Mercury Uptake, Phytotoxicity and Field Sample Analysis

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- Mercury uptake by vegetations.
- Phytotoxicity studies.
- Mercury detection.
- Field sample analysis.

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Outline:

- Phytotoxicity studies: Relative leaf water content, biomass reduction, Hg induced oxidative stress, internal structural change, etc.
- Plant species: beard grass, three ferns, two cultivars of Indian mustards and water lettuce).
- Different pathways for mercury uptake (root and leaf).
- Spiked and aged soil with different mercury contaminants.
- Phytofiltration / Phytoextraction evaluation.
- Chemical analysis and spectral monitoring of mercury uptake.

Mercury uptake:

- Brake fern accumulated highest loadings in shoots and roots (1469 and 6802 mg/kg) after 18 days of growing in contaminated soils.
- Some mustard and fern species exhibit efficient metabolic defense and adaptation system to mercury-induce oxidative stress.
- Beard grass (*Polypogon monospeliensis*) showed severe stress and limited root to shoot translocation (maximum 65 mg/kg in shoot).
- Water lettuce effectively removed Hg from water in range 0-20 mg/L.
- Leaf Hg uptake was observed.
- Mercury in aged HgS-contaminated soil was still biologically available.

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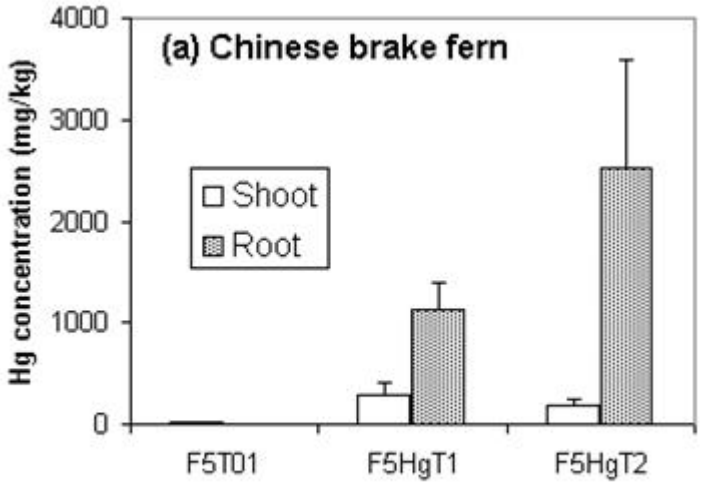
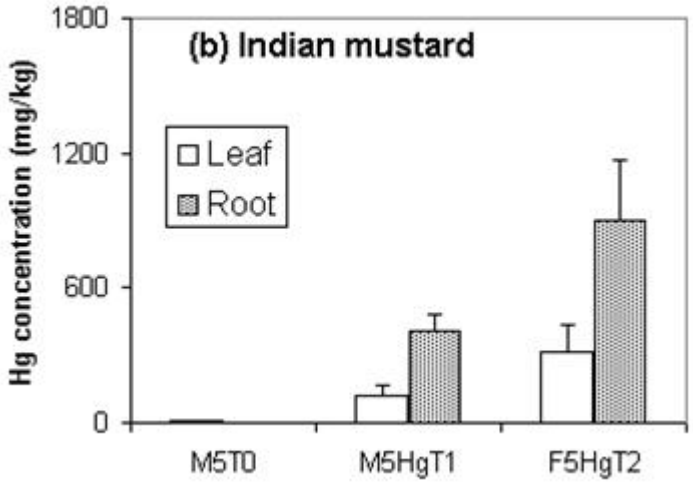
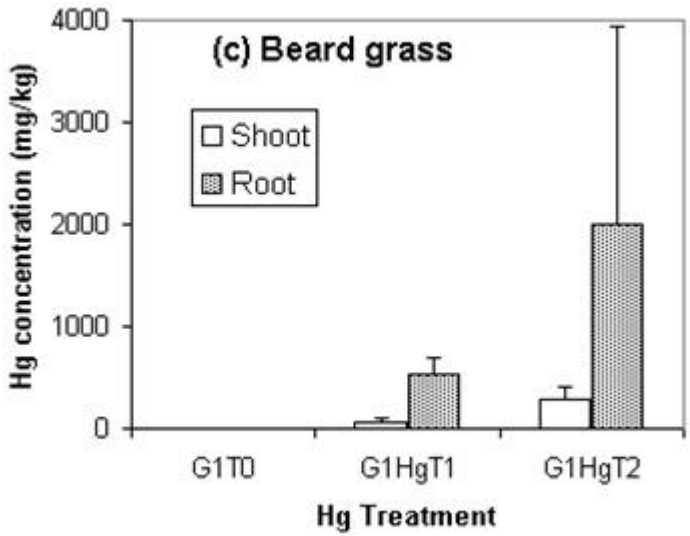
Hg Uptake:







