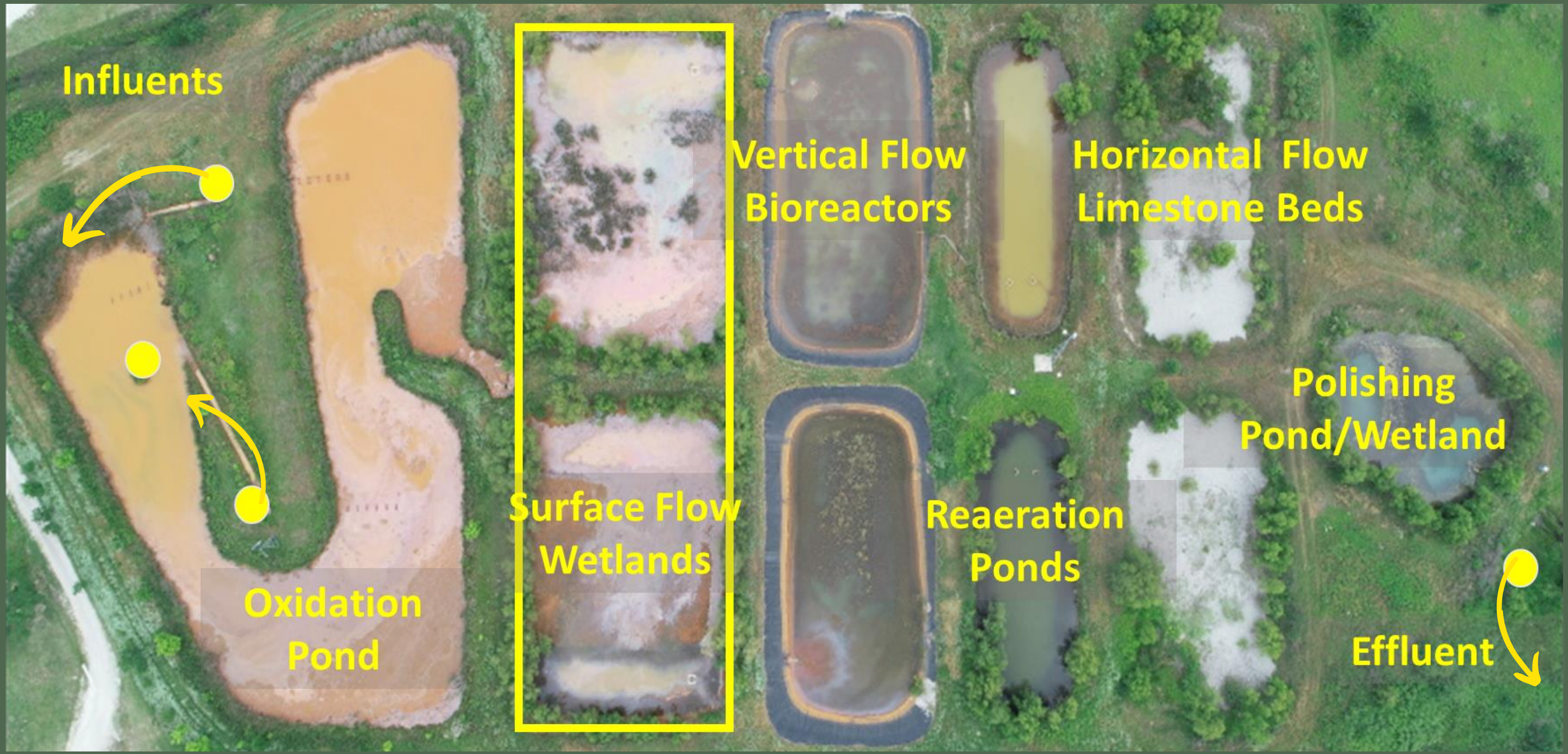


2008

Natural Biogeochemical, Microbiological Processes

Passive Treatment System (PTS)

Mayer Ranch Passive Treatment System



2008

Natural Biogeochemical, Microbiological Processes

2019

Floods Resulted in Vegetation Loss

2020

Selectively Replanted with *Typha latifolia*

Surface Flow Wetlands

Oxidize, Hydrolyze, and Precipitate of Iron (Fe) (Nairn et. al. 2020)

Sorption of Pb and Cadmium (Cd) (Nairn et. al. 2020)

Phytoextraction of Aquatic Plants (Klink 2017)

Common Cattail (*Typha latifolia*)

Known for Phytoextraction of Trace Metal (Klink 2017)

High Tolerance to Toxic Conditions (Bonannoa and Cirelli 2017)

Restricted Translocation to Aboveground Tissue (Bonannoa and Cirelli 2017)

Return of Wetland Wildlife

2013

NA Beaver
(*Castor canadensis*)

2017

Bobcat
(Lynx rufus)

2022

NA River Otter
(*Lontra canadensis*)

Muskrat
(*Ondatra zibethica*)

Elevated Concentrations of
Metals Found in Liver/Kidneys
(Parker 2004)

Cattail Stands may be
a Principal Source
(Parker 2004)

Chronic Exposure
Associated with Organ Disease
and Development Issues
(Ganoe et. al. 2020)

