BioMost, Inc.
Mining & Reclamation Services
Specializing in Mine Drainage Treatment
Design • Build • Maintain

CREW
Center for Restoration of Ecosystems and Watersheds
University of Oklahoma

Potential Use of Mine Drainage Derived Iron Oxides for Drinking Water Treatment in Developing Nations

OU WaTER Conference

Oct. 24-25th, 2011

Cody "Buck" Neely

BIOMOST INC

Overview

- Mining in Developing Nations
- A Way of Life
- Environmental Impacts
- Potential Benefits
- Sorption Batch Experiments
  - As & Zn
- Results & Conclusions

Small Scale Mining in Developing Nations

- Long History
- Small Scale – Subsistence Mining
  - Family
  - Community
- Vast mineral deposits
- Small Scale Mine Can Account for up to 80 – 100% of Gold, Diamonds, and Gemstones in Developing Nations

- Gold, Silver, & Precious Metals
- Gemstones & Diamonds
- Coal & Metal ores
  - Economy of Scale

A Way of Life

- Economic Struggles
- Globally Small Scale Mining
  - ~ 13 million people
  - (more than the formal mining sector)
- Women & children
- Dangers
- Human health concerns
- High mortality rate
- Hope of striking it big remains – giving the impoverished a reason to continue

Environmental Impacts

- Little to No Observed Regulation
- Environmental Safeguards
- Acid Mine Drainage
- High Metal Loadings
  - Devastate Aquatic Ecosystems

Potential Benefits of Residual Solids

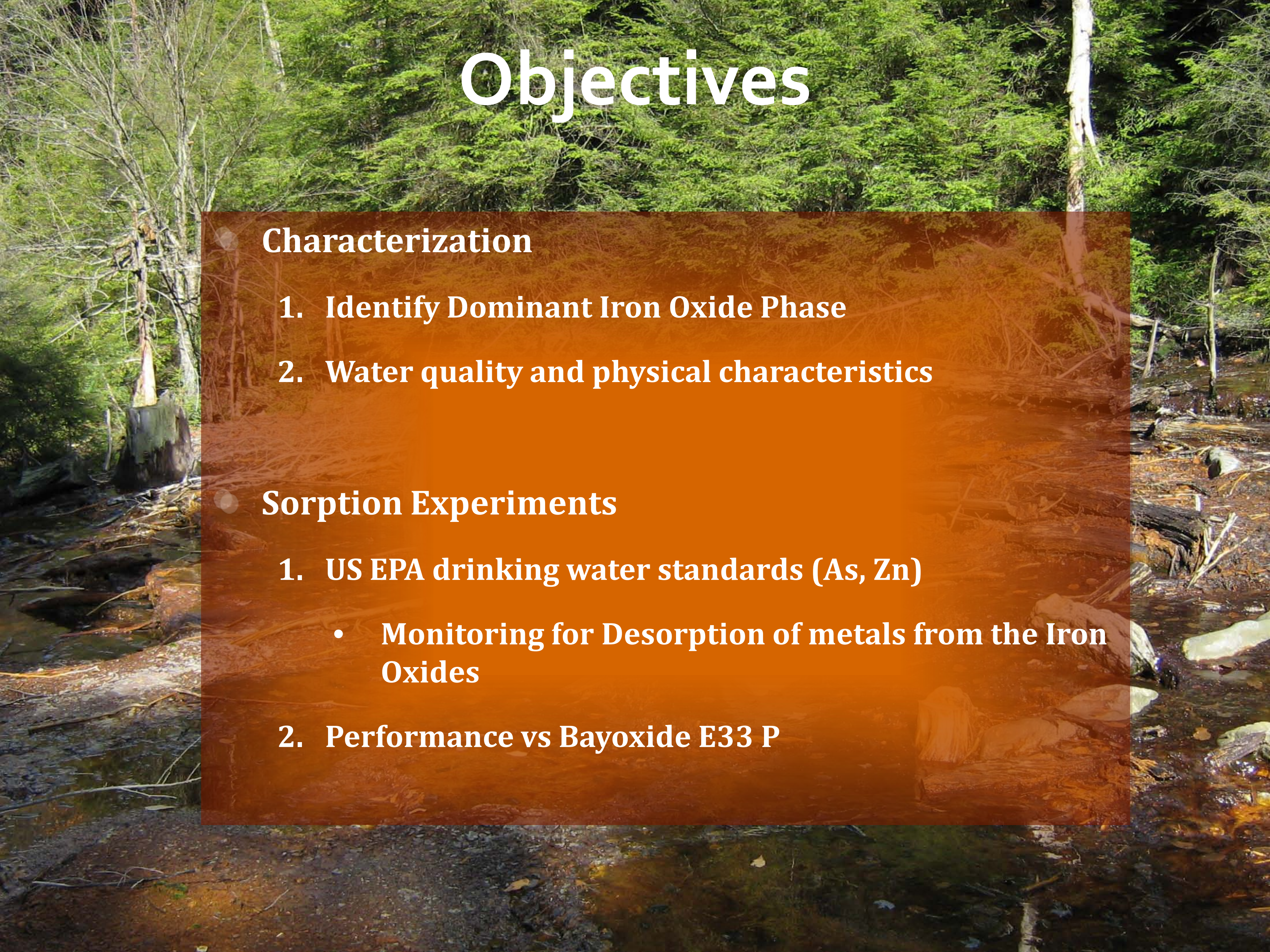
- Excellent Sorbents
- Abundant Quantities
- Reusing a Waste

