The 10th International In Situ and On-Site Bioremediation Symposium
Baltimore, MD May 5-8, 2009

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Phytoremediation of Mercury and Methylmercury Contaminated Sediments by Water Hyacinth (*Eichhornia crassipes*)

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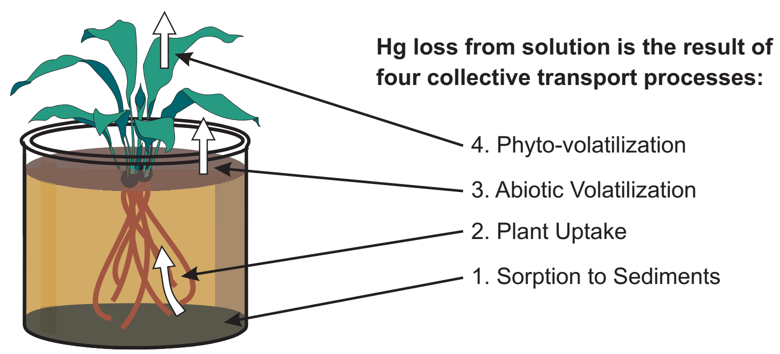
Abstract

Phytoremediation has potential to be implemented at mercury (Hg) and methylmercury (MeHg) contaminated sites. Water hyacinths (*Eichhornia crassipes*) were investigated for their ability to assimilate Hg and MeHg into plant biomass, in both aquatic and sediment-associated forms, over a 68-day hydroponic study. Previous investigations have demonstrated the promise of *E. crassipes* for Hg assimilation as a potential remediation technique under specific laboratory conditions (Skinner, 2007). The suitability of *E. crassipes* to assimilate both Hg and MeHg was evaluated under differing PO_4 concentrations (0.0 mg-PO_4, 2.5 mg-PO_4/L, 12.5 mg-PO_4/L, and 22.5 mg-PO_4/L) light intensities (94 Lux and 976 Lux) and sediment: aqueous phase contamination ratios. Because aquatic rhizospheres have the ability to enhance MeHg formation (Acha, 2005) MeHg levels in water, sediment and *E. crassipes* roots and shoots were also measured.

Mercury and MeHg were found to concentrate preferentially in the roots of *E. crassipes* with little translocation to the shoots or leaves of the plant, a result consistent with studies from similar macrophytes (Skinner, 2007; Gupta, 1998). Sediments were found to be the major sink for Hg as they were able to sequester Hg, making it non-bioavailable for water hyacinth uptake (plant tissue concentrations of ~10,000 mg-Hg/kg dry plant biomass and ~1,000 mg-MeHg/kg in the absence of sediments and ~2,000 mg-Hg/kg and < 200 mg-MeHg/kg in the presence of sediments). We observed an optimum PO_4 concentration (2.5 mg-PO_4/L) at which Hg and MeHg uptake is enhanced (~3X greater Hg and MeHg uptake compared to 0.0 mg-PO_4/L, 12.5 mg-PO_4/L or 22.5 mg-PO_4/L conditions). Increasing light intensity served to enhance the translocation of both Hg and MeHg. Assimilation of Hg and MeHg into the biomass of water hyacinths represents a potential means for remediation of contaminated waters and sediments under the appropriate

Water Hyacinth (E. crassipes)

- Thrives in wetland environments (such as seasonal oxbow lakes)
- Yields high biomass
- Robustness to stresses in both light and nutrient status
- Inexpensive to produce commercially throughout the U.S.



Materials and Methods

- **Sediment Characterization (all values based on dry weight)**
  - Moderately organic (4.95 mg-C/kg), extremely poorly sorted clay/silt
  - Mercury (45.1 mg-Hg/kg),
  - Total Metals (As 8.06 mg/kg; Ba 153 mg/kg; Cd 0.599 mg/kg; Cr 56.0 mg/kg; Pb 26.3 mg/kg; Se 1.77 mg/kg, Ag 0.227 mg/kg)
- **Aqueous Hg Contamination**
  - $HgCl_2$ solution (18.2 mg-Hg/L)
- **Spiked Sediment**
  - 1% Hg solution ($HgCl_2$) added to 3 kg wet sediment (1970 mg-Hg/kg)
- **PO_4 Addition**
  - Hg solution spiked with $NaH_2PO_4{\cdot}H_2O$ to low (2.5 mg-PO_4/L), medium (12.5 mg-PO_4/L), and high (22.5 mg PO_4/L)
- **Light Conditions**
  - Sunlight conditions represented by shaded (94 Lux) and full light (976 Lux)
- **Tissue Sampling and Analysis**
  - Mercury: Cold Vapor Atomic Absorption (EPA 245.6)
  - Methylmercury: Distillation, Aqueous Ethylation, Purge and Trap, Cold Vapor Atomic Fluorescence (EPA 1630) (Bloom, 1989)

Overall Research Objectives

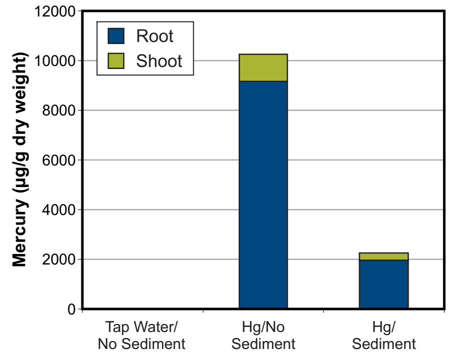
Evaluate the role of *E. crassipes* in transformation and assimilation of Hg and enhancement of production in and concurrent assimilation of MeHg from aquatic environments