HYPOTHESES

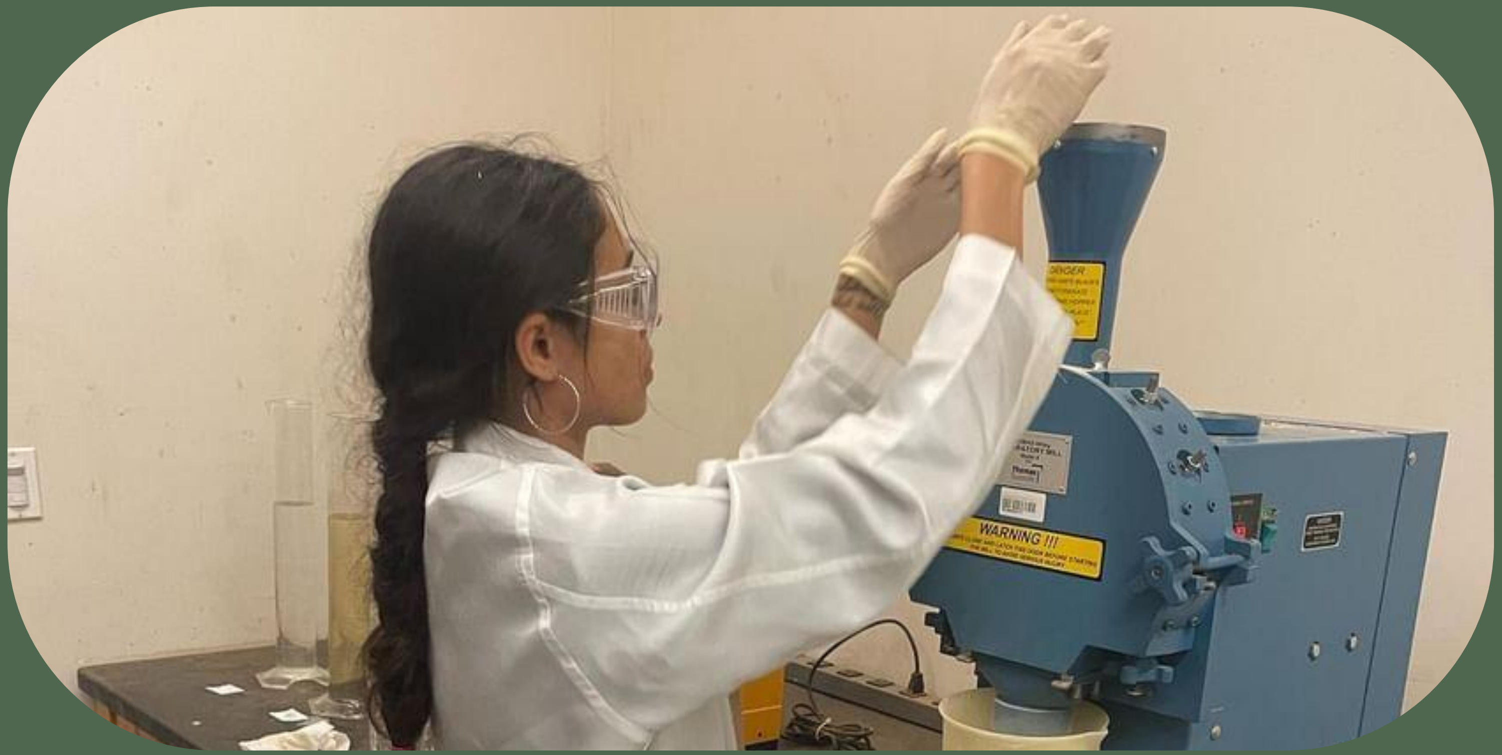
Trace Metal Bioaccumulation in Planted Vegetation of a Mine Drainage Passive Treatment System and Potential Ecological Risk

HYPOTHESIS 1

Surface Flow Wetlands Planted with Common Cattail will Contribute to Greater Trace Metal Removal Through Phytoextraction

OBJECTIVE 1

Compare Effluent Water Quality of Replanted and Unplanted Wetlands From 2021 - 2023 and Assess Trace Metal Accumulation in Plant Tissue



HYPOTHESIS 2

Greatest Concentration of Targeted Metals will be in the Cattail Roots Due to High Uptake From Soil and Water and Low Translocation to Aboveground Plant Tissue

OBJECTIVE 2

Characterize Uptake Pathways of Selected Trace Metals Using Enrichment Factors (EF) and Translocation Factors (TF)

Enrichment Factors (EF)

— Water $\mathbf{EF = Rt \div Cw}$

— Soil $\mathbf{EF = Rt \div Cs}$

Rt = root concentration

Cw = water concentration

Cs = soil concentration

of selected trace metals

Translocation Factors (TF)

— Rhizome:Root $\mathbf{TF = Rh \div Rt}$

— Shoot:rhizome $\mathbf{TF = S \div Rh}$

Rh = rhizome concentration

Rt = root concentration

S = shoot concentration

of selected trace metals

HYPOTHESIS 3

Muskrat Consumption of Cattails Containing Elevated Metal Concentrations will Result in a Hazard Quotients (HQs) Greater than One Due to Bioaccumulation

OBJECTIVE 3

Using Conservative Assumptions, Calculate Ingested Average Daily Dose (ADD) and Reference Dose (RfD) to Determine HQs

Hazard Quotient (HQ)

