

Riverbank Sediment Characterization & Preliminary Treatment Results

Carol Ptacek and David Blowes
University of Waterloo

Students:

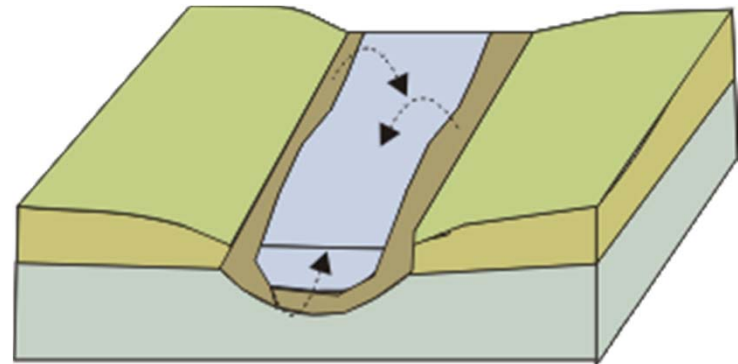
Krista Desrochers, M.Sc. Candidate

Peng Liu, Ph.D. Candidate

Blair Gibson, Ph.D. Candidate

Ou Wang, B.Sc. Candidate

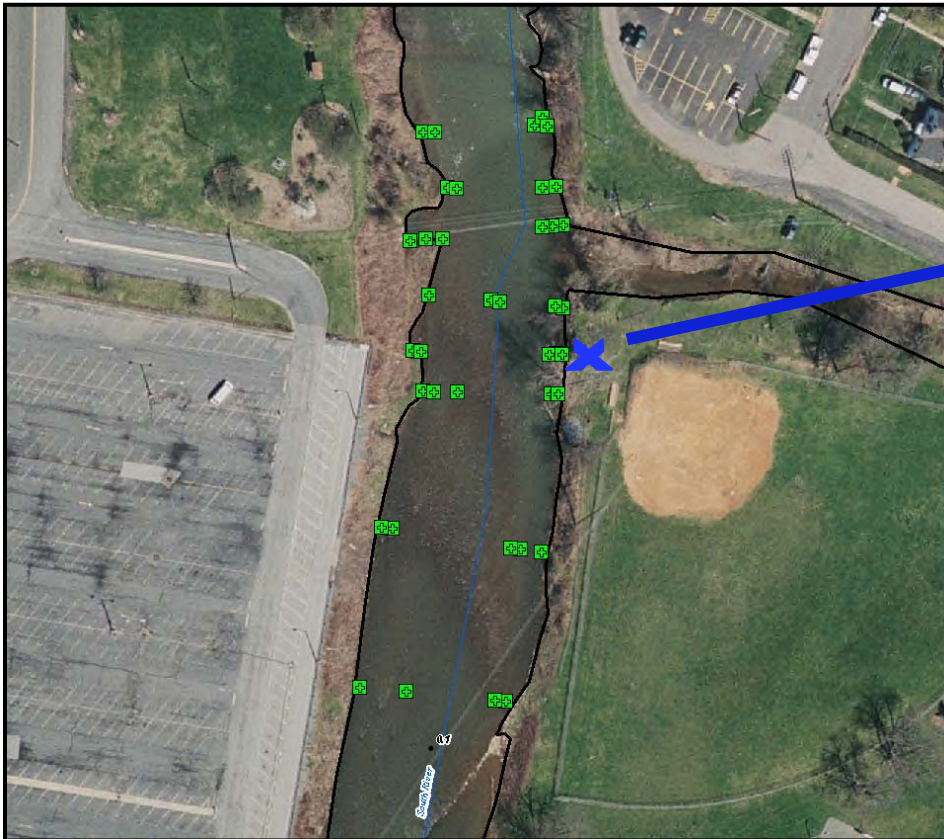
- Characterize solid-phase composition and forms of Hg in the bank sediments
- Assess variability in the release of Hg from bank leaching vs. bank erosion
- Identify potential geochemical approaches to decrease the release of Hg from the sediments





South River RRM 0.1

Bank Stabilization Pilot Site



Sediment Characterization

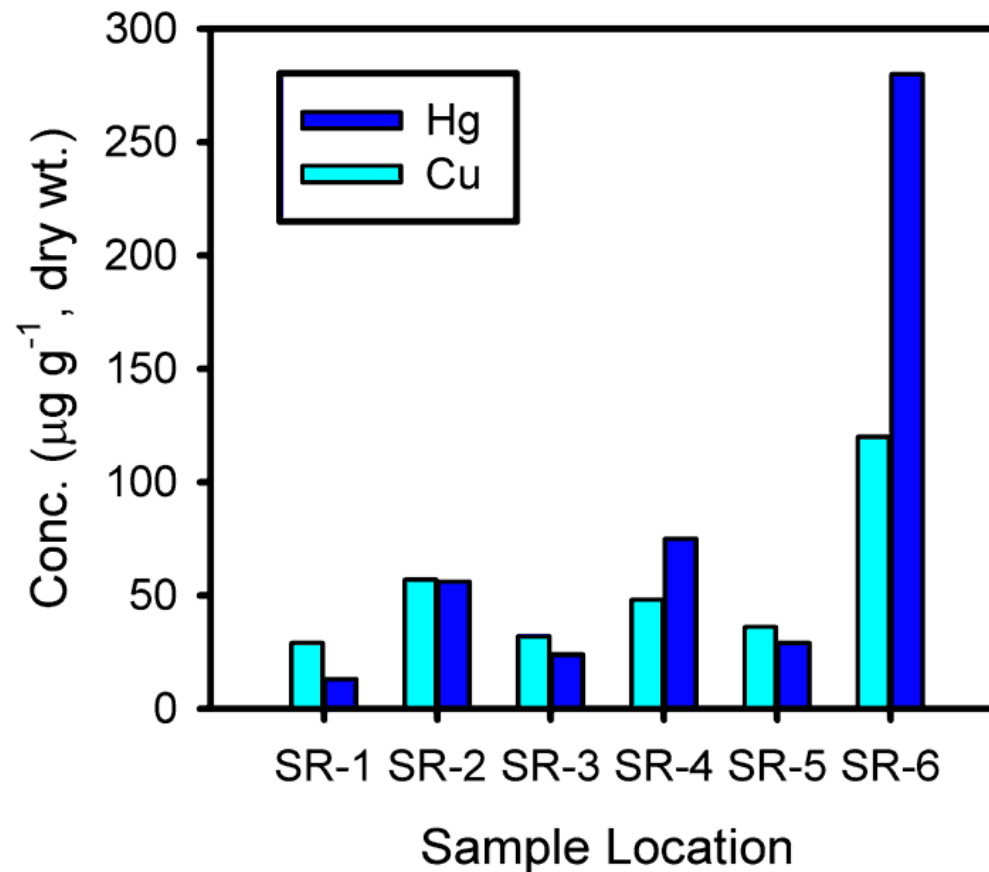
- Bulk chemistry
- Chemical extractions
- Mineralogy
 - XRF & XANES
 - XRD & clay speciation

