An Innovative System for the Efficient and Effective Treatment of Non-Traditional Waters for Reuse in Thermoelectric Power Production

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Water in Thermoelectric Power Generation

- Water availability essential to meet future power generation needs
- Increasing competition for freshwater
- Need to reduce freshwater withdrawal
- Beneficial reuse of water
- Effective and low-cost water management strategies are needed

Project Objective

- Evaluate constructed wetland treatment systems as an effective and low cost strategy for managing waters for reuse in thermoelectric power generation for cooling or other purposes
- Waters investigated ("non-traditional")
  - Ash basin waters
  - Cooling waters
  - Produced waters
  - Flue gas desulfurization (FGD) waters

What Are Constructed Wetland Treatment Systems?

Systems carefully designed to "treat" (transfer or transform) constituents in impaired water in order to make the water suitable for reuse or to decrease the environmental risk these constituents may pose in receiving systems.

Constructed Wetland Treatment System

Key Concepts of Constructed Wetland Treatment Systems

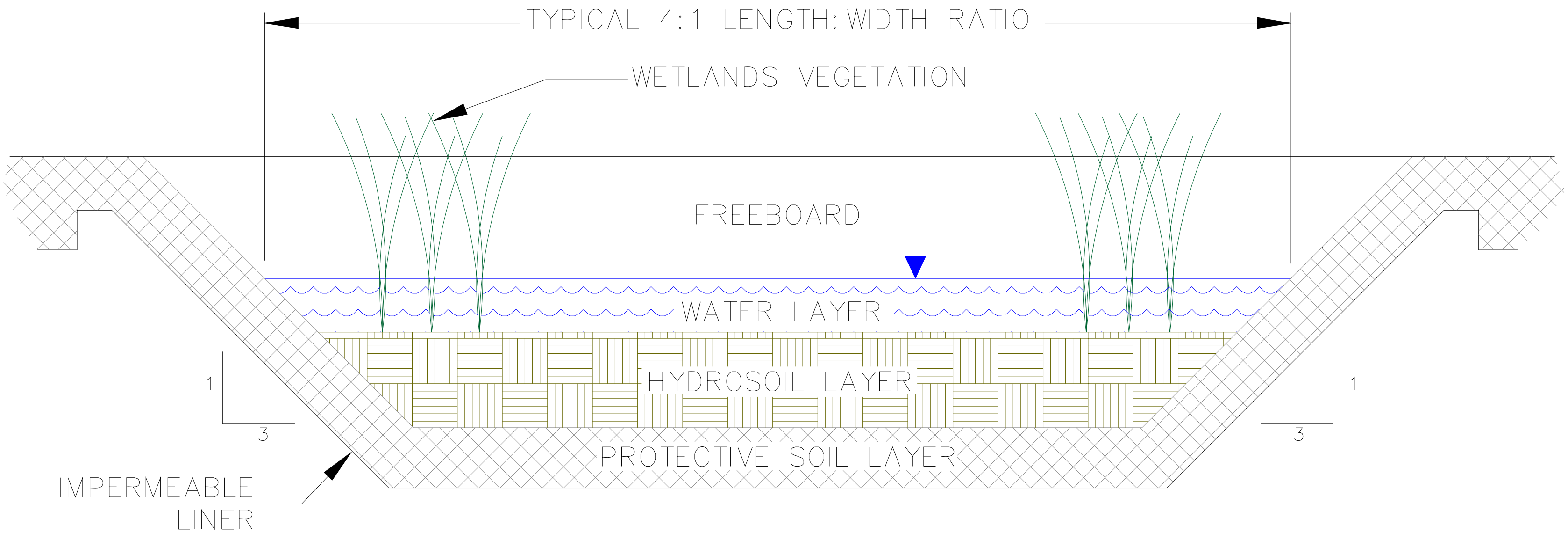
- *Goal*: remove targeted constituents from aqueous phase and partition these to sediments in non-bioavailable forms.
- *Method*: replicate natural systems
  - Biogeochemical processes in sediments
  - Plants provide organic matter: carbon and energy source.
  - Solar powered
  - Design for seasonal variations

    e.g., annual plant dieback renews sediment binding surfaces

Features of Constructed Wetland Treatment Systems

- Treat multiple constituents; wide range of concentrations
- Designed and permitted as water treatment systems with an anticipated life expectancy and closure plan
- Support of regulatory community
- Typically cost 50% to 90% less than conventional treatment systems

Design



TYPICAL 4:1 LENGTH: WIDTH RATIO
WETLANDS VEGETATION
FREEBOARD
WATER LAYER
HYDROSOIL LAYER
PROTECTIVE SOIL LAYER
IMPERMEABLE LINER
1
3
1
3

Project Approach

- Characterize non-traditional waters (NTW) and establish beneficial reuse criteria.
- Design and build a pilot-scale constructed wetland treatment system (CWTS).
- Measure performance of the CWTS.
- Determine how observed performance is achieved in CWTS.
- Assess performance of CWTS in terms of beneficial reuse criteria.