Adult Ondatra zibethica HQs

— $\mathbf{HQ = ADD \div RfD}$

ADD = Average Daily Dose

RfD = Reference Dose

Average Daily Dose

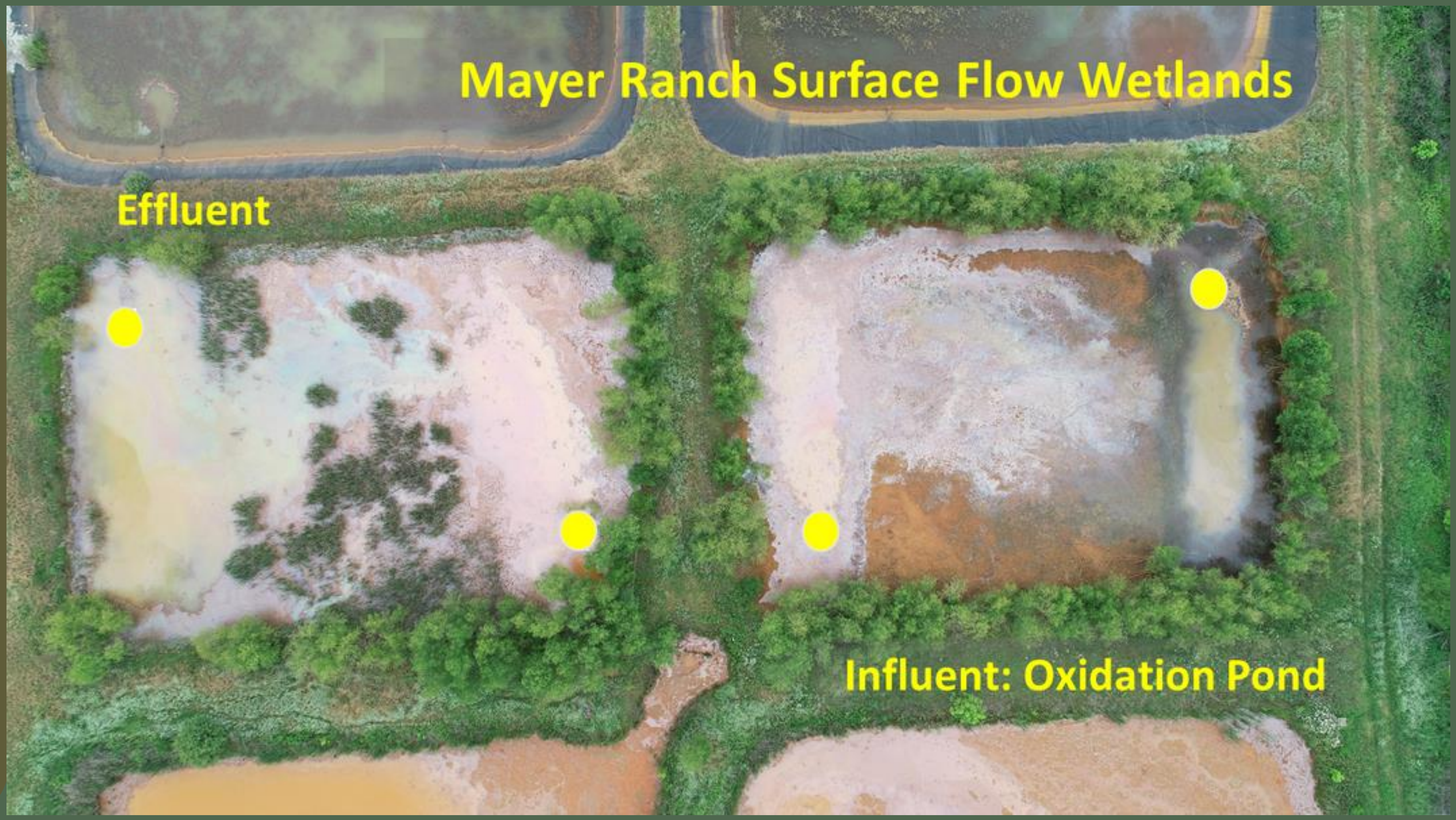
$$\mathbf{ADD = \frac{(C \cdot CF \cdot IR \cdot ED \cdot EF)}{(BW \cdot AT)}}$$

- C = metal concentration
- CF = unit conversion factor
- IR = ingestion rate
- ED = exposure duration
- EF = exposure frequency
- BW = muskrat body weight
- AT = averaging time

METHODS

Trace Metal Bioaccumulation in Planted Vegetation of a Mine Drainage Passive Treatment System and Potential Ecological Risk