Resuspension Experiments

- Sediment ratio variations
- Colloid characterization

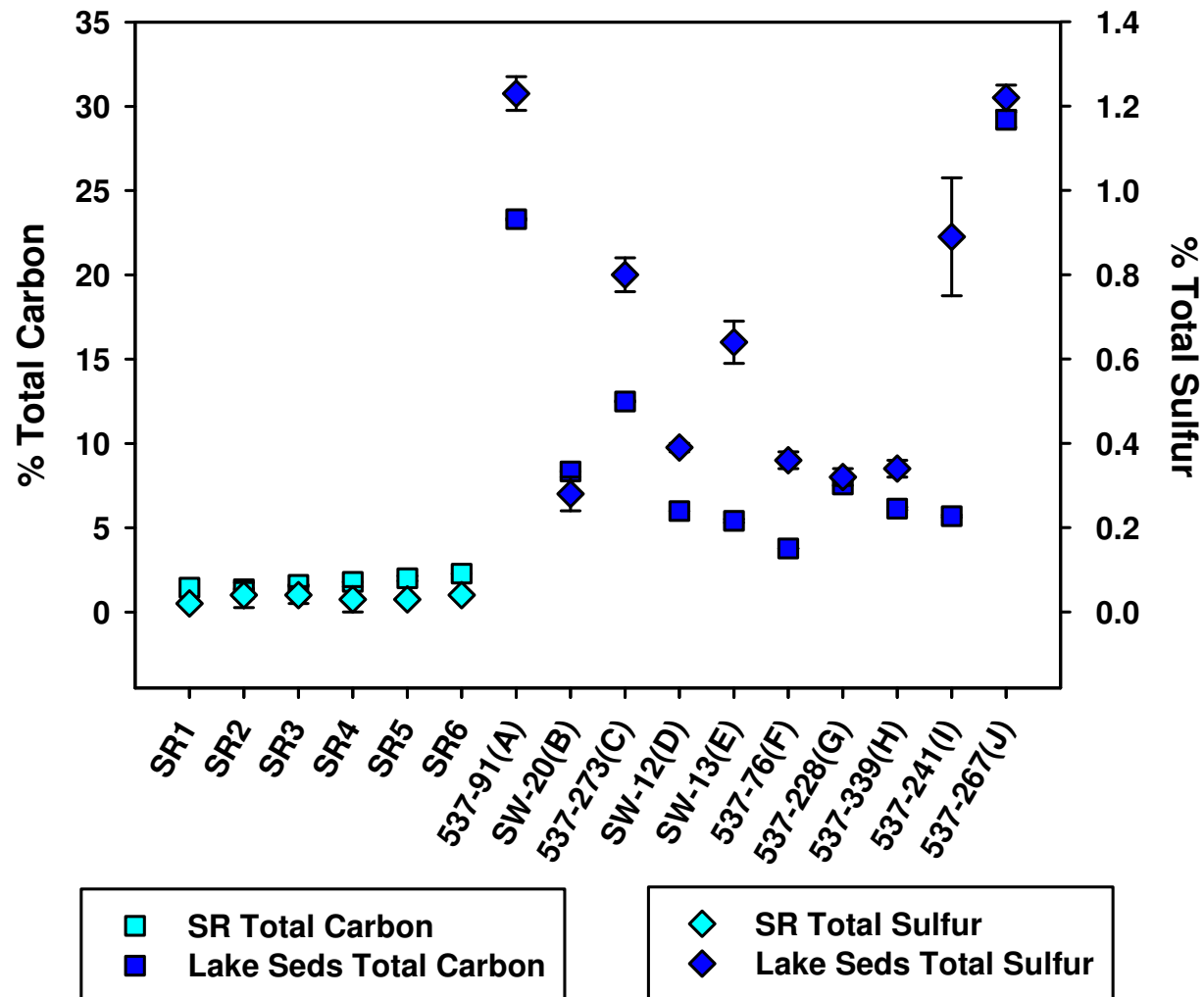
Bank Filtration Experiments

- Flow rate fluctuations & stagnation
- Colloid characterization



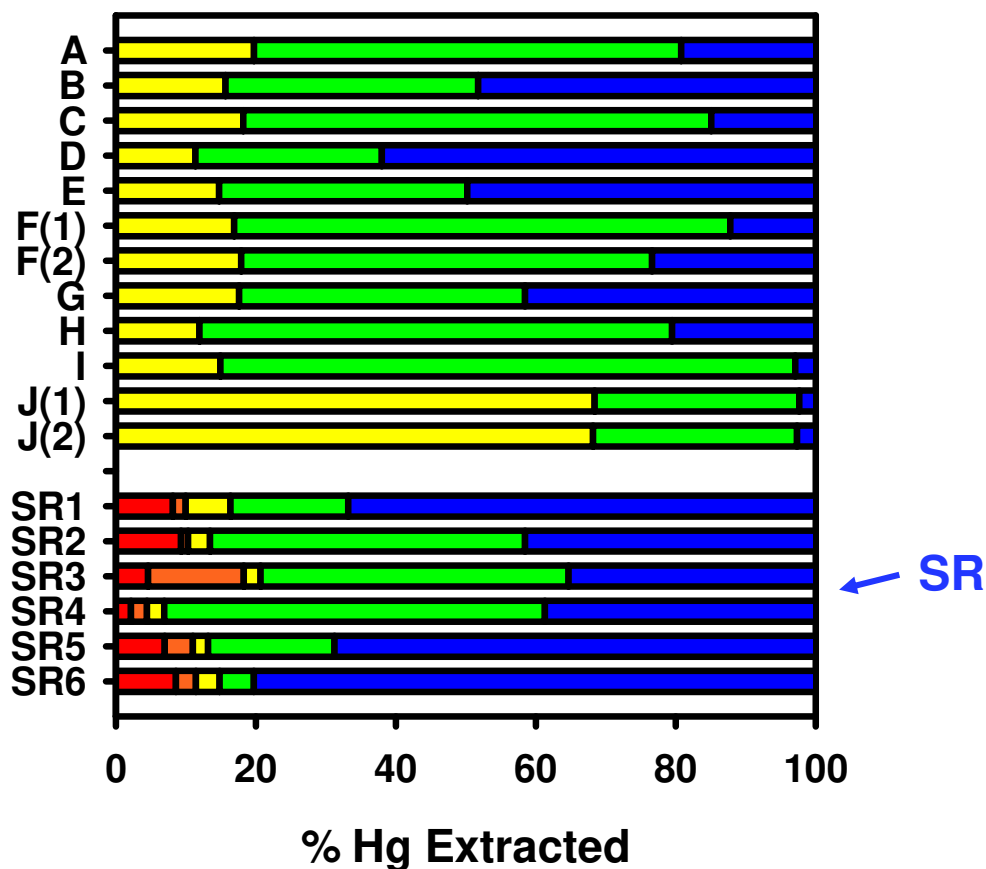
- Large variation in total Hg in sediment
- Hg correlated to Cu