- Manufactured vs Recovered
- Accessibility / Availability
- Cost

- Recovered Iron Oxides Appear to be a good Candidate for Drinking Water Improvements in Developing Nations

Typically Water Treatment is *<u>NOT</u>* Performed with Mine Drainage Derived Iron Oxides

Objectives



- **Characterization**
  1. **Identify Dominant Iron Oxide Phase**
  2. **Water quality and physical characteristics**
- **Sorption Experiments**
  1. **US EPA drinking water standards (As, Zn)**
     - **Monitoring for Desorption of metals from the Iron Oxides**
  2. **Performance vs Bayoxide E33 P**

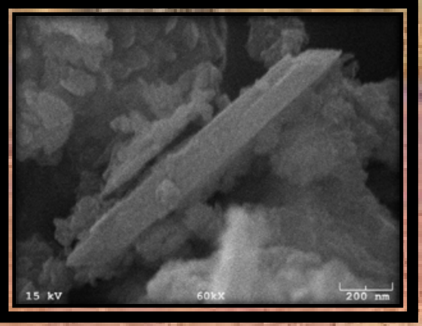
Site Selections

4 Passive Treatment Systems

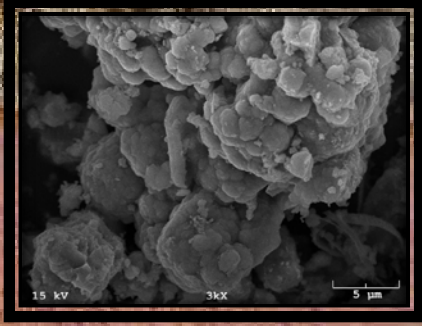
- **MRPTS (276.9 m^2g^{-1})**
- **Red Oak**
- **Hartshorne**
- **Leboskey**

9 Environmental Discharges

- **Gowen Battles Confluence**
- **Gowen Battles Seep (58.5 m^2g^{-1})**
- **Gowen Burgers Seep**
- **Howe**
- **Jeffries Field**
- **Panola Seep #1**
- **Panola Seep #2 (124.8 m^2g^{-1})**
- **Pine Lane – PA**
- **GCI**