Project Schedule

	Year 1 (2005-2006)				Year 2 (2006-2007)				Year 3 (2007-2008)			
	Q 1	**Q2**	**Q3**	**Q4**	**Q 1**	**Q2**	**Q3**	**Q4**	**Q 1**	**Q2**	**Q3**	**Q4**
Task 1: **Water Characterization**												
Task 2: **Reuse & Discharge Criteria**												
Task 3: **Design & Construct**												
Task 4: **System Performance**												
Task 5: **Suitability**												
Task 6: **Decision Support System**												

Task 1. Water Characterization

Ash basin waters

low ionic strength;
Se, Hg, As, Cr, Zn, Al,
Cu, suspended solids

Cooling waters

site specific ionic
strength; biocides,
oxidants, Cu, Zn, Pb

Task 1. Water Characterization

Produced waters

high ionic strength (chlorides); Zn, As, Cd, Pb, Cu, Se, organics (oil and grease)

Flue gas desulfurization waters

high ionic strength (chlorides); Hg, Se, As

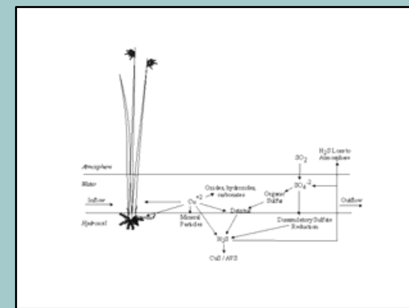
Task 2: Beneficial Reuse Parameters

- External reuse (i.e., irrigation, surface flow augmentation)
  - NPDES permits
  - Toxicity
- Internal reuse
  - Corrosion
  - Chemical scaling
  - Biofouling

Task 3: Design and Construct Pilot-Scale CWTS

Literature

Theoretical Modeling



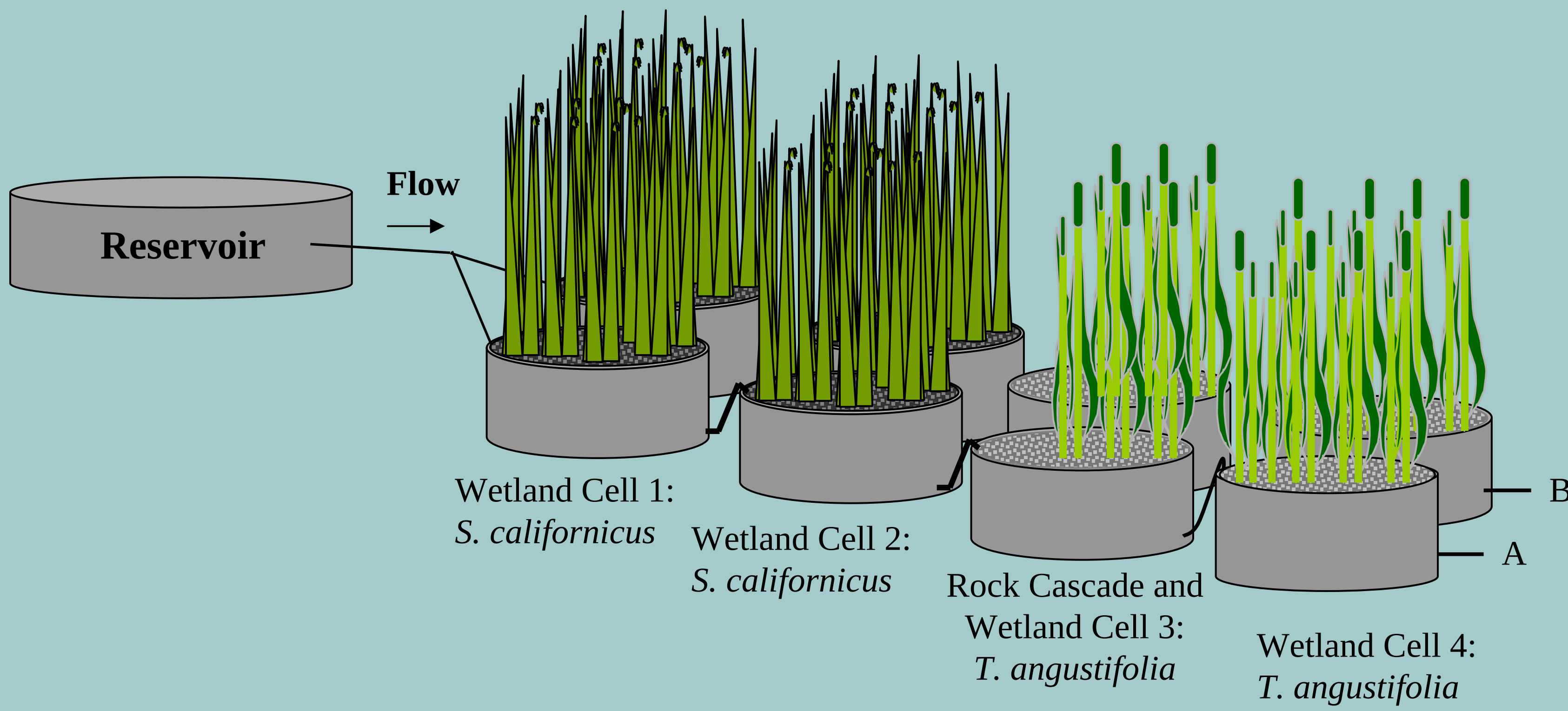
Pilot-Scale Physical Model of CWTS

Full-scale System

Constructed Wetland Treatment System: Treatment Strategy for Hg (as an example)

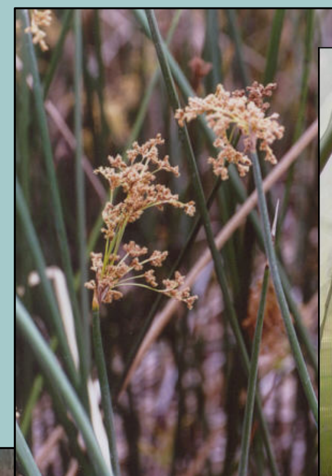
- **Mercury stabilization in sediment**
  - **Sorption to organic material and minerals such as clays**
  - **Reduction is preferred pathway because of strong bonds**
- **Hg + S $\rightarrow$ HgS (mercuric sulfide, cinnabar)**
- **> S:Hg and ~ -200 mV redox potential**