- Low C & S (SR) compared to other sites (LS) with elevated Hg



- Hg speciation highly variable in South River bank sediment

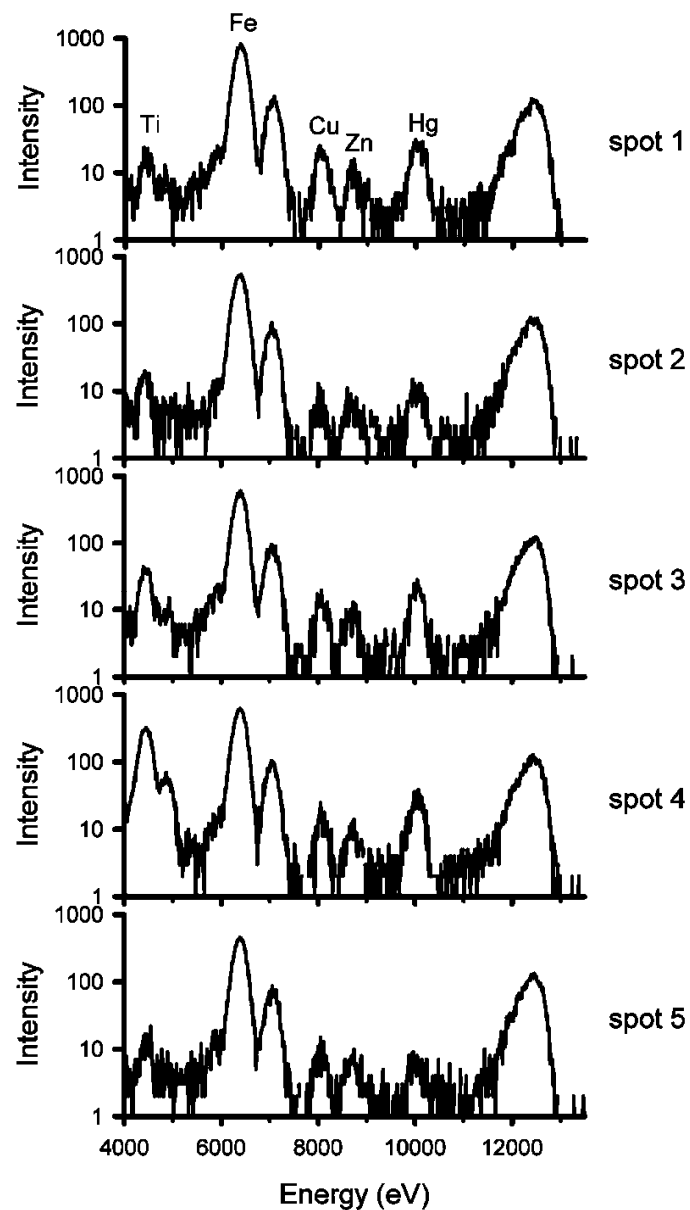
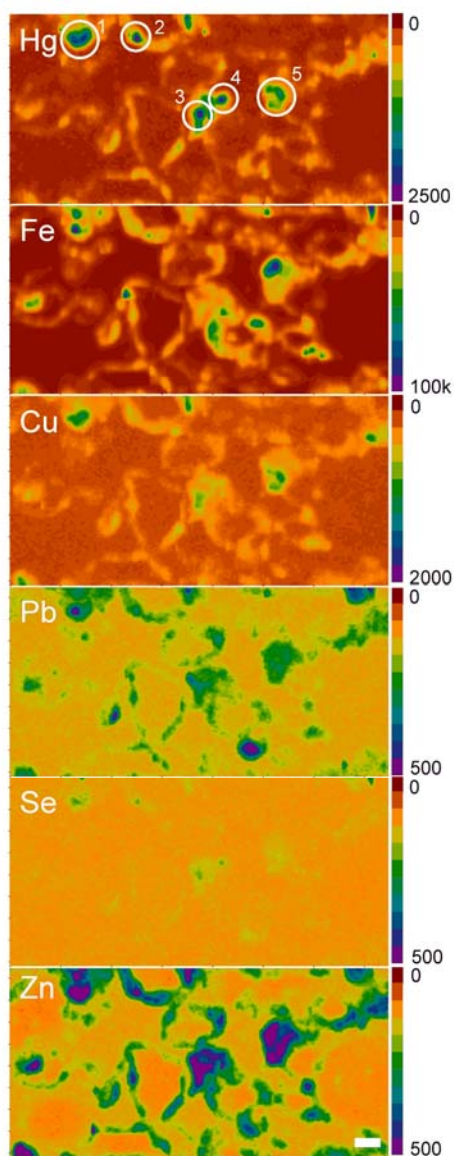
	Extraction Solution	Target Hg Species
F1	Deionized Water	Water Soluble (HgCl ₂ , HgSO ₄)
F2	0.01M HCl + 0.1M CH ₃ COOH	Human Stomach Acid Soluble (HgSO ₄ , HgO, Hg _{ads})
F3	1M KOH	Organo-chelated (Hg _{chel} , Hg ₂ Cl ₂)
F4	12M HNO ₃	Elemental Hg (Hg ⁰ , thiol-Hg, Hg _{amal})
F5	Aqua Regia	Mercuric Sulfide (HgS, HgSe, HgAu)