--Yi Su, F. X. Han, J. Chen, B. B.Maruthi Sridhar, and D. L. Monts, 2008, *International Journal of Phytoremediation*, **10**:547-560

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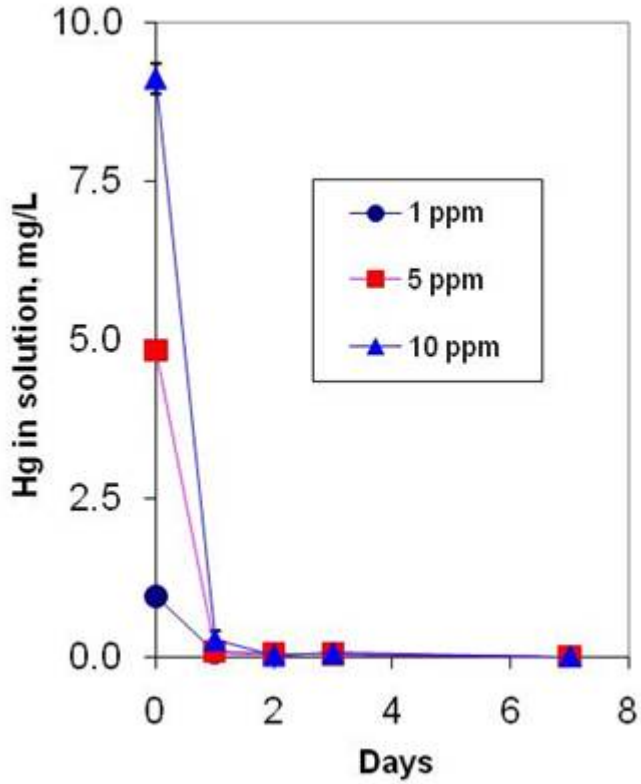
Mercury Phytofiltration by Water Lettuce:

- Water lettuce can effectively removed Hg in range 0-10 mg/L.
- Most Hg was removed after first 24 Hours.
- At the end of 7 days, no Hg residual was found in solution.
- Maximum Hg accumulation in roots was up to 2.5 wt %.



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Mercury Accumulation and Phytotoxicity in Ferns:

- Mercury exposure triggered stronger oxidative stress (accumulation of H_2O_2 and TBARS) and phytotoxicity (leaf burning symptoms, break-down of thylakoid in chloroplast) in *P. vittata* (brake fern) than in *N. exaltata* (Boston Fern).