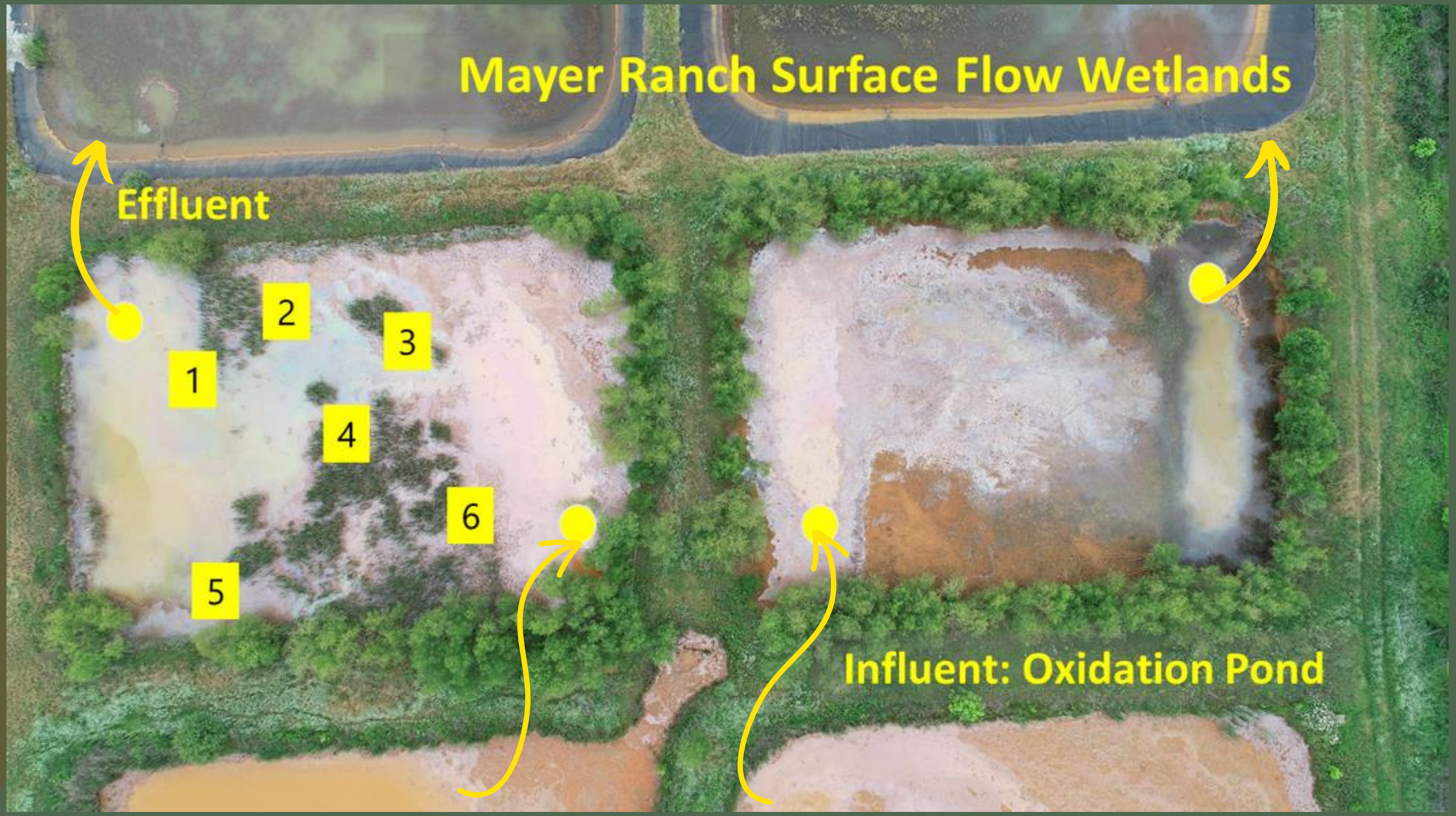
Field Methods



sUAS

- Estimate Vegetated Cover
- Determine Quadrat Sites

Field Methods

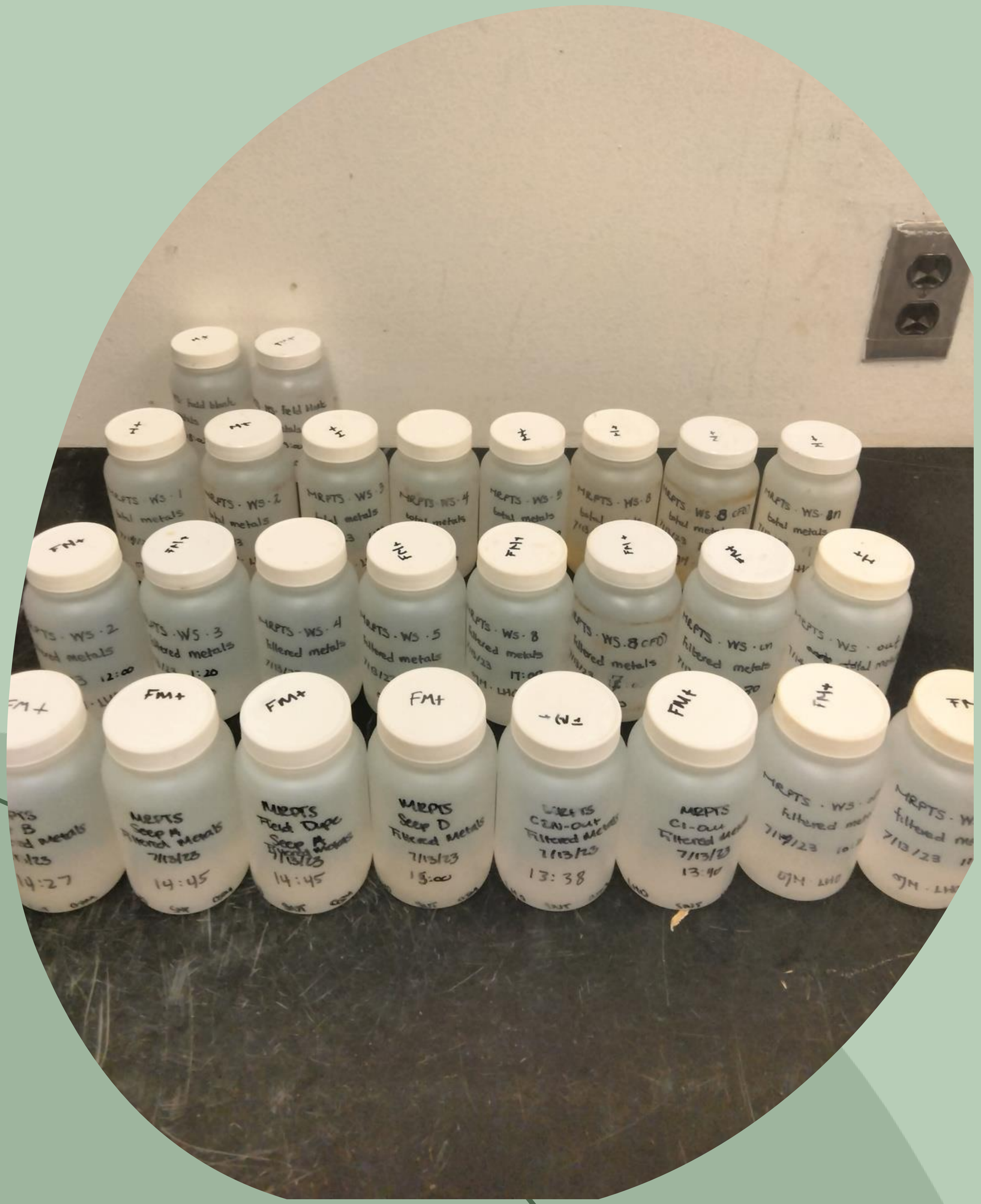


sUAS

- Estimate Vegetated Cover
- Determine Quadrat Sites

SIX SAMPLING SITES

- Measured Physicochemical, Turbidity, and Alkalinity
- Collected Water, Sediment, Root, Rhizome, Shoot, Flower



Water Analysis

- **Physiochemical Parameters:** pH, Temperature, Dissolved Oxygen, Specific Conductivity, Total Dissolved Solids, Oxidation-reduction Potential.
- **Alkalinity and Turbidity**
- **Anions:** Cl^-, NO_2, NO_3, P, and SO_4^{2-}
- **Total / Dissolved Trace Metals and Major Cations:** Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, S, Se, Si, and Zn

Soil Analysis

- **Moisture Content**
- **Organic Matter Content**
- **Trace Metals and Major Cations:** Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, S, Se, Si, and Zn