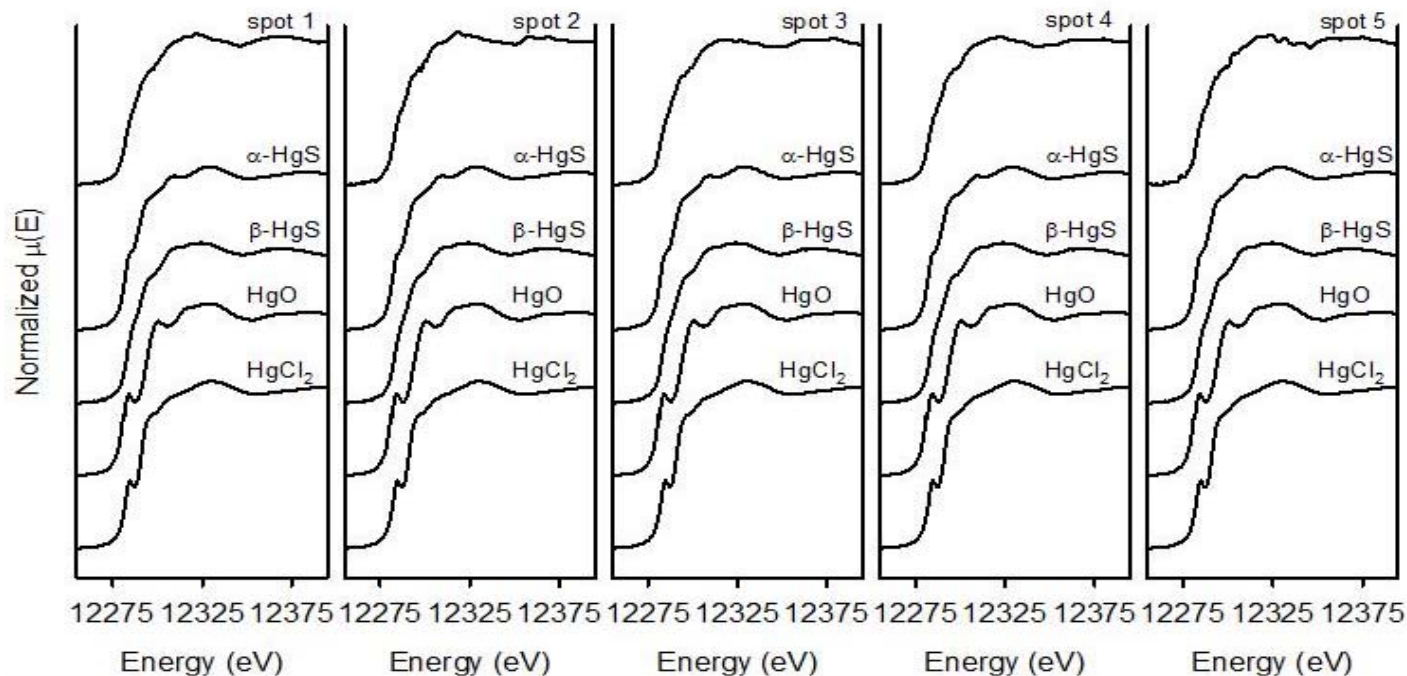
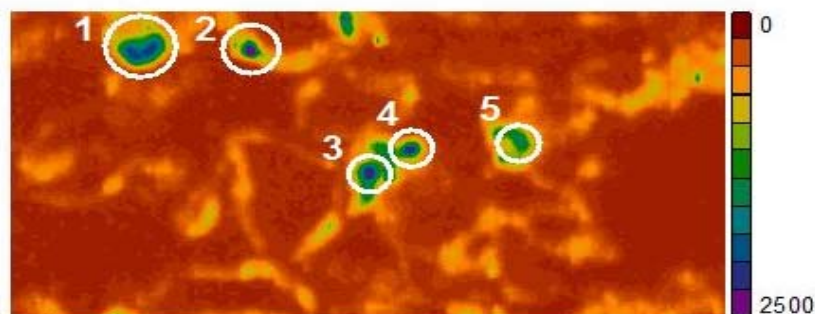
- ~2-9% of Hg mass extracted by DI water
- Greatest mass in “sulfide fraction”

SR6 Synchrotron Characterization

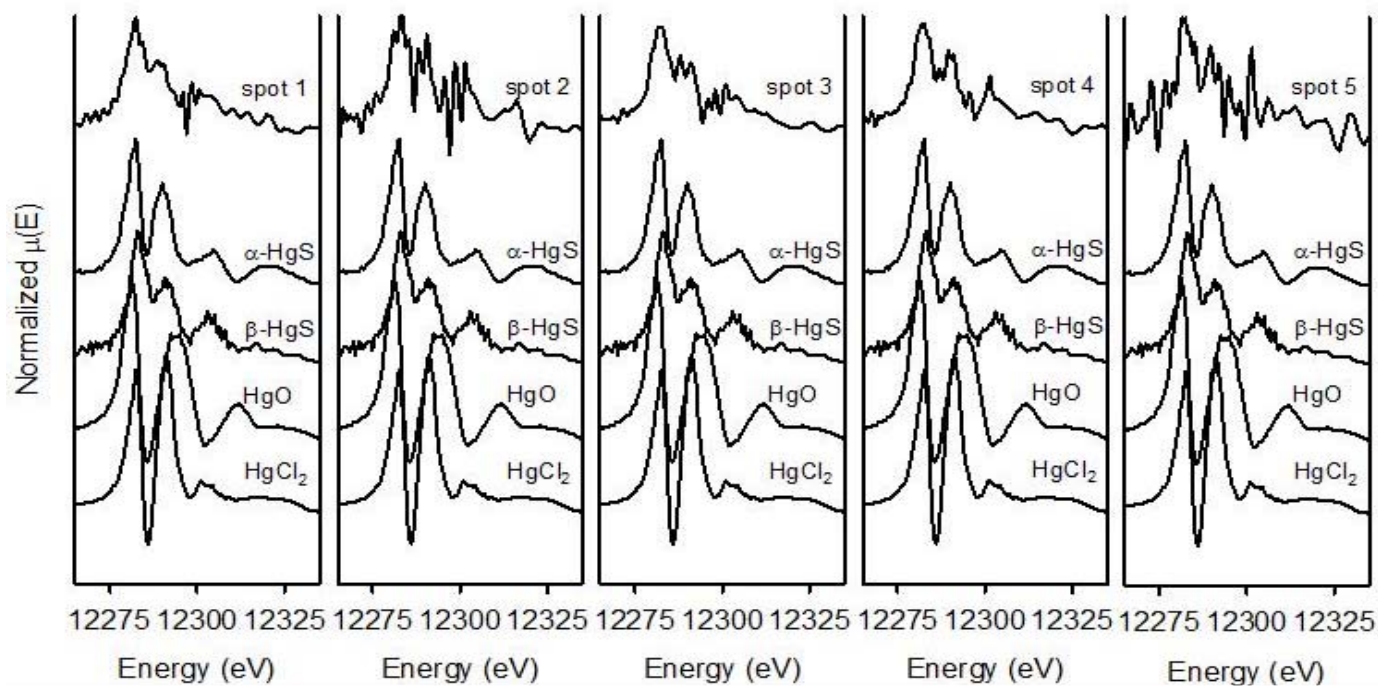
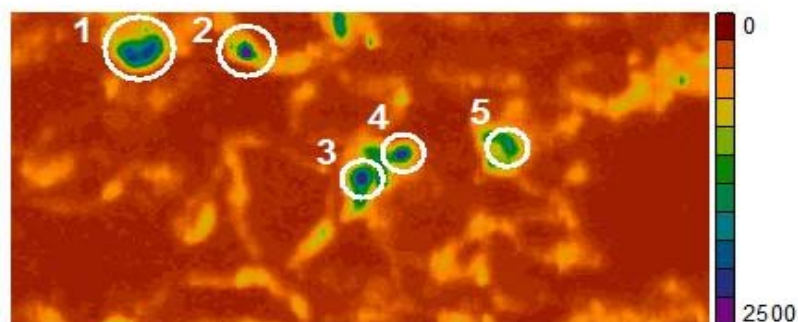
Micro X-ray Fluorescence (XRF) Mapping and X-ray
Absorption Near Edge Structure (XANES) Analysis of
South River Sediment



- All Hg XANES spectra from sediment are similar
 - Implies same form of Hg at each location