Pilot-Scale CWTS



Reducing Wetland Cells

- Eh ≤ -150 mV
- Organic-rich sediment
- Removal of metals via reductive pathways




Schoenoplectus californicus

Oxidizing Wetland Cells

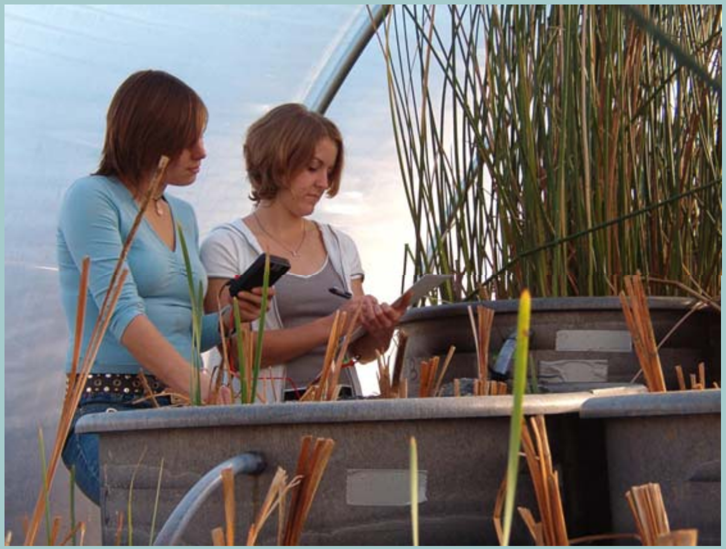
- **Eh > -50 mV**
- **Sandy sediment**
- **Removal of water soluble organics via oxidative pathways**



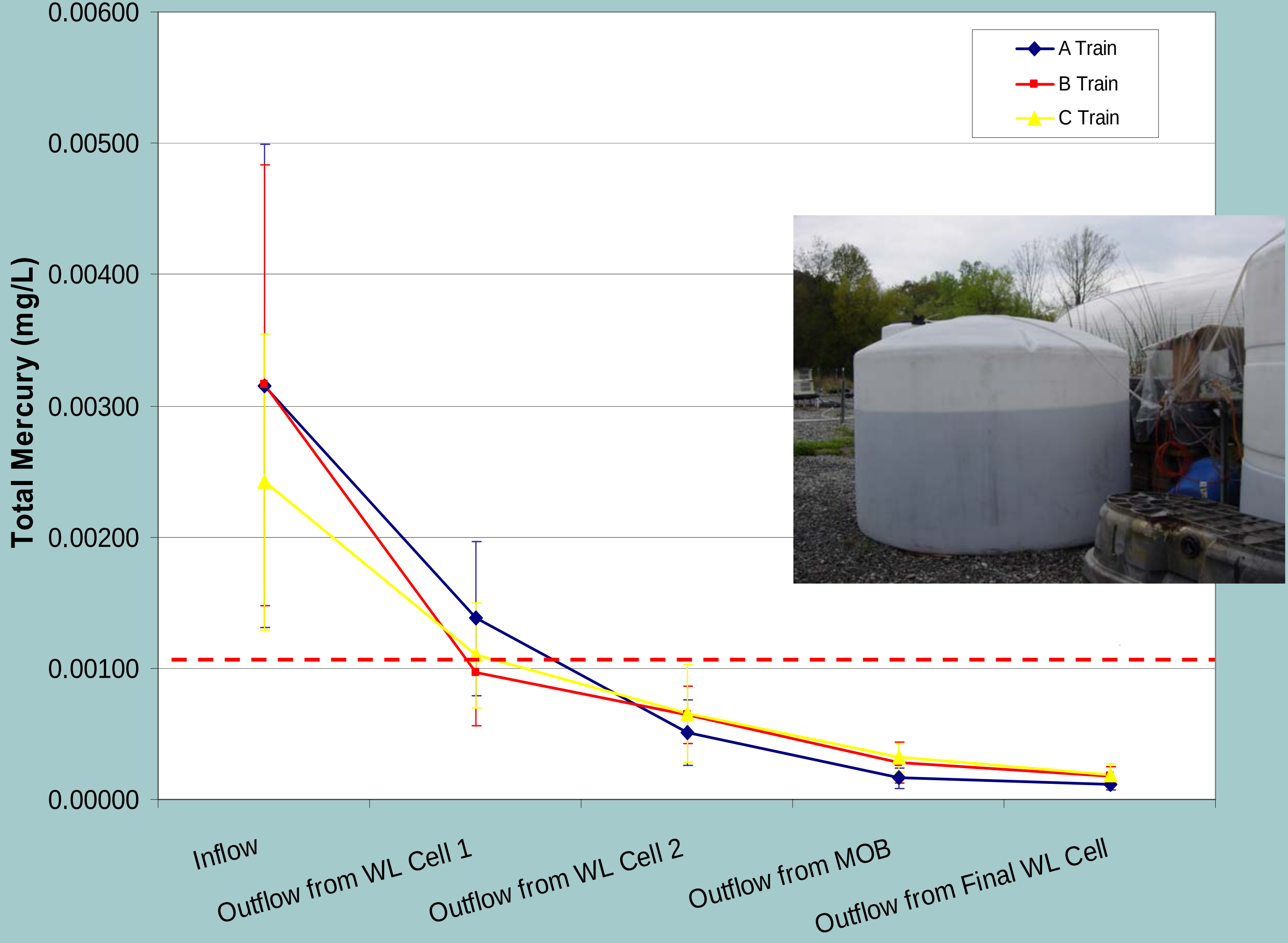

Typha augustifolia

Task 4: Evaluate Treatment Performance (in progress)