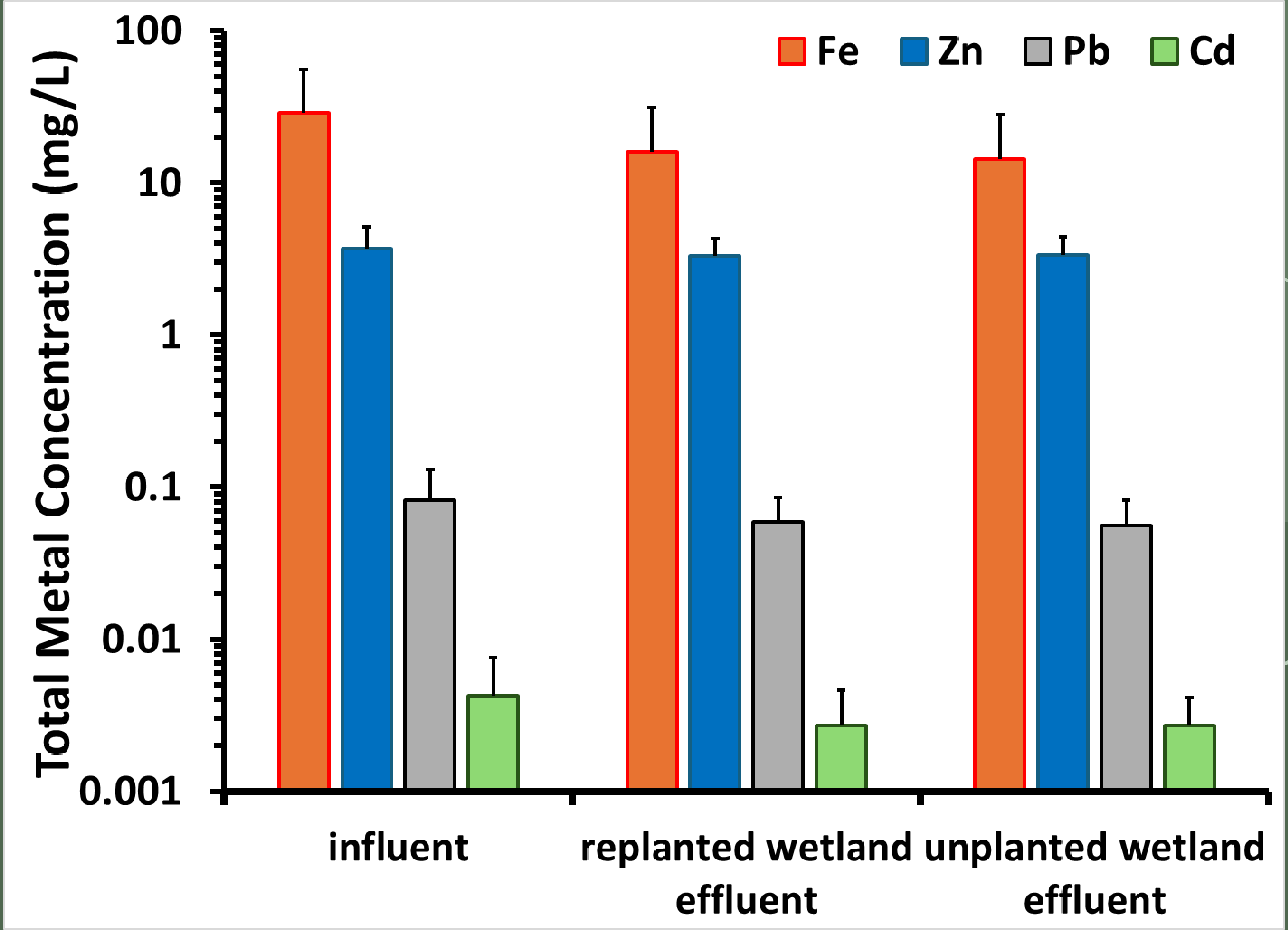
Plant Analysis

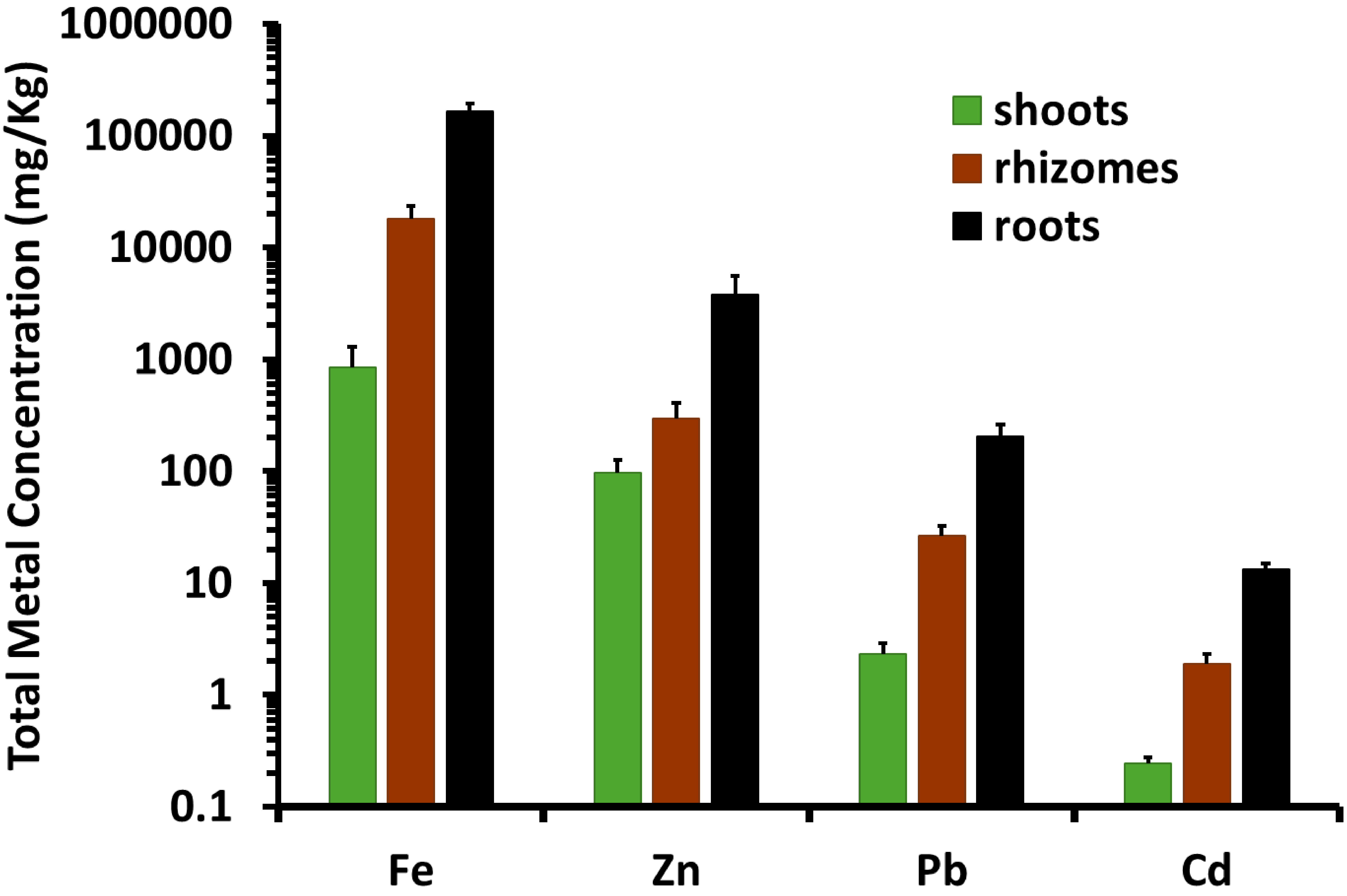
- **Biomass**
- **Moisture Content**
- **Organic Matter Content**
- **Trace Metals and Major Cations:**

Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, S, Se, Si, and Zn.