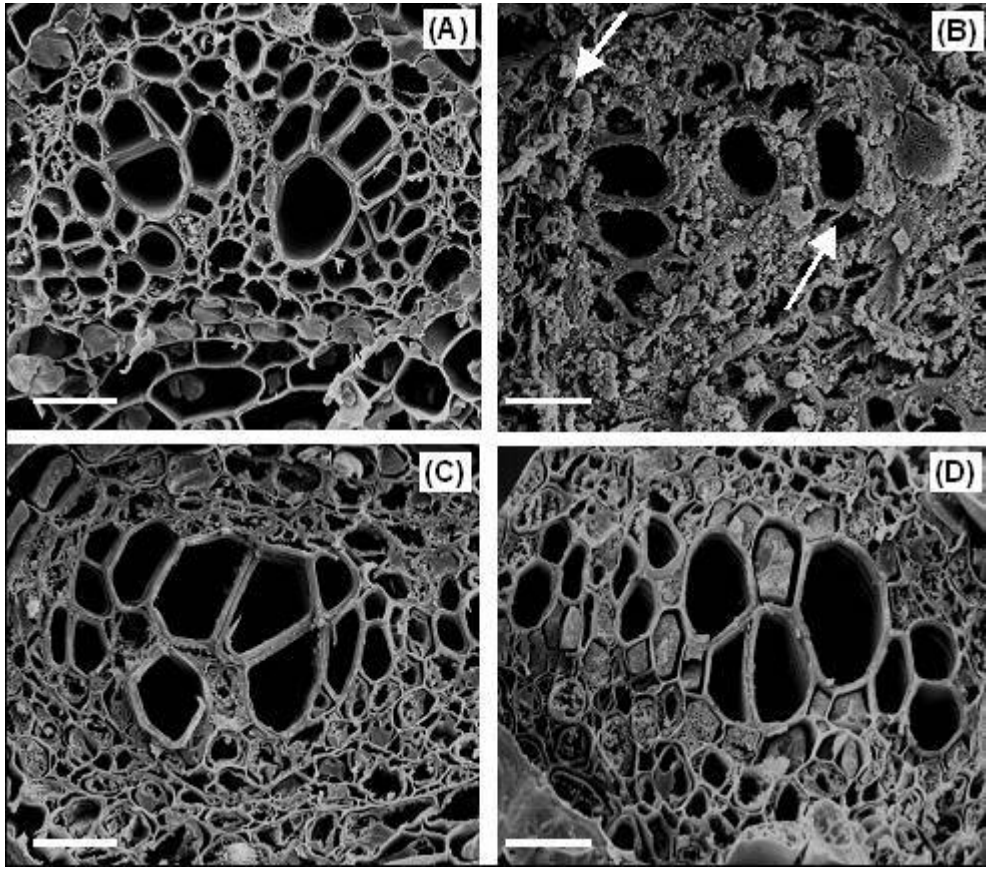
- Although the roots of both ferns accumulated large amounts of mercury (much higher than in other plants reported in the literature). *N. exaltata* showed a more efficient anti-oxidative system than *P. vittata* under mercury stress.

- The reduced ascorbate (ASA) and oxidized ascorbate (DHA) are regulated.

- Mercury exposure led to an increase in the concentration of glutathione (GSH) in both fern species.

P. vittata, control

Hg treated



N. exaltata, control

Hg treated

SEM micrographs of fern leaf cellular structure. Arrows showed the deformation of cell shape the shrinkage of vascular bundle in *P. vittata* induced by mercury. Bar indicates 20 μm.

-- J. Chen, S. Shiyab, F. X. Han, D. L. Monts, C. A. Waggoner, Z. Yang and Yi Su, 2009, "Bioaccumulation and physiological effects of mercury in Pteris vittata and Nephrolepis exaltata", Ecotoxicology, 18 (1): 110-121.