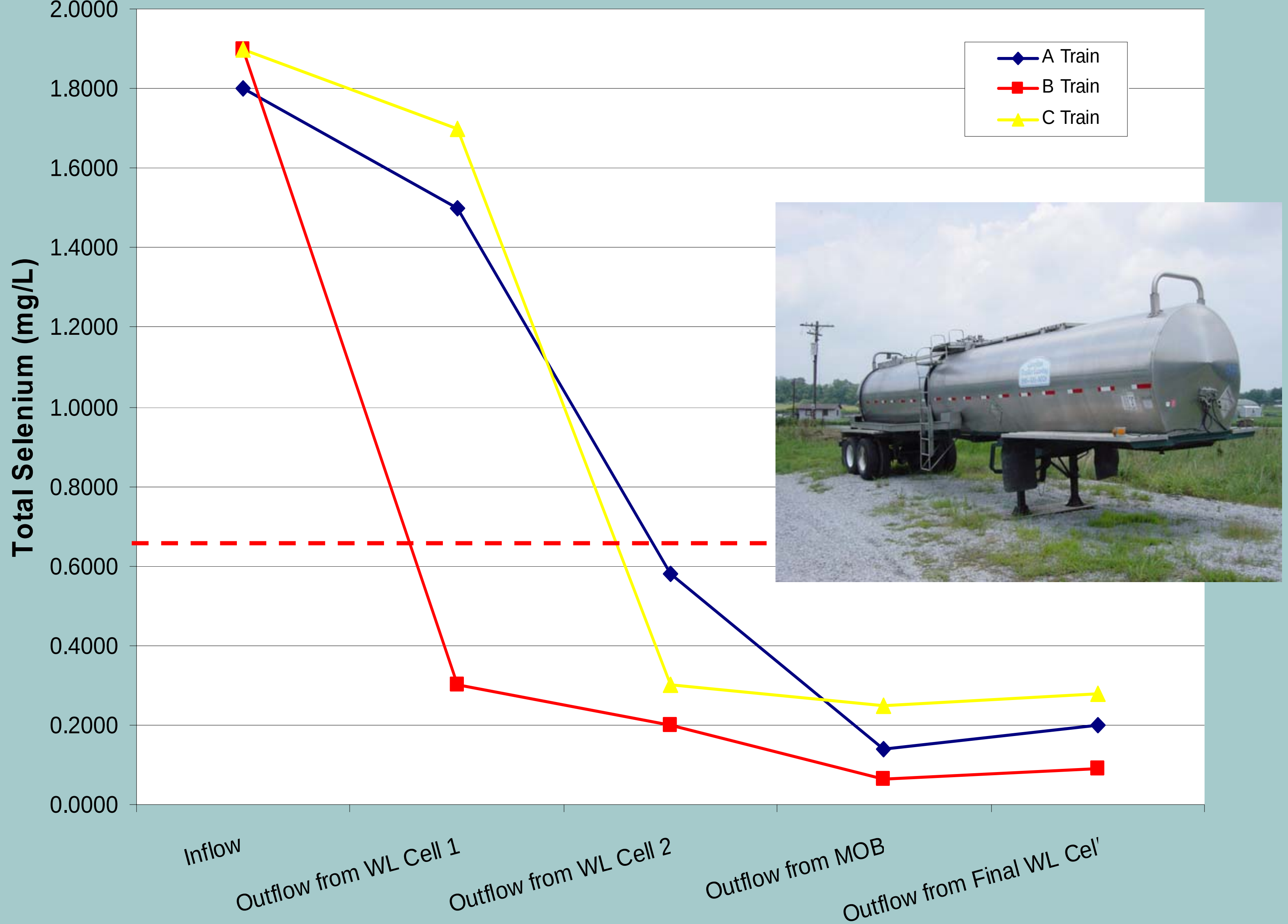
- Concentrations of targeted constituents in non-traditional waters
- Corrosion, scaling, and biofouling
- Toxicity