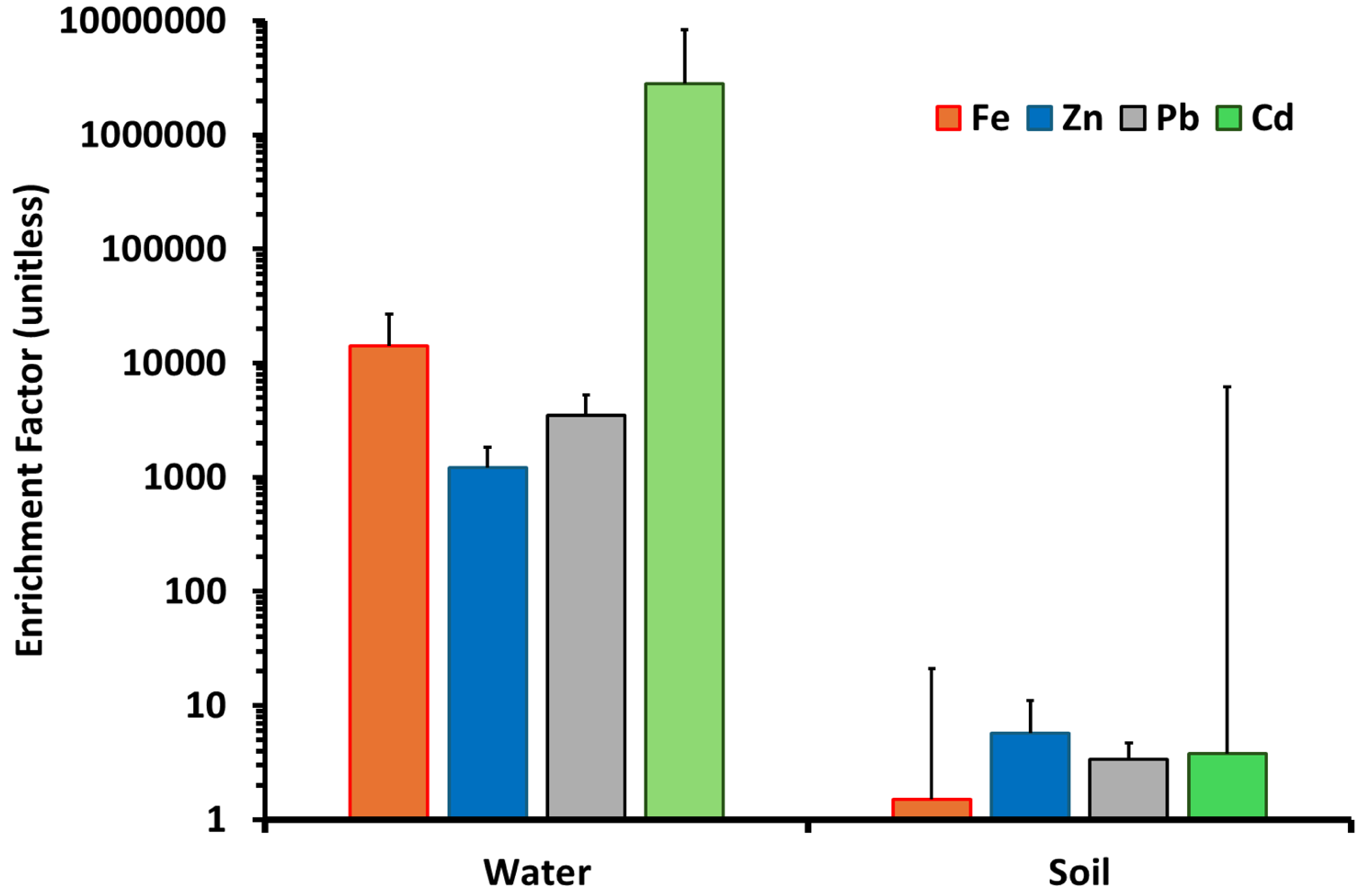
RESULTS

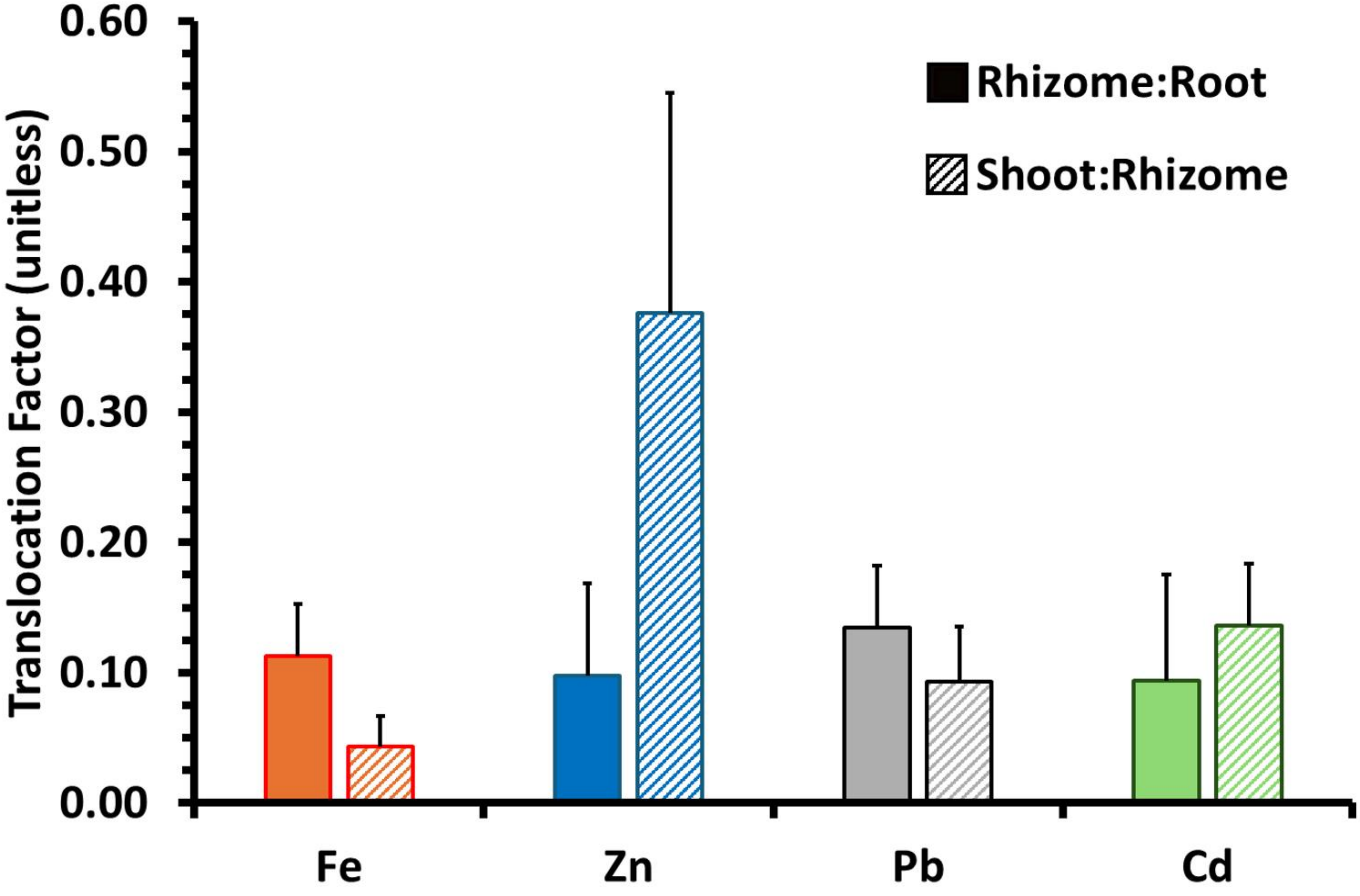
Trace Metal Bioaccumulation in Planted Vegetation of a Mine Drainage Passive Treatment System and Potential Ecological Risk