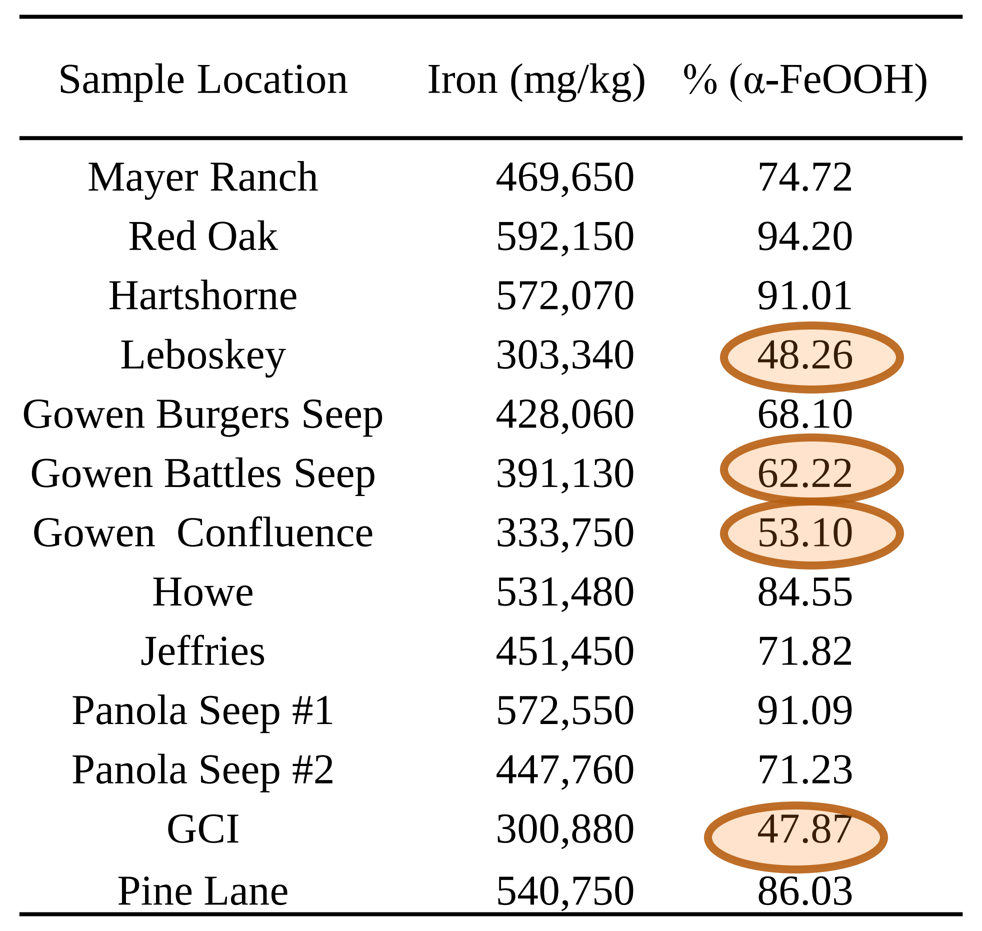


Characterization



- Munsell Color
- Particle Density
- Specific Surface Area (BET)
- Crystallinity (AOD)
- Morphology (SEM)
- Iron Phase (XRD)
- Precipitate Chemistry
- Particle Size Distribution
- Organic Matter Content (LOI)
- Moisture Content

% Goethite (α-FeOOH)



Sample Location	Iron (mg/kg)	% (α-FeOOH)
Mayer Ranch	469,650	74.72
Red Oak	592,150	94.20
Hartshorne	572,070	91.01
Leboskey	303,340	48.26
Gowen Burgers Seep	428,060	68.10
Gowen Battles Seep	391,130	62.22
Gowen Confluence	333,750	53.10
Howe	531,480	84.55
Jeffries	451,450	71.82
Panola Seep #1	572,550	91.09
Panola Seep #2	447,760	71.23
GCI	300,880	47.87
Pine Lane	540,750	86.03