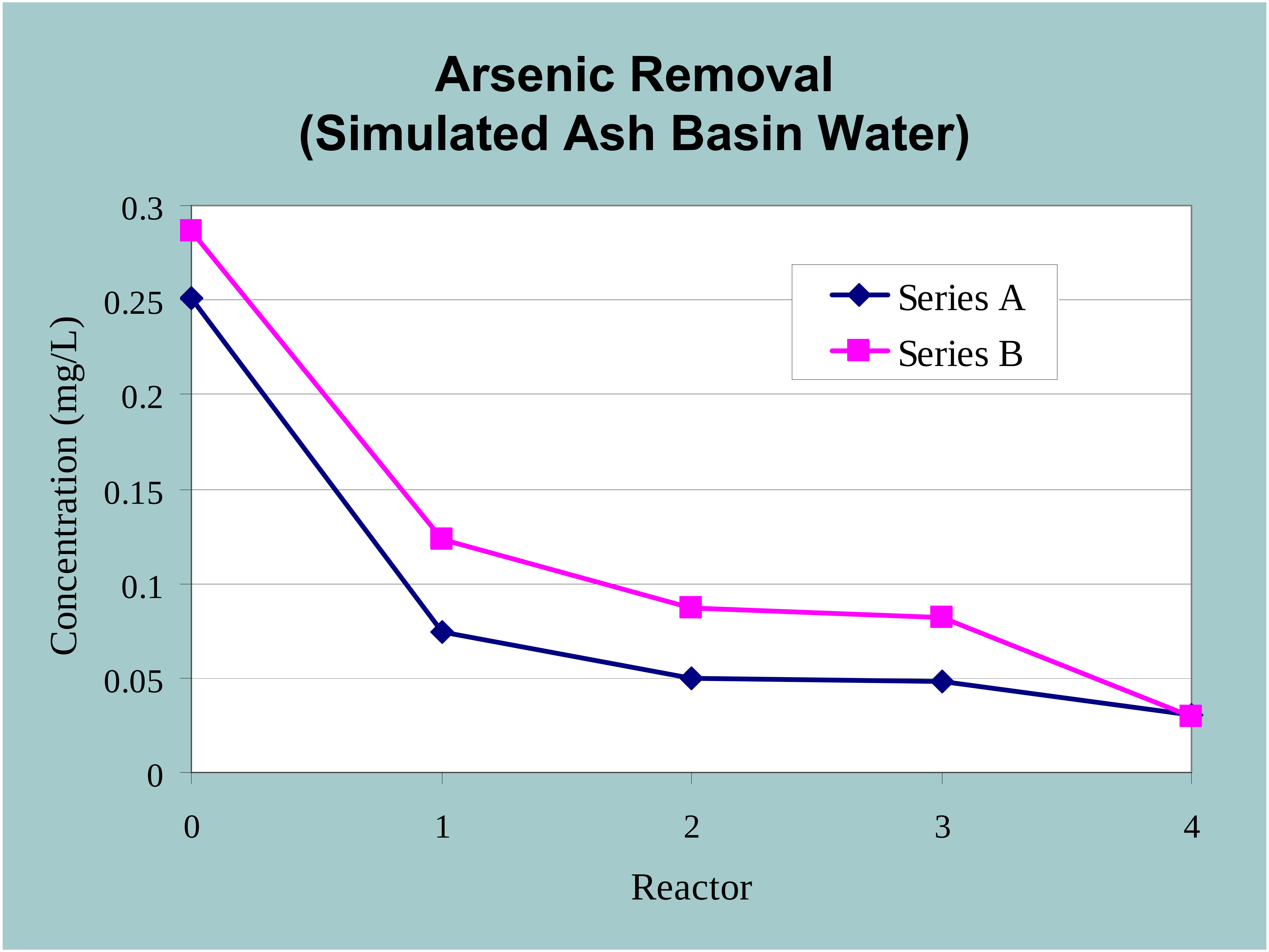


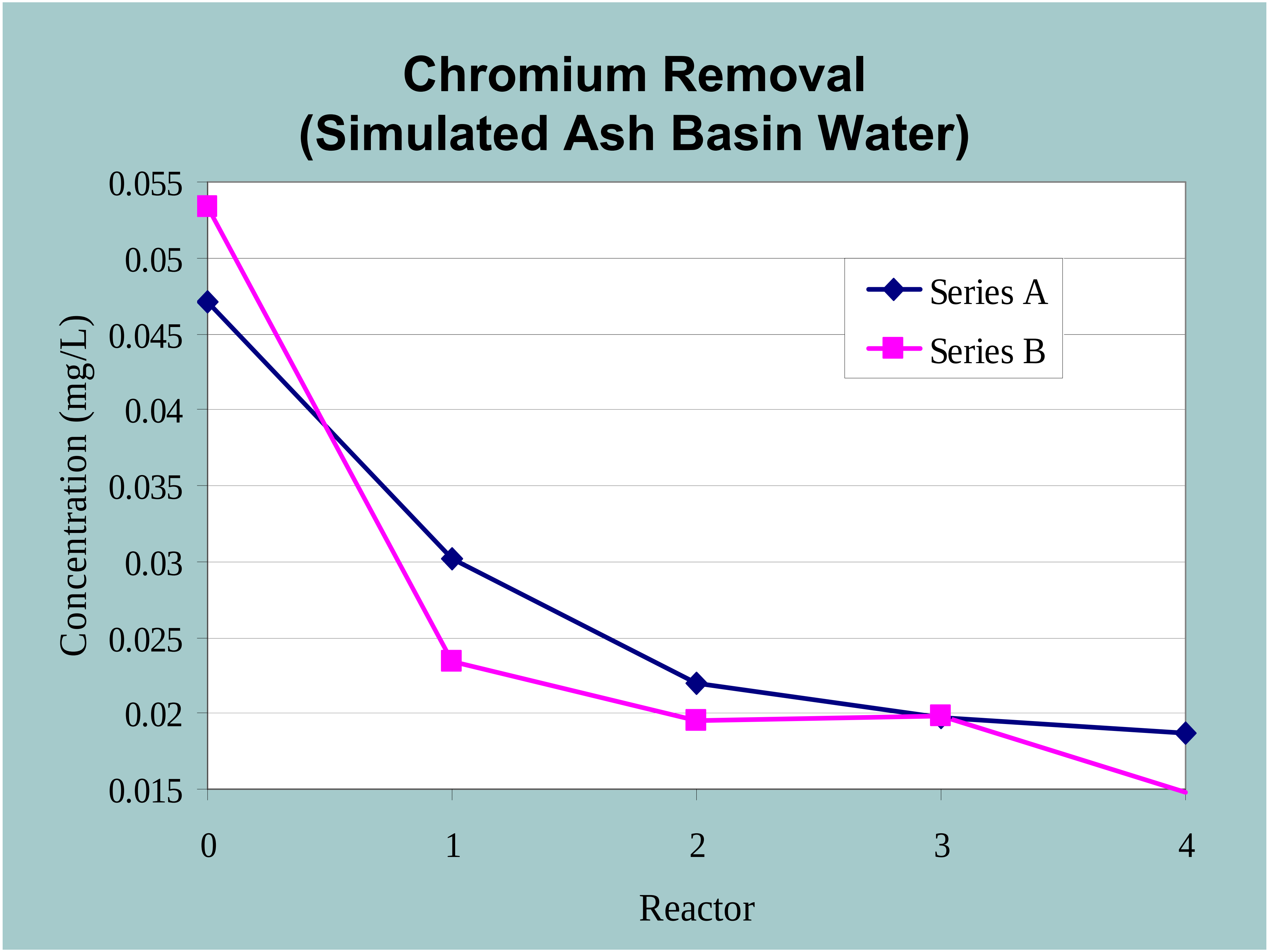
Mercury Removal
(Simulated FGD Water)