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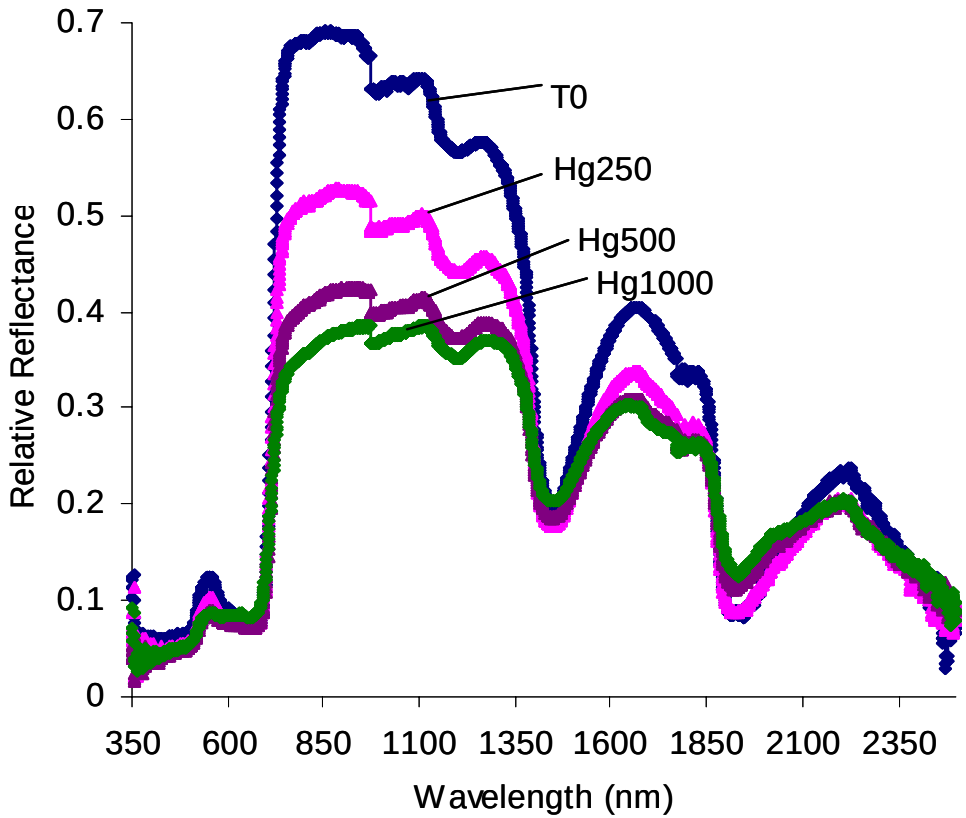
Canopy Reflectance:



Averaged (n = 5) canopy reflectance spectra of control (T0),Hg-treated brake fern groups on the last day (18th day) of metal treatment.

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Mercury Accumulation Induced Changes in Two Mustard Cultivars:

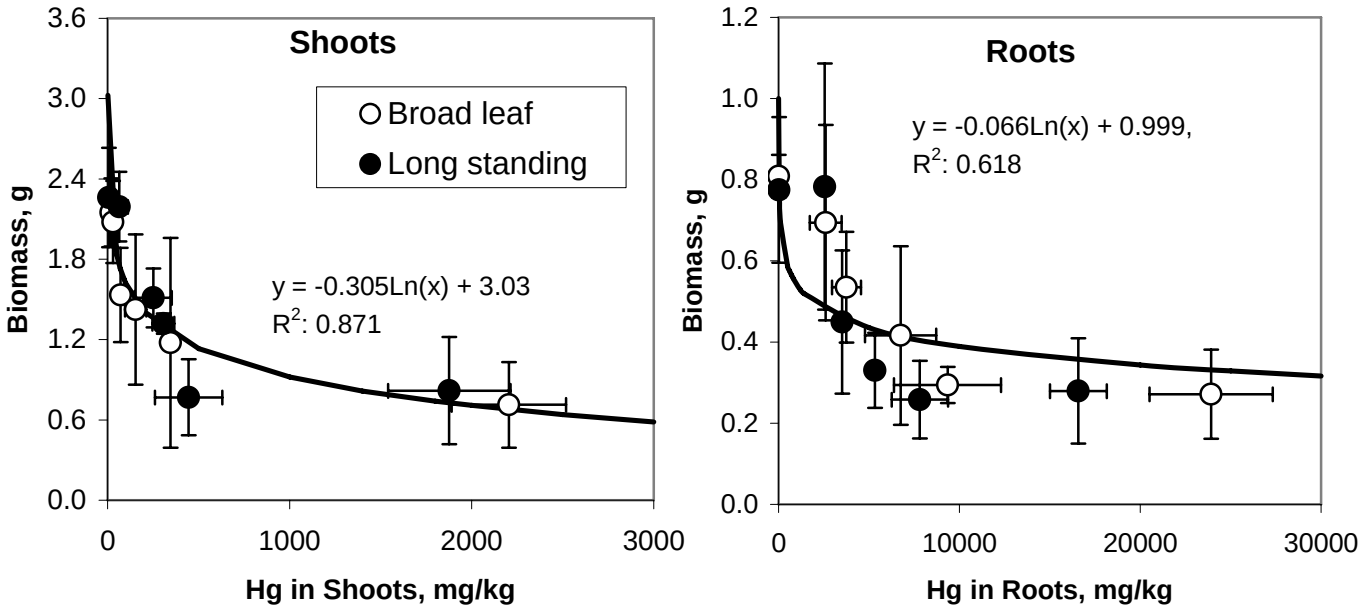
- Mercury exhibited a significant phytotoxicity in these two cultivars of Indian mustard. Mercury uptake induced a significant reduction in both biomass and leaf relative water content.