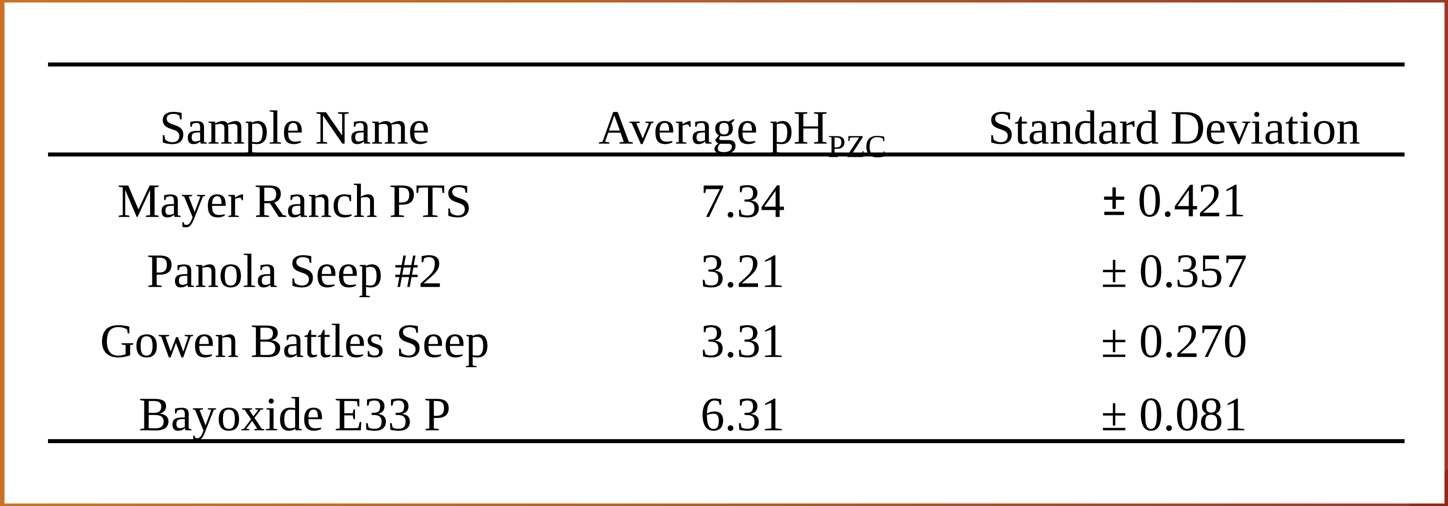
Sorption Batch Experiments

Feasibility Study

- Anion: Arsenate
- Cation: Zinc

Point of Zero Charge

- **pH Above pH_{pzc} Cation Removal**
- **pH Below pH_{pzc} Anion Removal**



Sample Name	Average pH_{PZC}	Standard Deviation
Mayer Ranch PTS	7.34	± 0.421
Panola Seep #2	3.21	± 0.357
Gowen Battles Seep	3.31	± 0.270
Bayoxide E33 P	6.31	± 0.081