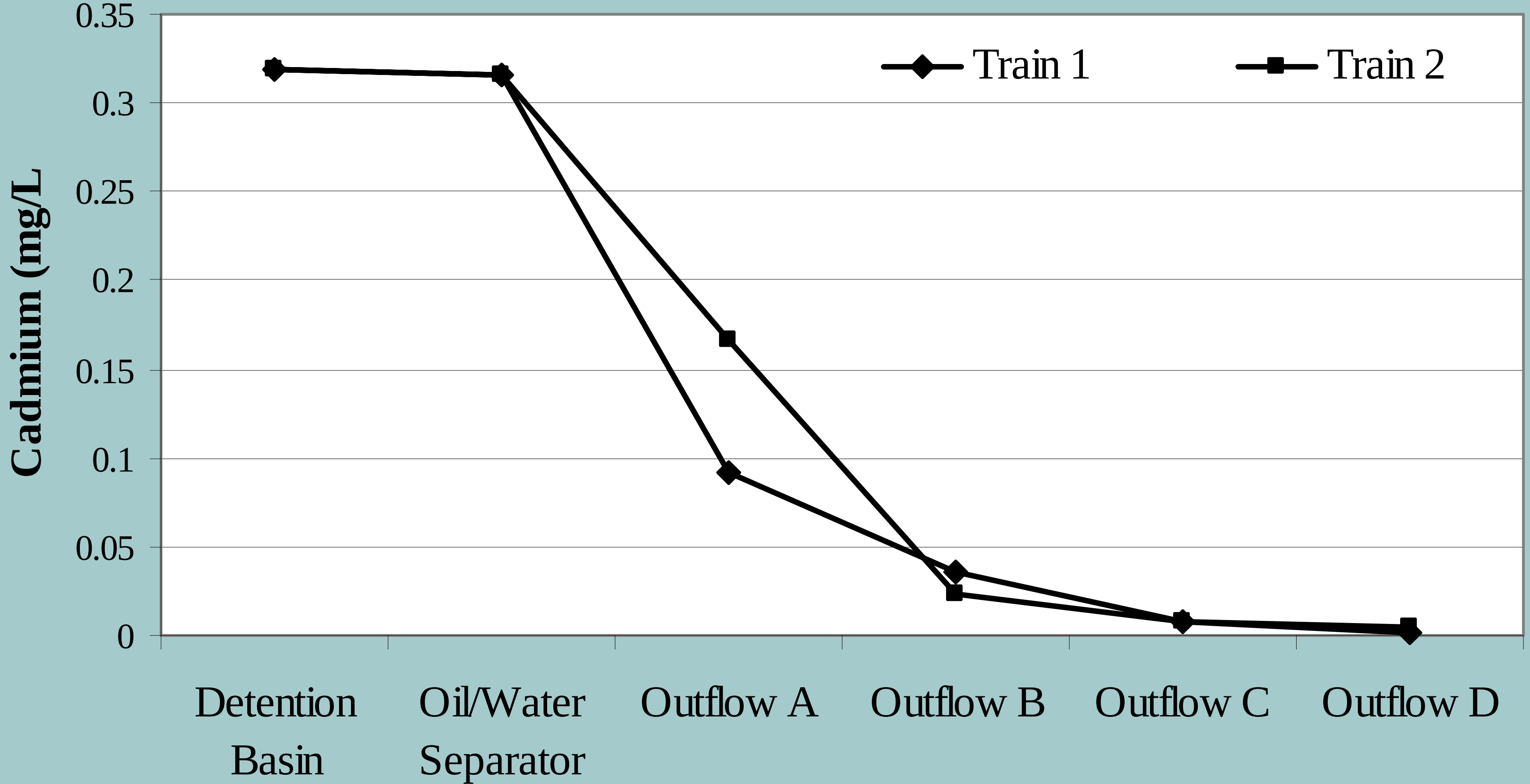
Selenium Removal
(Actual FGD Water)