- Microscopy studies indicated that elevated mercury concentrations in plants significantly changed leaf cellular structure: thickly stained areas surrounding the vascular bundles; decreases in the number of palisade and spongy parenchyma cells; and reduced cell size and clotted depositions.

- The palisade chloroplasts exhibited decreases in their amounts and starch grains as well as a loss of spindle shape.

--- Shiyab, S., J. Chen, F.X. Han, D.L. Monts, F.B. Matta, M. Gu, and Yi Su. 2009. Phytotoxicity of mercury in Indian mustard (*Brassica juncea L.*). *Ecotoxicology and Environmental Safety* 72: 619– 625.

Hg accumulation and vegetation stress:



Effect of mercury accumulation on biomass production

--- Shiyab, S., J. Chen, F.X. Han, D.L. Monts, F.B. Matta, M. Gu, and Yi Su. 2009. Phytotoxicity of mercury in Indian mustard (*Brassica juncea L*.). *Ecotoxicology and Environmental Safety* 72: 619– 625.

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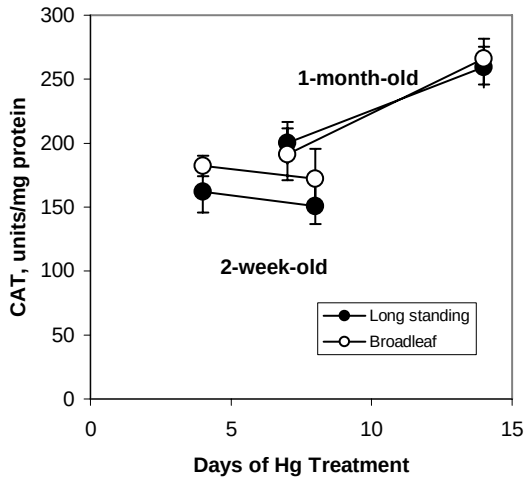
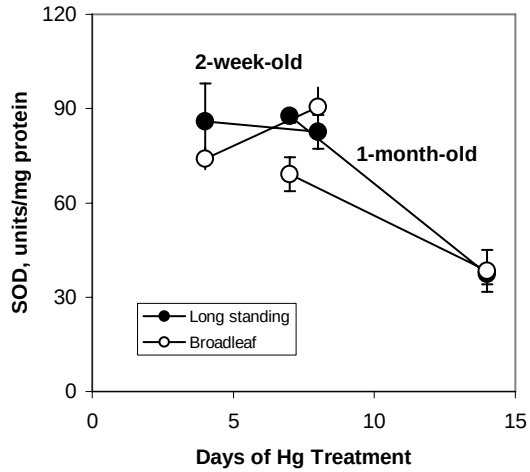
Mercury Induced Phytotoxicity in Two Mustard Cultivars:

- Mercury exposure induced strong antioxidative response in both cultivars.
- Indian mustards effectively generated enzymatic antioxidant defense system (CAT) to scavenge H_2O_2.
- Antioxidant enzymes (catalase,CAT;peroxidase, POD; and superoxide dismutase SOD) were the most sensitive indices of mercury-induced oxidative response.