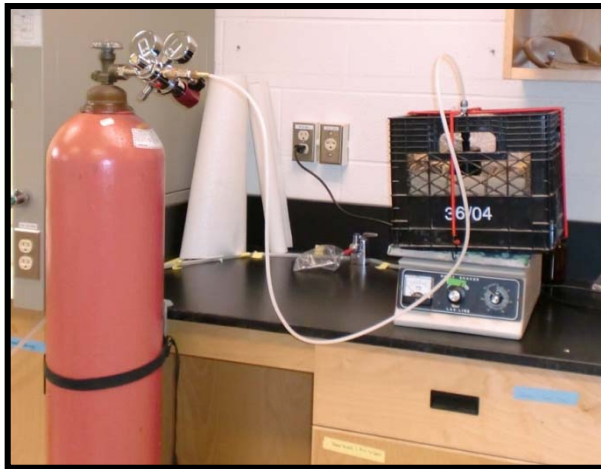


- Spectra are very similar to spectrum for metacinnabar, implying HgS formation

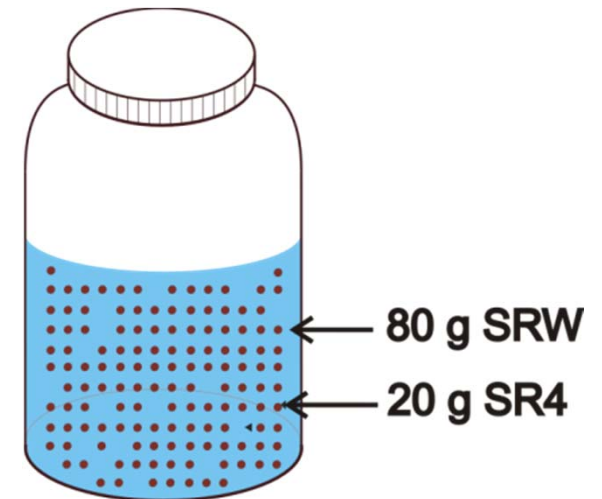


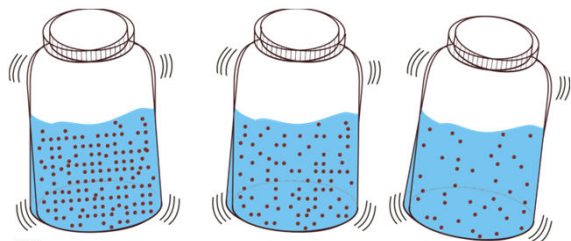
Purpose:

- What is the variability in Hg release due to riverbank erosion?
- What portions are “dissolved” and “colloidal” ?