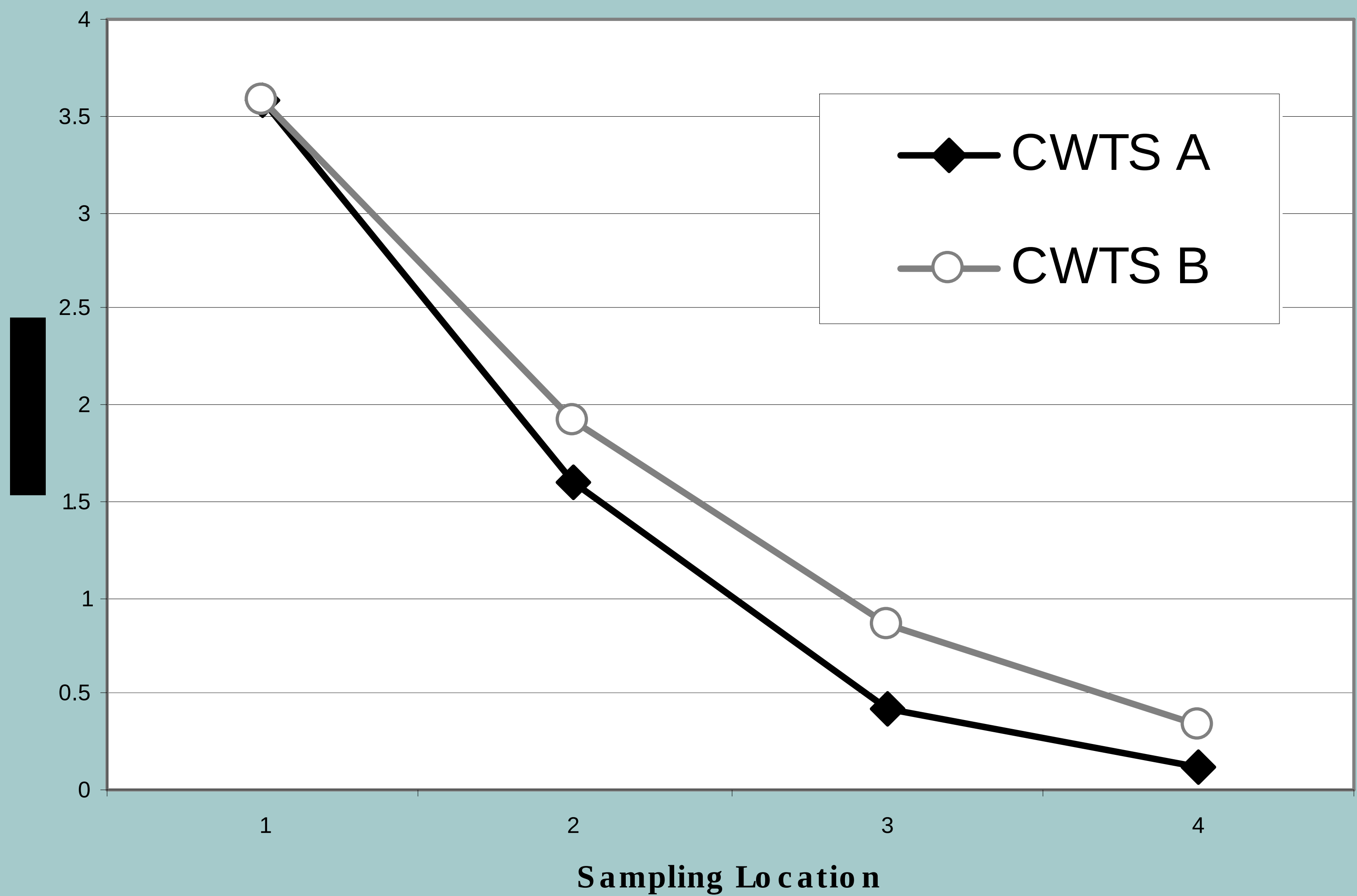

Arsenic Removal
(Simulated Ash Basin Water)
Concentration (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
Reactor
Series A
Series B


Chromium Removal
(Simulated Ash Basin Water)
Concentration (mg/L)
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0
1
2
3
4
Reactor
Series A
Series B

Cadmium Removal
(Simulated Produced Water)