pH of Forming Environment

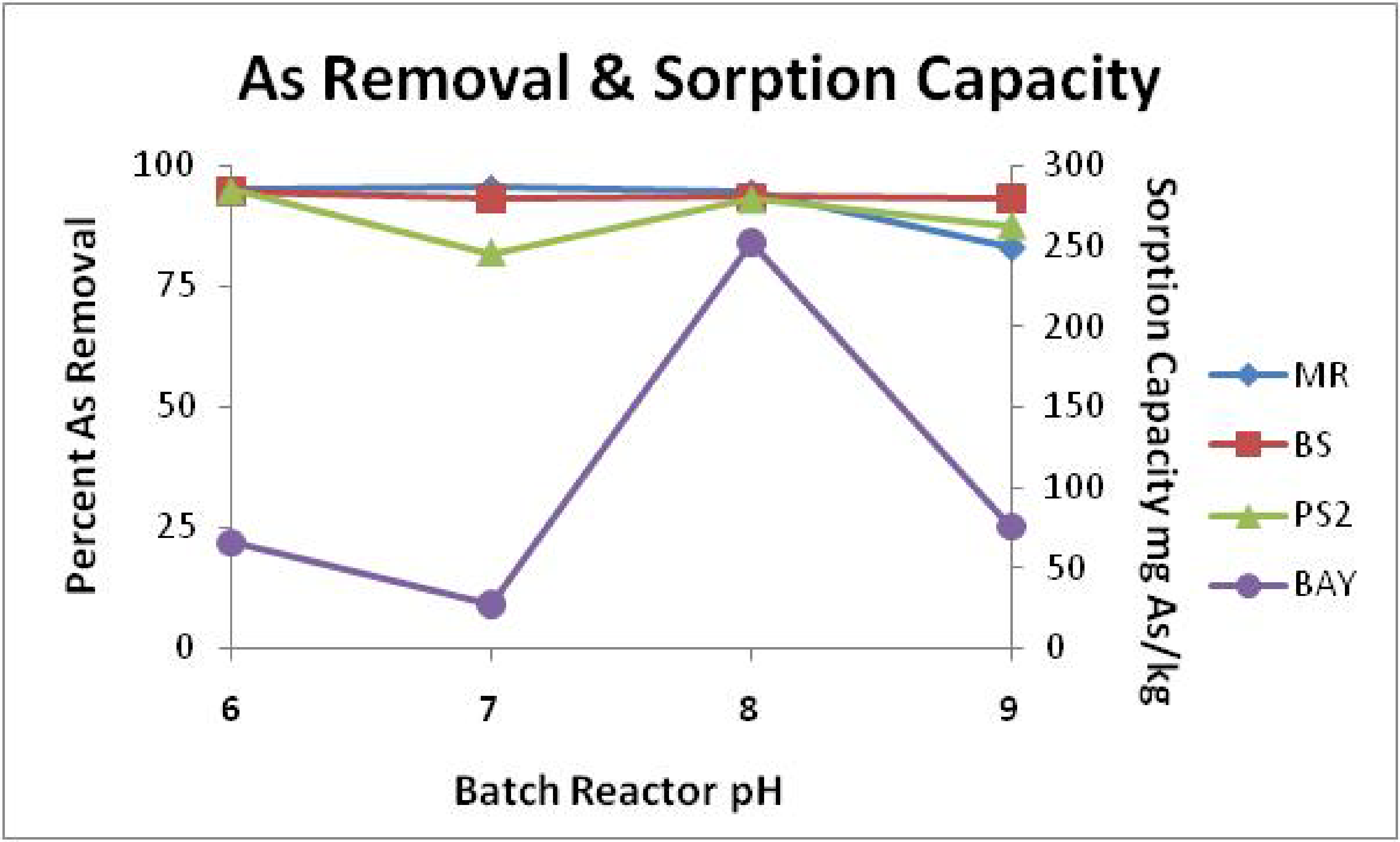
Mayer Ranch 5.95 **Panola Seep #2 3.08**