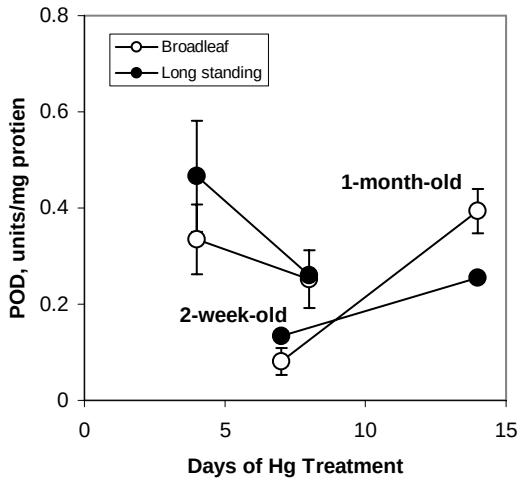
--- Shiyab, S., J. Chen, F.X. Han, D.L. Monts, F.B. Matta, M. Gu, Yi. Su and M.A. Masad. 2009. Mercury-induced oxidative stress in Indian mustard (Brassica juncea L.). Environmental Toxicology,24 (5): 462-471

Phytotoxicity of Mercury:





Changes in concentrations of CAT, SOD and POD in shoots of Indian mustard grown in the solution containing 5 mg/L Hg as a function of mercury exposure duration .



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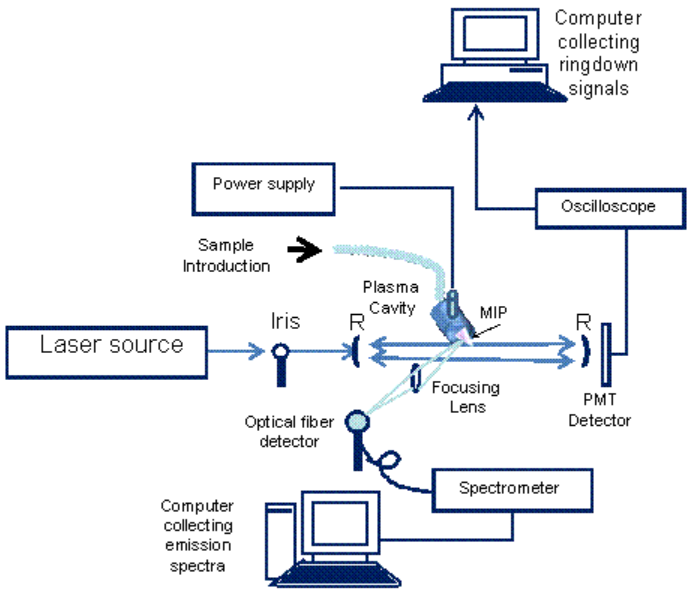
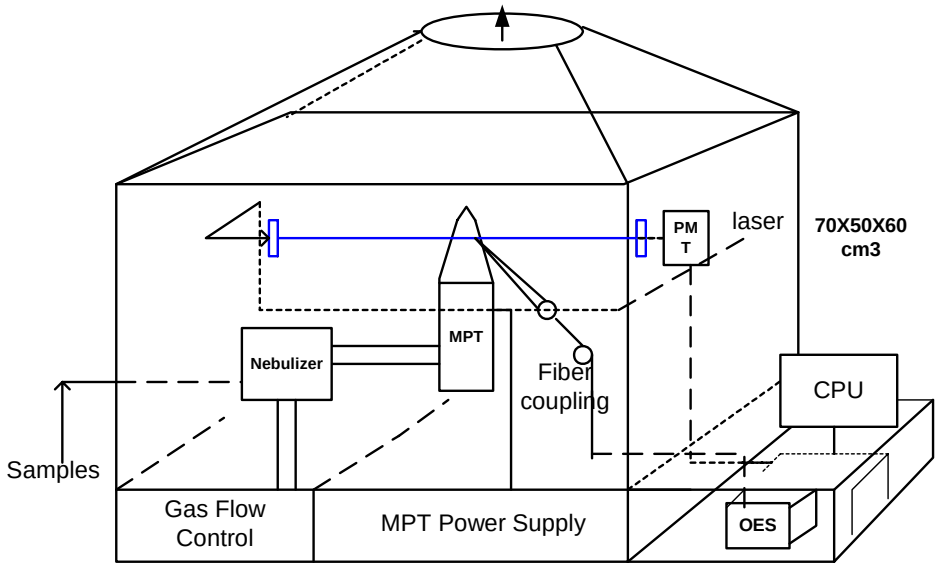
Mercury Detection and Field Sample Analysis:

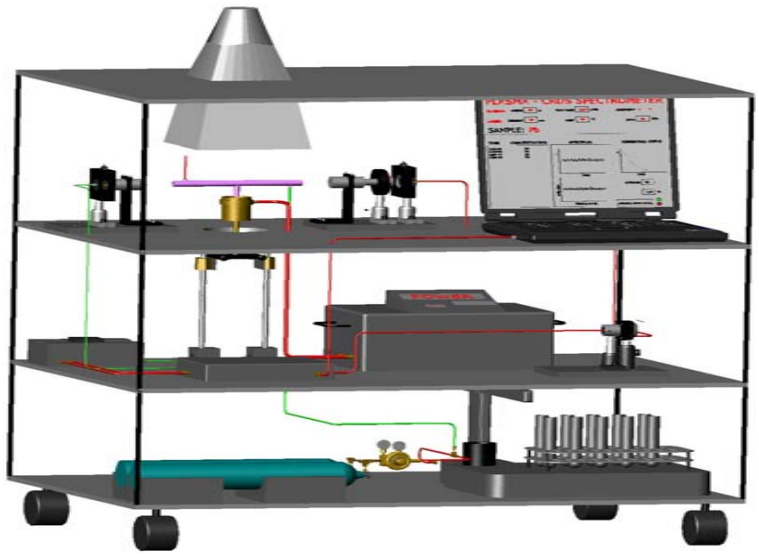
- Standard method: CVAAS (cold vapor atomic absorption spectrometry). Need sample preparation ->solution.
- Another laboratory method: ICP-AES (inductively coupled plasma-atomic emission spectrometry). Need sample preparation ->solution.
- Portable mercury analyzer - RA915 from Ohio Lumex.
  No sample preparation needed, works well for air, water samples. Works with small size vegetation samples. Somewhat challenge for soil samples.
- Other methods: SIBS? Other AA based approach? Gold nanoparticle?
- Need a reliable/portable Hg analyzer for every kind of field samples.

Mercury Detection with CRDS and/or micro-plasma systems: In development.