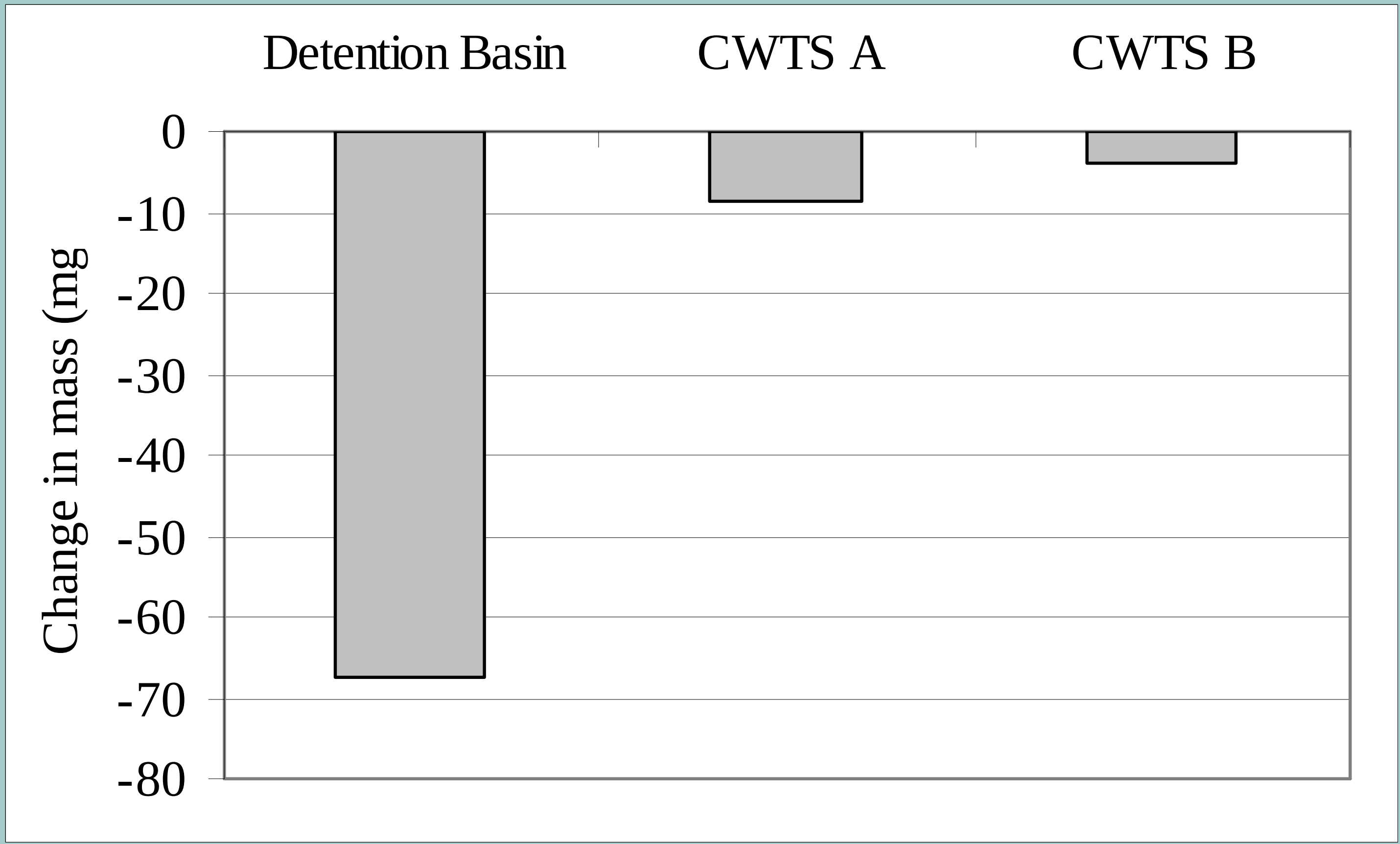


Copper Removal
(Simulated Cooling Water)



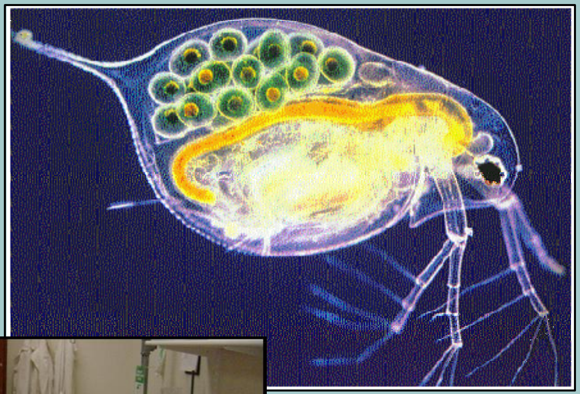
Corrosion, Scaling, and Biofouling

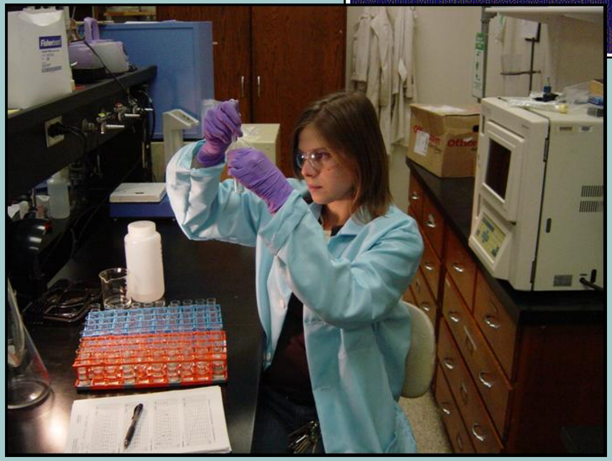
Reduction in Corrosion Potential in Cooling Waters

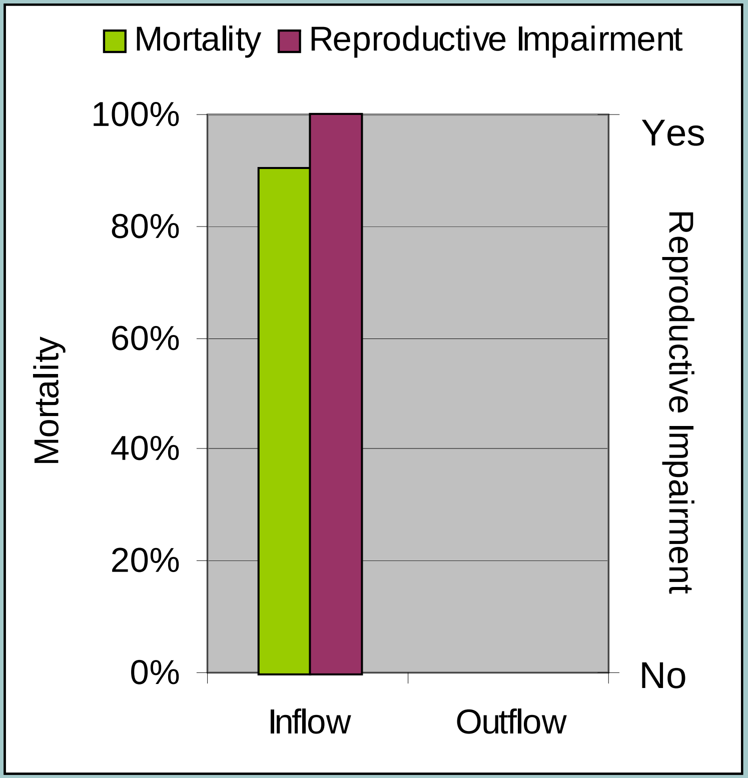


Pilot-Scale Performance - Toxicity

- *Ceriodaphnia dubia*
- Inflow and outflow water







Simulated produced water

Conclusions

- **Multiple constituents requiring treatment are present**
  - Ash basin waters
  - Cooling waters
  - Produced waters
  - Flue gas desulfurization (FGD) waters
- **e.g. in addition to Hg, As, and Se, other constituents are present in ash basin waters and FGD waters**

Conclusions (continued)

- Targeted constituents are being treated successfully by pilot-scale CWTS.
  - Ash basin waters
  - Cooling waters
  - Produced waters
  - Flue gas desulfurization waters
- Corrosion and scaling are reduced by treatment in the pilot-scale CWTS.
- Toxicity is reduced by treatment in the pilot-scale CWTS.
- Treated water has potential for beneficial reuse (next task).

Graduate Research Assistants

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