Battles Seep 3.70

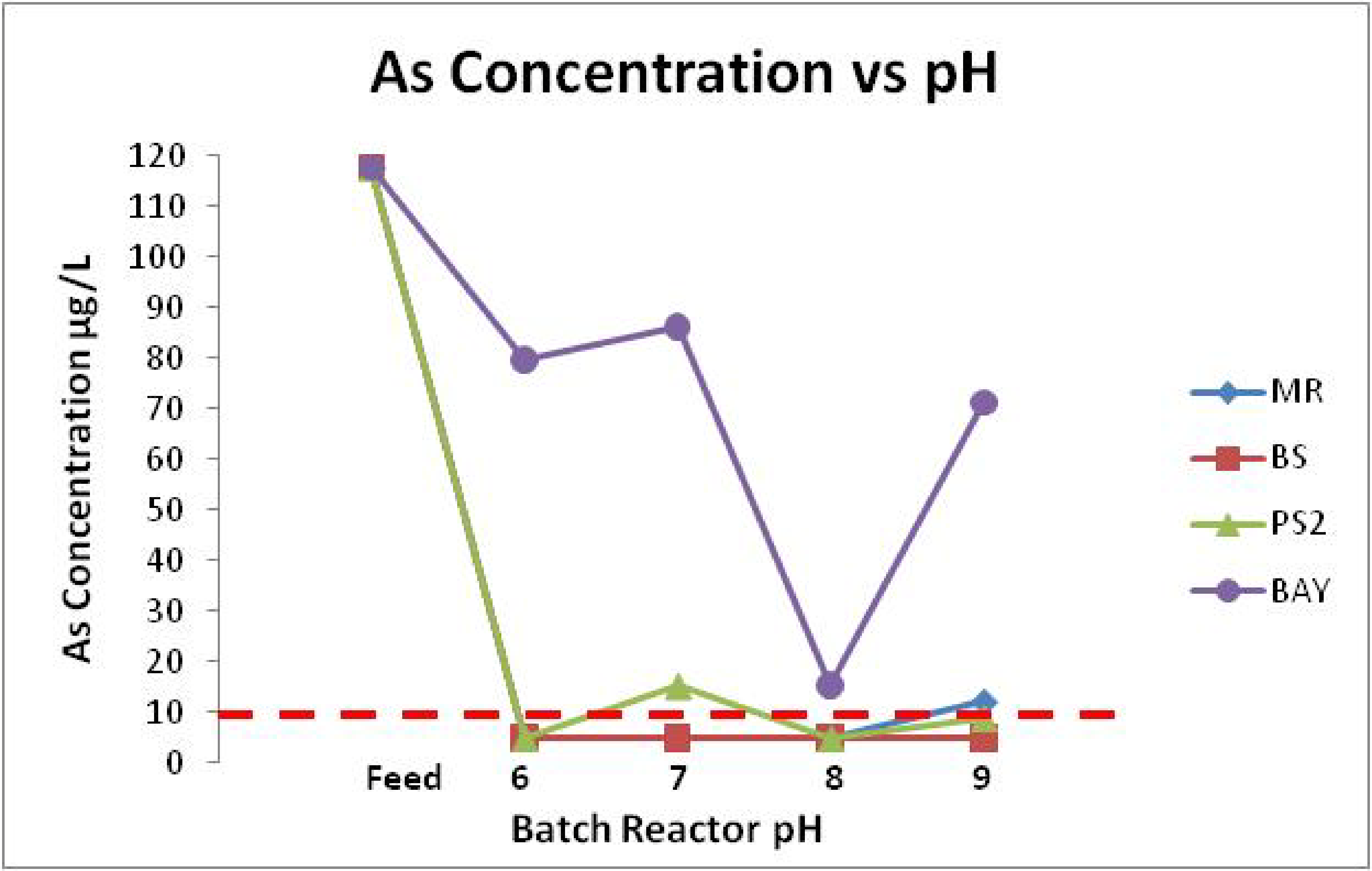
Arsenate Sorption Experiment

<u>Conditions (23 ± 1 °C)</u> (n=1)

- 117.79 ± 4.08 µg/L initial concentration
- 3 hour equilibrium
- 0.1000 g sorbent