P-CRD-Hg-Be-2010 Spectrometer



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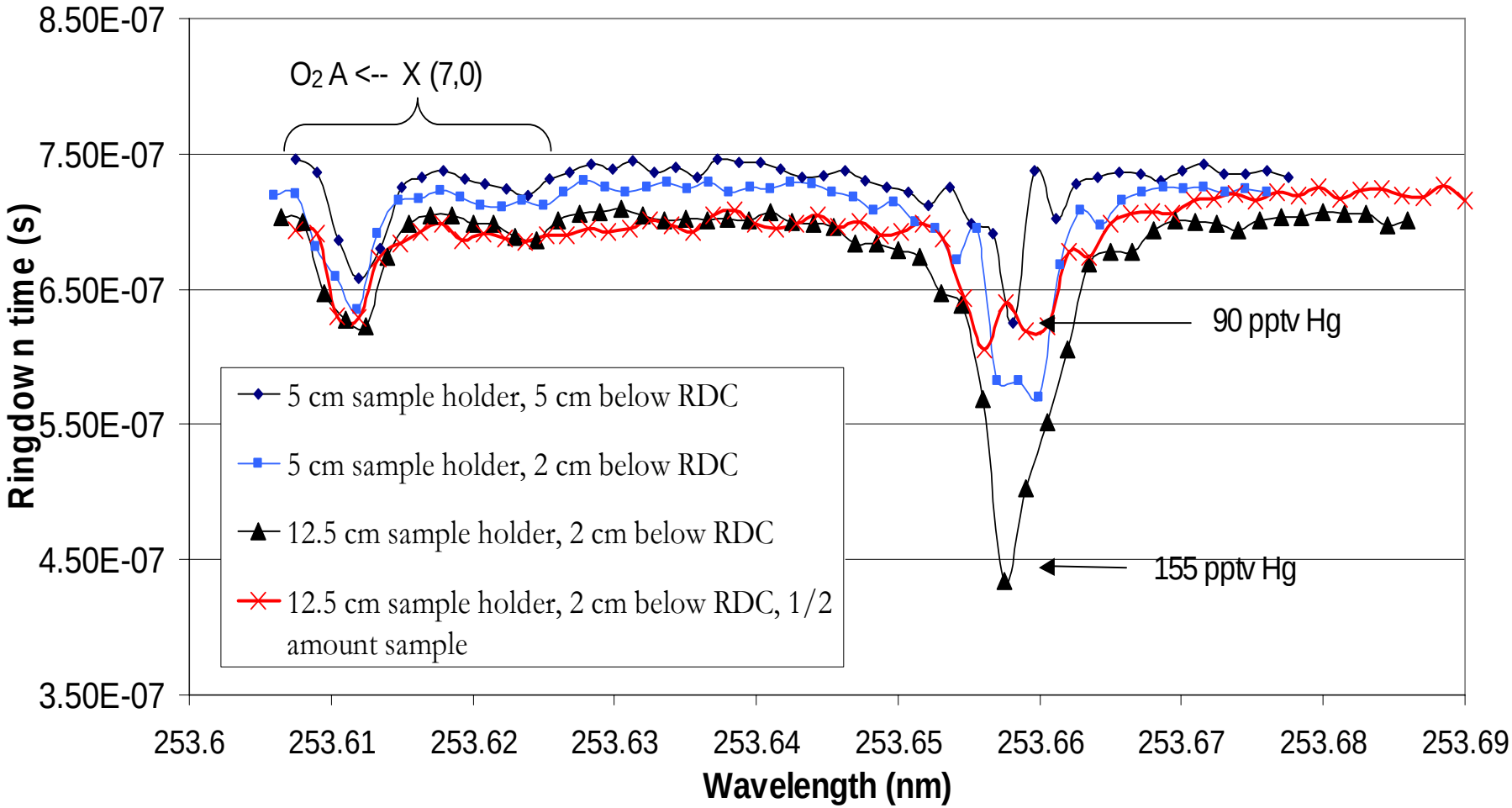
Hg vapor detection above contaminated soil by Cavity Ringdown Spectrometry (CRDS):



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Summary:

- Studied mercury uptake, accumulation; resulted vegetation stress and phytotoxicity.
- Vegetation uptake of mercury contaminants from aged soil with HgS was observed.
- Certain vegetation species could be used for phytofiltration of mercury contaminated water, and phytoremediation of contaminated soil.
- Vegetation uptake and phytotoxicity can be used as indicators for mercury bioavailability and be part of overall ecosystem assessment.

Acknowledgement:

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