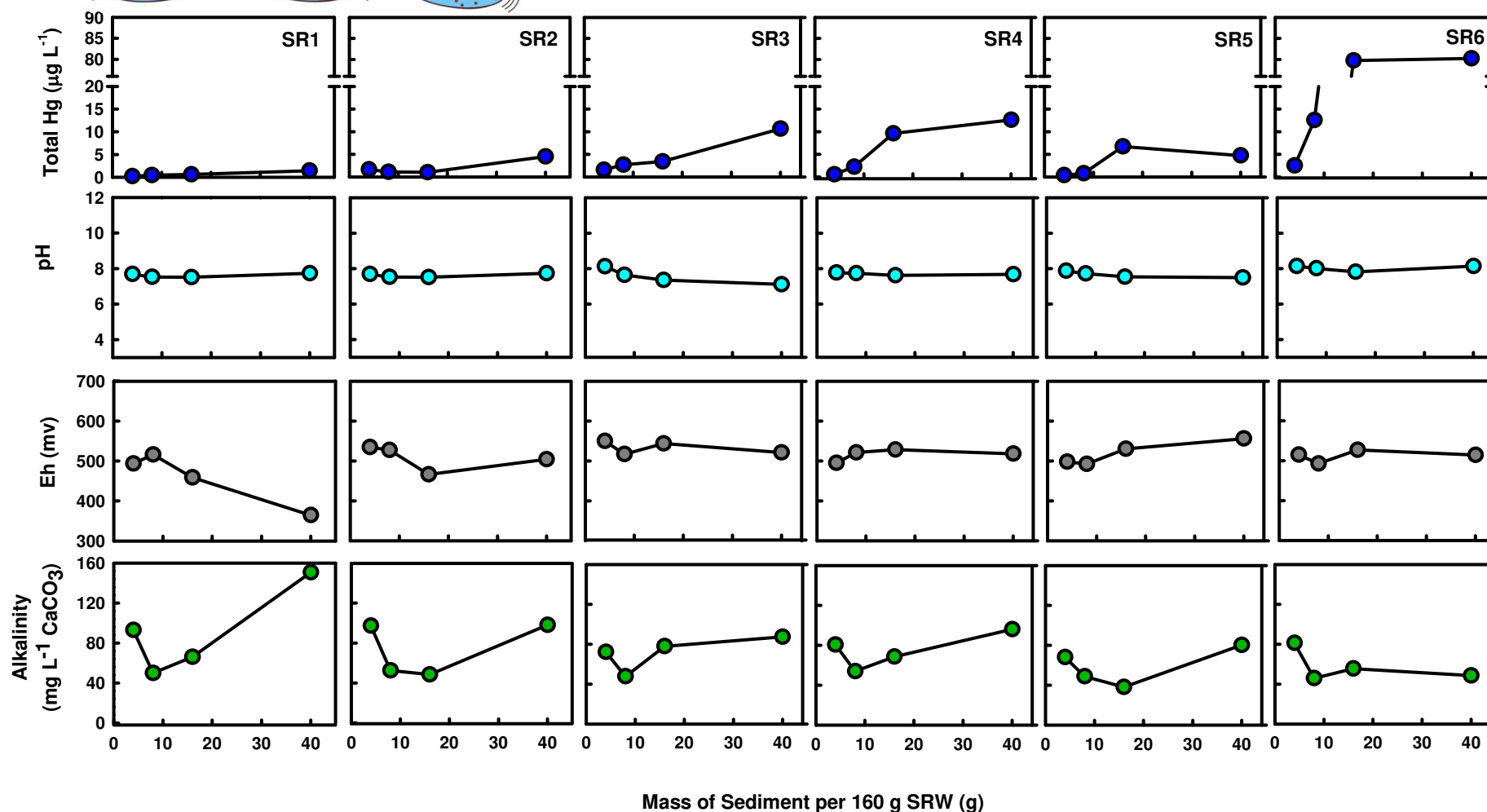


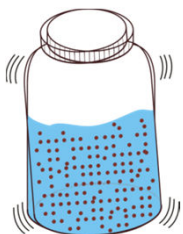
5000 MWCO Filter
Fraction



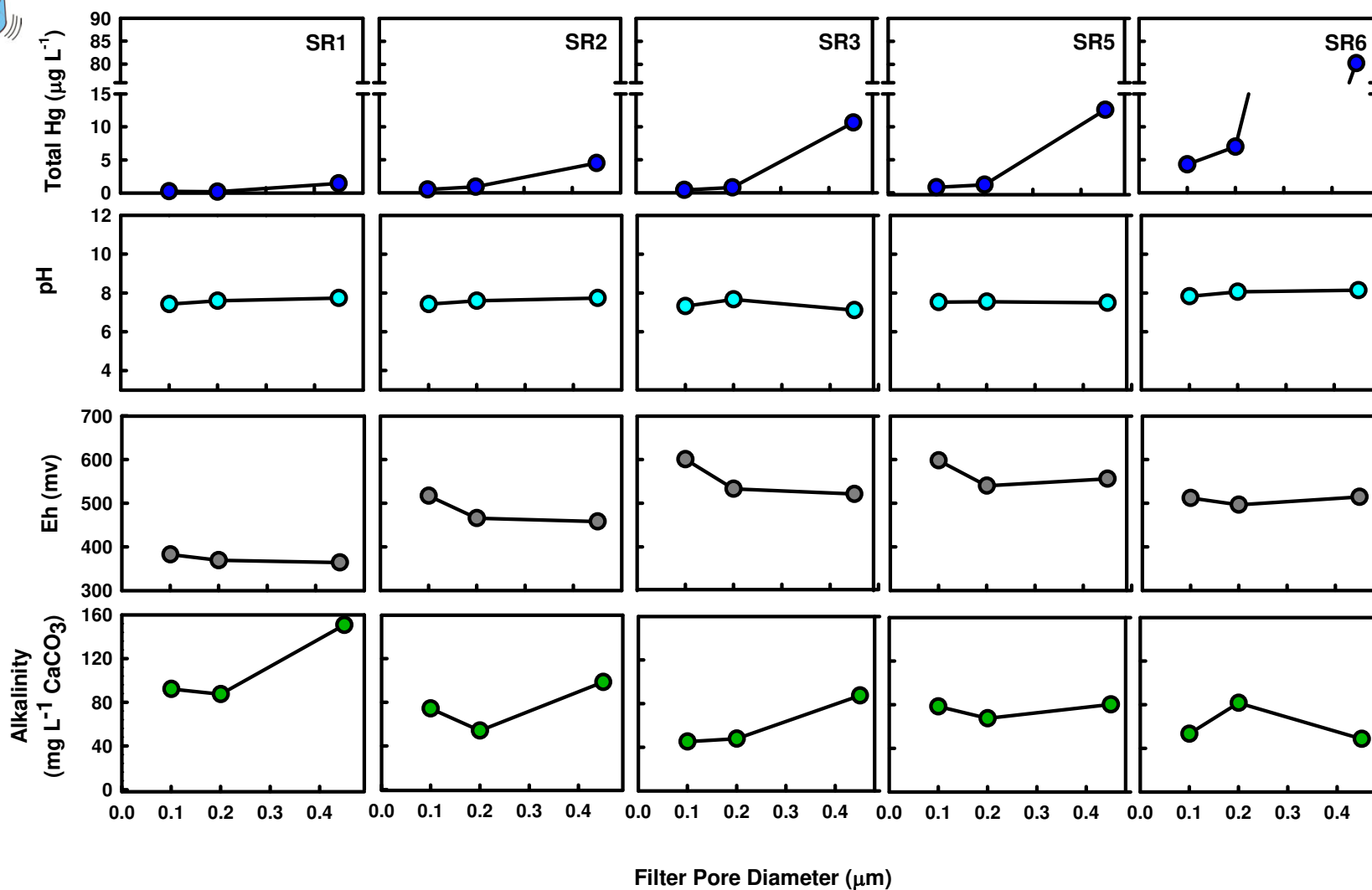


- Large variability in Hg release
- Possible Hg solubility control



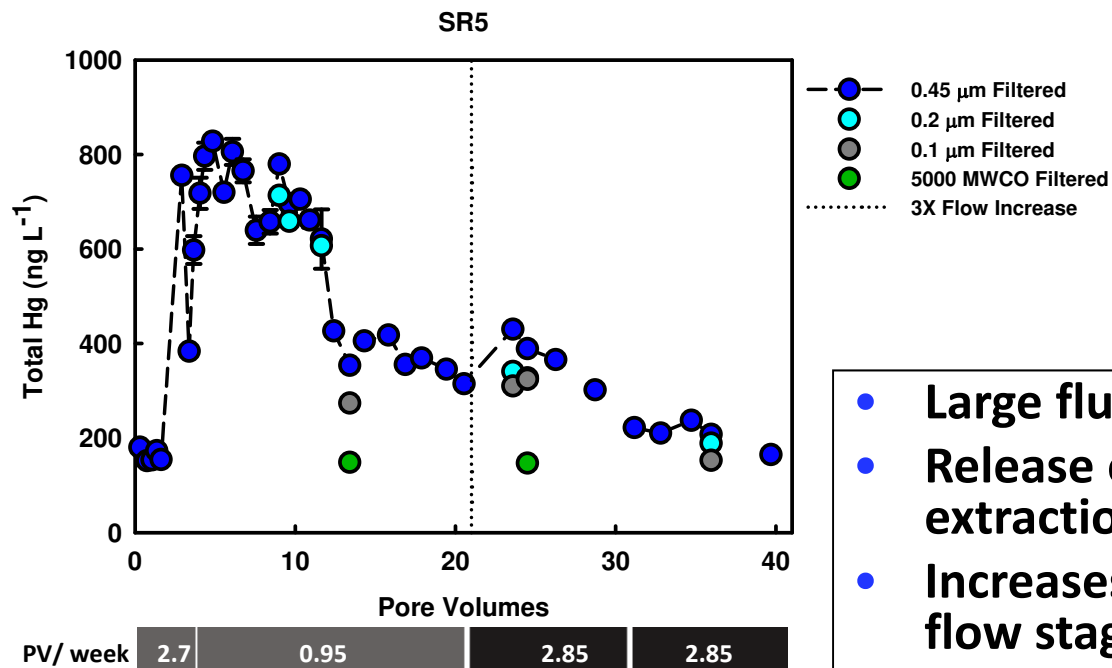


- Large variability in filter-size fractions
- Greatest variation for SR3, SR5 & SR6 samples



- Slow flow of river water through bank sediments to simulate advective-diffusive transport
- Fluctuate velocity to evaluate:
 - mass transfer limitations
 - colloid-facilitated transport