Fe
Zn
Pb
Cd
Total Metal Concentration (mg/L)
100
10
1
0.1
0.01
0.001
influent
replanted wetland effluent
unplanted wetland effluent



Total Metal Concentration (mg/Kg)
1000000
100000
10000
1000
100
10
1
0.1
shoots
rhizomes
roots
Fe
Zn
Pb
Cd


Fe
Zn
Pb
Cd
Enrichment Factor (unitless)
10000000
1000000
100000
10000
1000
100
10
1
Water
Soil


Translocation Factor (unitless)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rhizome:Root
Shoot:Rhizome
Fe
Zn
Pb
Cd

Adult Muskrat HQs

Effluent

1

	S	Rh
Fe	0	123
Zn	3	9
Pb	0	4
Cd	15	15

2

	S	Rh
Fe	21	298
Zn	5	13
Pb	0	7
Cd	11	27

3

	S	Rh
Fe	26	270
Zn	8	8
Pb	0	6
Cd	14	24

4

	S	Rh
Fe	26	190
Zn	7	6
Pb	0	4
Cd	11	17

5

	S	Rh
Fe	20	238
Zn	6	8
Pb	0	5
Cd	11	21

6

	S	Rh
Fe	16	228
Zn	4	4
Pb	0	5
Cd	10	22

Influent: Oxidation Pond

Adult Muskrat HQs

Effluent

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Influent: Oxidation Pond

CONCLUSIONS

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Findings

H1: REJECTED

Surface Flow Wetlands Planted with Common Cattail will Contribute to Greater Trace Metal Removal Through Phytoextraction.

Findings

H1: REJECTED

Surface Flow Wetlands Planted with Common Cattail will Contribute to Greater Trace Metal Removal Through Phytoextraction.

H2: ACCEPTED

Greatest Concentration of Targeted Metals will be in Cattail Roots Due to High Uptake From Soil and Water and Low Translocation to Aboveground Plant Tissue

Findings

H1: REJECTED

Surface Flow Wetlands Planted with Common Cattail will Contribute to Greater Trace Metal Removal Through Phytoextraction.

H2: ACCEPTED

Greatest Concentration of Targeted Metals will be in Cattail Roots Due to High Uptake From Soil and Water and Low Translocation to Aboveground Plant Tissue

H3: ACCEPTED

Muskrat Consumption of Cattails Containing Elevated Metal Concentrations will Result in a Hazard Quotient Greater Than One

Future Work

- Potential Ecological Risks Posed by Other Stages of PTS

Future Work

- Potential Ecological Risks Posed by Other Stages of PTS
- Elemental Concentrations in Wildlife Known to Live in and Near the PTS


LITERATURE REVIEWED

Bonannoa, G. and Cirelli, G. L. 2017. Comparative analysis of element concentrations and translocation in three wetland congener plants: Typha domingensis, Typha latifolia and Typha angustifolia.

Campbell, K.L. and MacArthur, R.A. 1994. Digestibility and Assimilation of Natural Forages by Muskrat. The Journal of Wildlife Management, Vol. 58, No. 4, pp. 633-641. https://www.jstor.org/stable/3809676

Klink, A. 2017. A comparison of trace metal bioaccumulation and distribution in Typha latifolia and Phragmites australis: implication for phytoremediation. Environmental Science Pollut Res. 24:3843–3852. DOI 10.1007/s11356-016-8135-6

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Nairn, R.W., J.A. LaBar, L.R. Oxenford, N.L Shepherd, B.K. Holzbauer-Schweitzer, J.G. Arango, Z. Tang, D.M. Dorman, C.A. Folz, J.I. McCann, J.D. Ingendorf, H.T. Stanfield, and R.C. Knox. 2020. Toward Sustainability of Passive Treatment in Legacy Mining Watersheds: Operational Performance and System Maintenance. Mine Water Solutions. Proceedings of the Postponed 14th International Mine Water Association Congress (ISBN 978-3-00-067297-2), Christchurch, New Zealand, pp. 123-128.

Parker G.H. 2004. “Tissue metal levels in Muskrat (Ondatra zibethica) collected near the Sudbury (Ontario) ore-smelters; prospects for biomonitoring marsh pollution”. Environmental Pollution. Volume 129, Issue 1, Pages 23-30


Thank you!

Olivia J. Mitchell - olivia.j.mitchell-1@ou.edu
Leif H. Olson - lolson@ou.edu
Robert W. Nairn - nairn@ou.edu

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CREW Center for Restoration of Ecosystems and Watersheds The University of Oklahoma

Gallogly College of Engineering School of Civil Engineering and Environmental Science The University of Oklahoma

Oklahoma Environmental Quality

GRDA Grand River Dam Authority

United States Environmental Protection Agency

Quapaw Nation O-Gah-Pah

City of Commerce On The Route To The Future

US Army Corps of Engineers ®