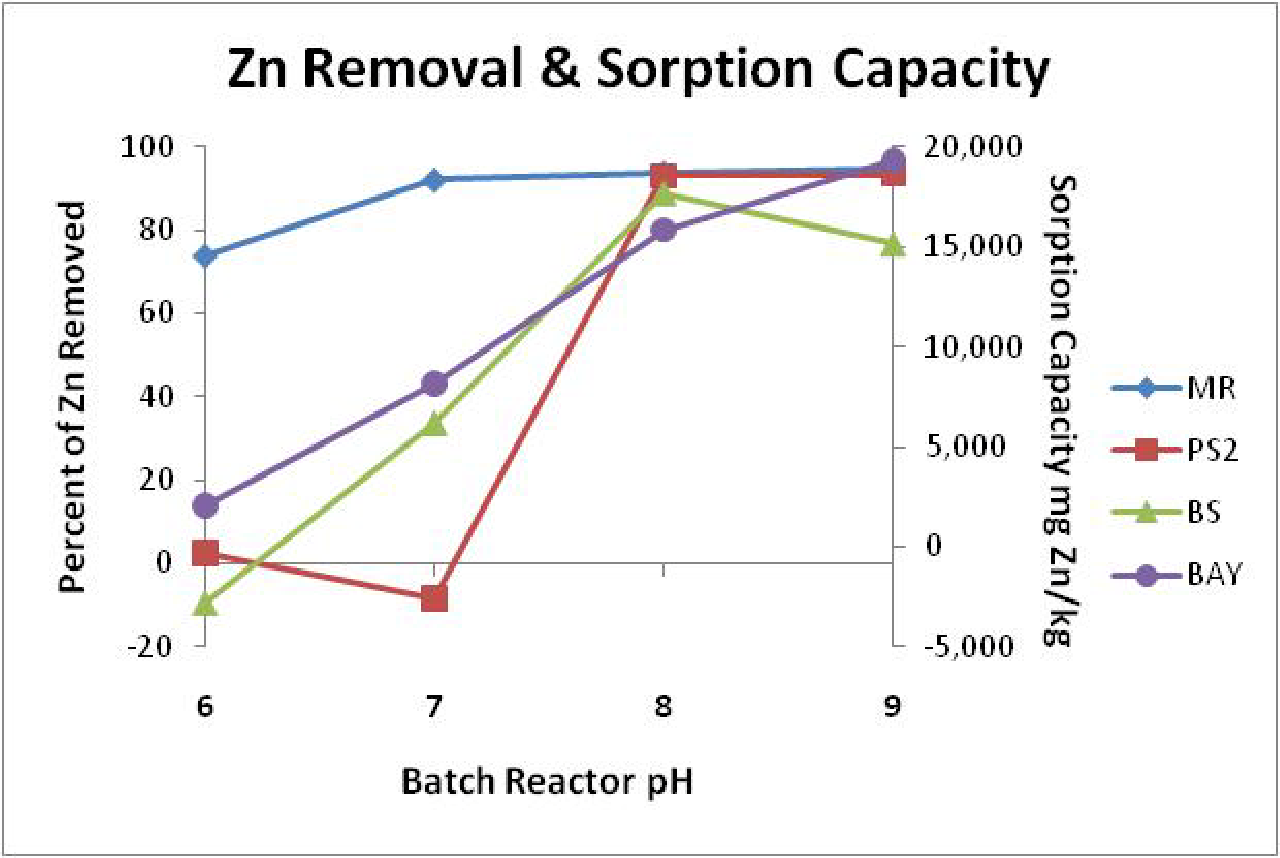
As EPA Drinking Water Standard



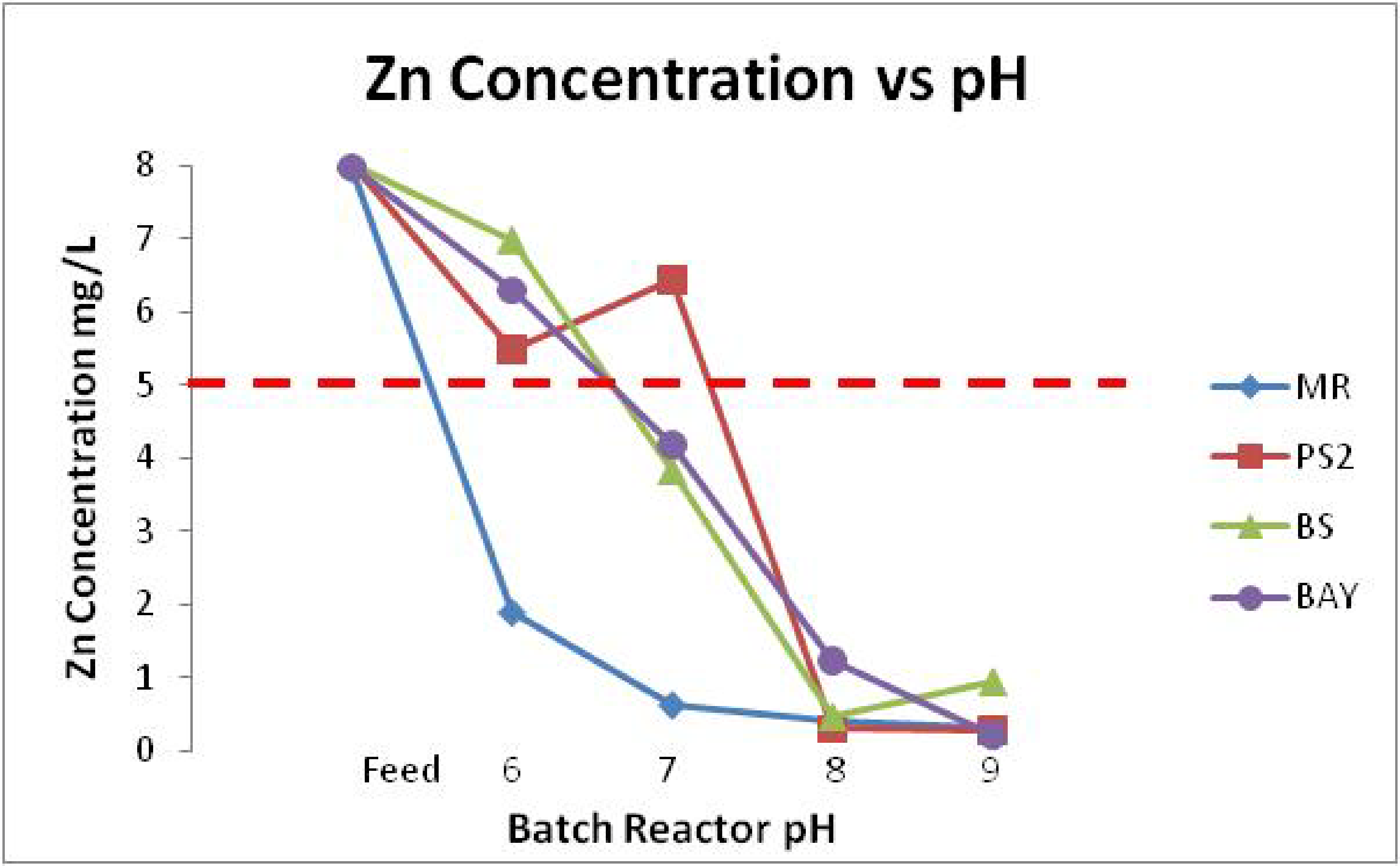
Zn Sorption Experiment

Conditions (23 ± 1 °C) (n=1)

- 7.99 ± 0.03 mg/L initial concentration
- 3 hour equilibrium
- 0.2500 g sorbent



Zn EPA Drinking Water Standard



Desorption

US EPA Primary Drinking Water Standards

				Primary Drinking Water Standards					
ID	As(V) Experiment	Zn^{+2} Experiment	pH	As (µg/L)	Cd (µg/L)	Cr (µg/L)	Cu (mg/L)	Ni (µg/L)	Pb (µg/L)
MR	X	X	6 - 9	< 10	< 5	< 100	< 1.3	< 100	< 15
BS	X	X	6 - 9	< 10	< 5	< 100	< 1.3	< 100	< 15
PS2	X	X	6 - 9	< 10	< 5	< 100	< 1.3	< 100	< 15
BAY	X	X	6 - 9	< 10	< 5	< 100	< 1.3	< 100	< 15
EPA Limit				**10**	**5**	**100**	**1.3**	**100**	**15**

All experiments below primary drinking water standards

Desorption

US EPA Secondary Drinking Water Standards

				Secondary Drinking Water Standards			
Sample Name	As(V) Experiment	Zn^{+2} Experiment	pH	Al (µg/L)	Fe (µg/L)	Mn (µg/L)	Zn (mg/L)
MR		X	6	61	< 300	< 50	< 5
BS	X		9	124	474	< 50	< 5
		X	9	< 50	656	< 50	< 5
PS2	X		6	< 50	353	< 50	< 5
	X		9	< 50	363	< 50	< 5
BAY	X	X	6 - 9	< 50	< 300	< 50	< 5
US EPA Limit				**50-200**	**300**	**50**	**5**

Bayoxide E33 P

- Unexpected performance with the exception of Zn experiment

- Possible explanations :
  - Constant agitation
  - Designed as packed bed media

Results & Conclusions

- Anion Removal (As(V))
  - Mine drainage derived iron oxides outperformed Bayoxide E 33 P
  - Arsenic feasibility appears promising
    - More testing required

- Cation Removal (Zn^{+2})
  - All sorbents met the treatment goal
  - Bayoxide highest capacity (pH 9)
  - Mayer Ranch preeminent mine drainage iron oxide
    - Low pH – greatest overall removal
  - Feasibility appears promising- (additional testing)
- Future Studies

If Mine Drainage Derived Iron Oxides can Help Improve Drinking Water Quality…Why Wait

Questions?