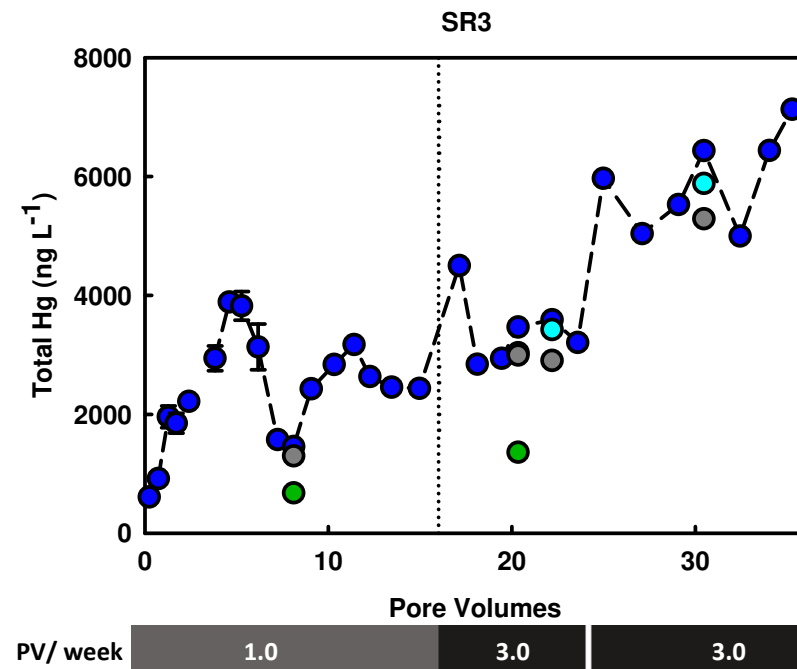
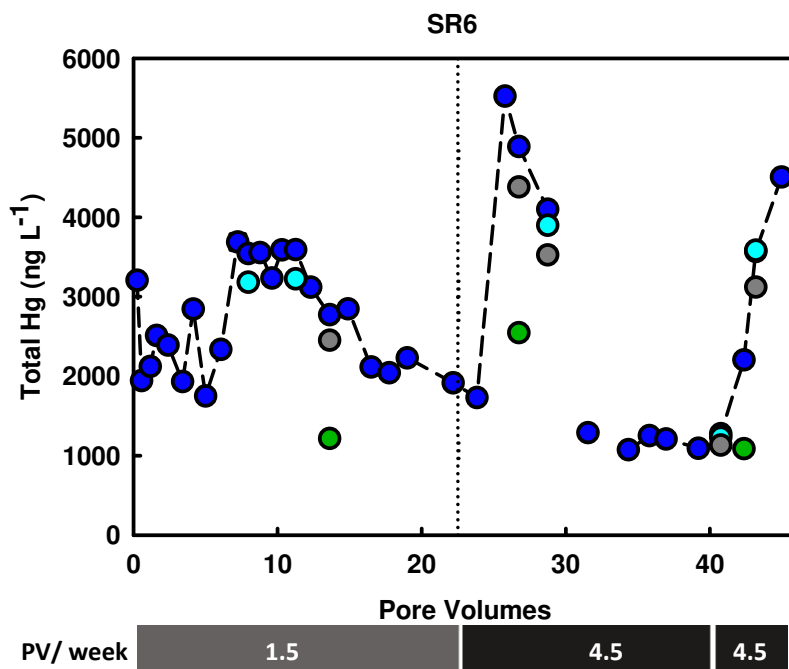


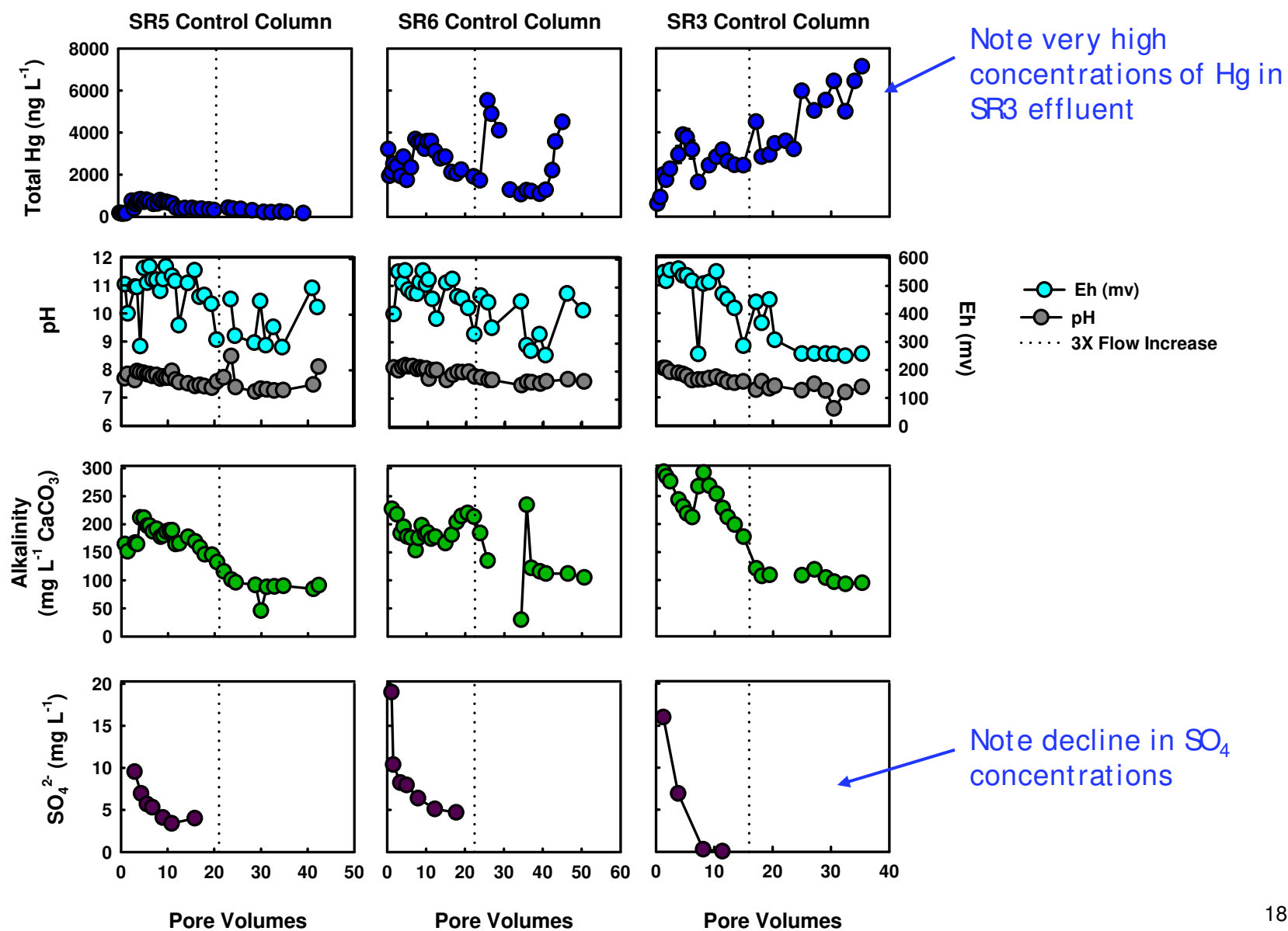


Control Columns

	SR5	SR3	SR6
Total Sed Hg ($\mu\text{g g}^{-1}$)	45.25	25.00	386.10
H ₂ O Soluble Hg ($\mu\text{g g}^{-1}$)	3.16	1.15	33.10