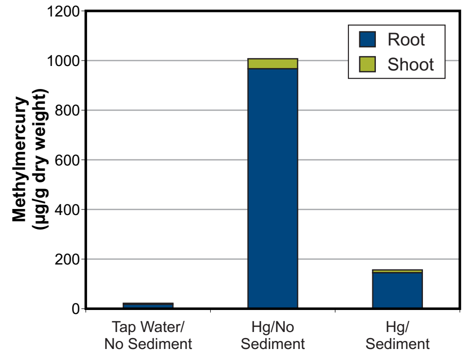
- Are *E. crassipes* able to remediate Hg contaminated sediments to a target level within a reasonable timeframe?
- Does the presence of *E. crassipes* cause enhanced and undesired methylation of Hg in sediments?
- What are the effects of the following on *E. crassipes* - Hg dynamics:
  - Levels of Hg contamination?
  - Presence of sediments?
  - Levels of nutrients (PO_4)?
  - Levels of light?

Results and Conclusions

Effect of the Presence of Sediment

Experimental Conditions: Aqueous Hg contamination with no added PO_4 under full light

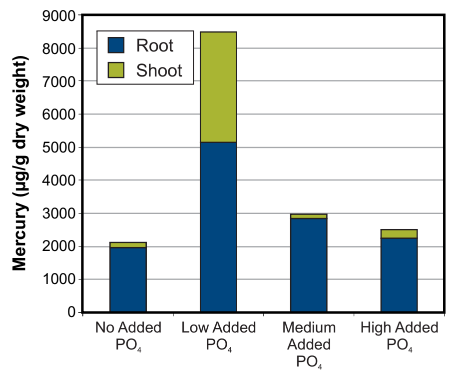


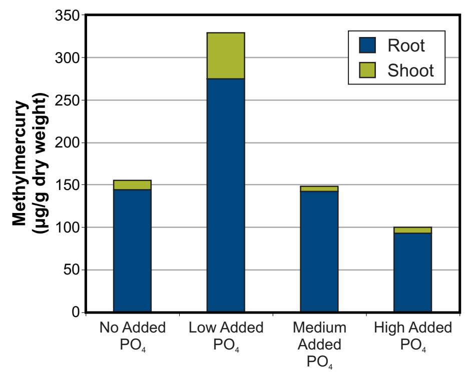


- In the presence of sedimentary material, *E. crassipes* will assimilate less Hg and MeHg compared to no sediments due to sequestration of Hg by sediments
- Uptake of MeHg outpaces uptake of Hg given initial concentration of MeHg in sediment making *E. crassipes* a good sink for MeHg even under relatively mild MeHg contamination
- *E. crassipes* experienced Hg poisoning which was ameliorated by addition of sediment thought to be due to sediment associated microorganisms or availability of sediment associated nutrients

Effect of PO_4 Concentration

Experimental Conditions: Aqueous Hg contamination and spiked sediment under full light

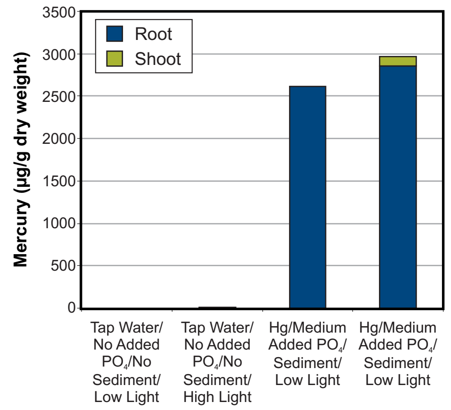


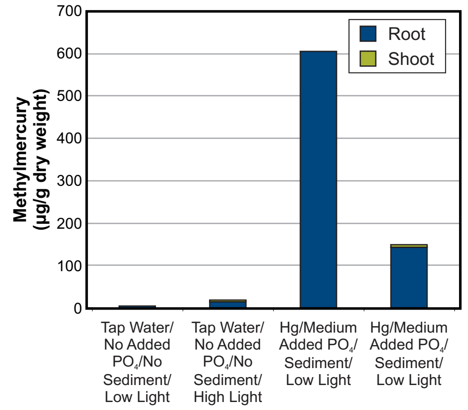


- Increasing nutrient concentration leads to decreased water intake by *E. crassipes* and thus decreased Hg and MeHg translocation to *E. crassipes* shoots and leaves
- An optimum PO_4 level exists for the uptake and translocation of both Hg and MeHg (2.5 mg-PO_4/L)
- Under nutrient rich conditions, overall Hg mass uptake will decline as gains in Hg concentration in *E. crassipes* are outpaced by the overall decline in plant biomass production

Effect of Light Intensity

Experimental Conditions: Aqueous Hg contamination and spiked sediment under no PO_4 and medium PO_4





- Full light leads to a slight increase in Hg uptake by *E. crassipes* even at elevated PO_4 concentrations
- Increase in light intensity increases the translocation of Hg and MeHg from root to shoot
- Increase in light intensity decreases the overall uptake of MeHg

Water Hyacinth Growth During 68 Day Hydroponic Study


High Light Condition


Water Hyacinth Exhibiting Signs of Mercury Poisoning

Net Mercury Removal

- > 97% of Hg was lost from the aqueous phase due to the combination of the four transport processes
- > 30% of Hg was lost from the aqueous phase due to plant uptake and volatilization

References

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