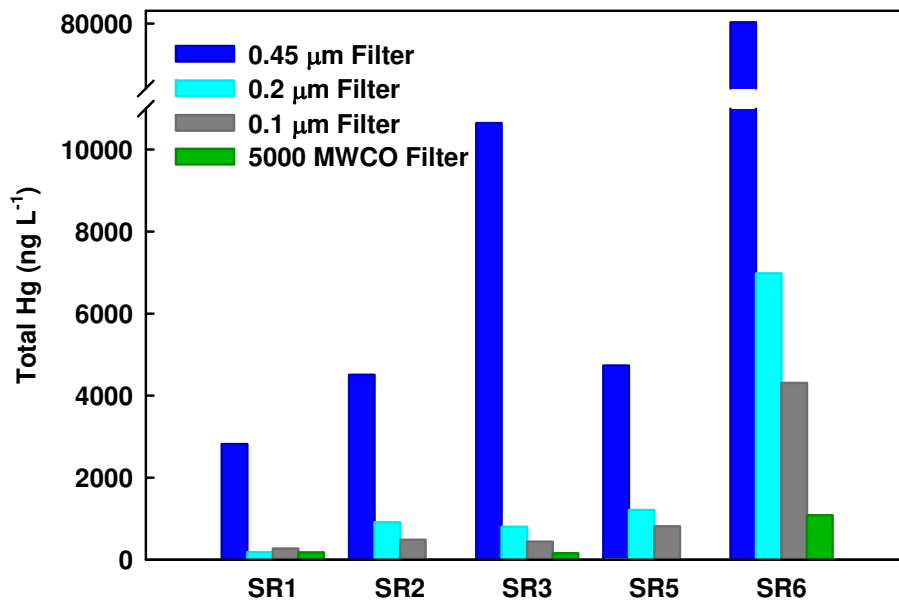
- Large fluctuations in Hg concentrations
- Release of Hg not correlated to extraction and resuspension results
- Increases in effluent Hg observed after flow stagnations



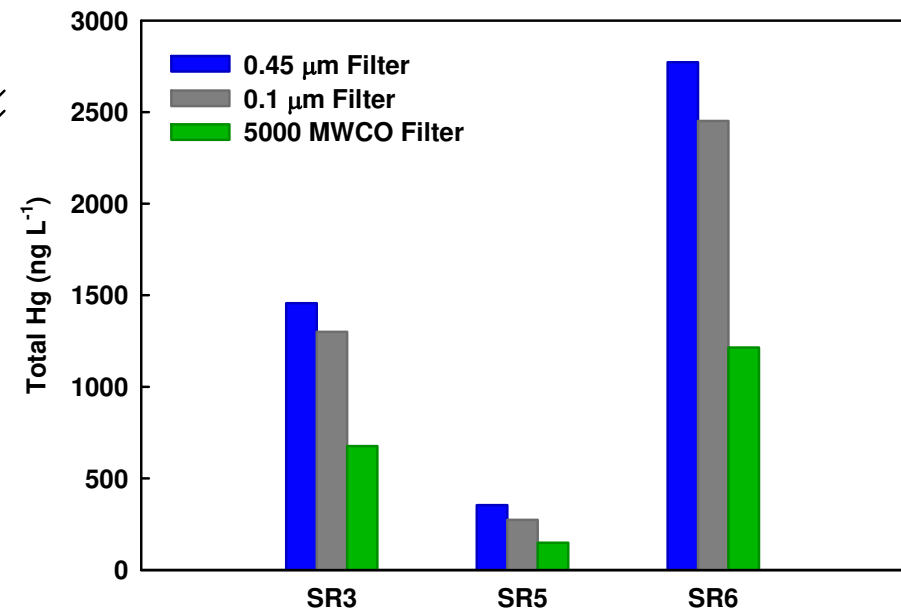


- Resuspension experiments - substantial differences in aqueous Hg for different filter sizes
- Transport experiments - less pronounced variations in Hg for different filter sizes

Resuspension Tests



Saturated Control Columns



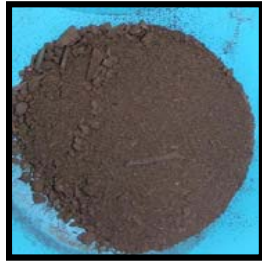
Static Screening Experiments

- Hg-spiked South River water
- Stabilization additions

Dynamic Treatment Experiments

- Treatment of column effluent water
- Leaching from co-blended reactive media/sediment mixtures

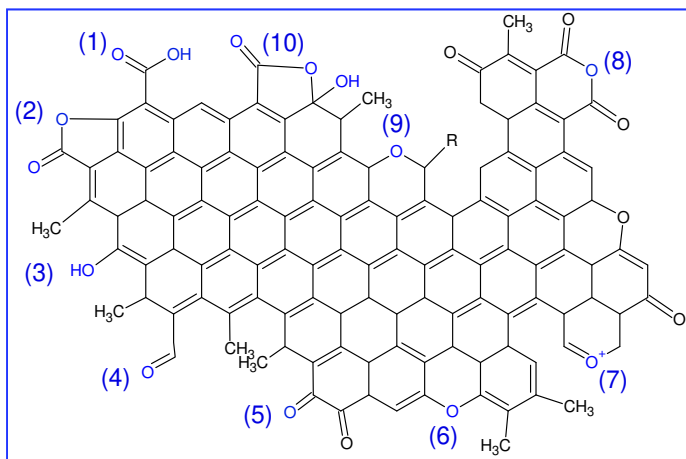
- Treatment of Hg-spiked South River water
 - Blended biochar and Hg-spiked water



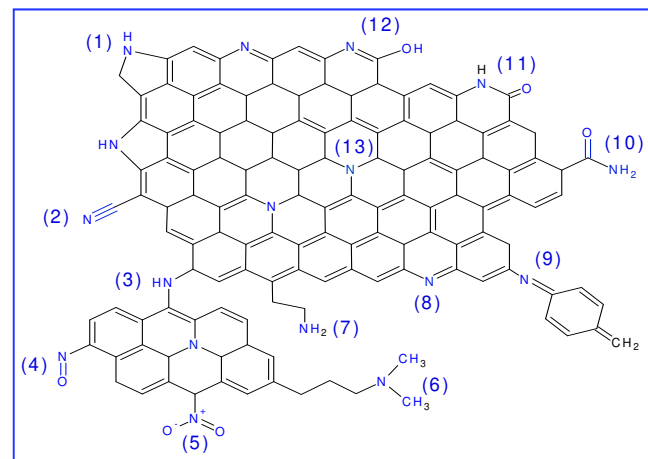
Mushroom Soil (B-MS) Pine Woodchips (B-PW) Poultry (B-PO)

- Preliminary Treatment of Bank Sediment (SR4 Sample)
 - Clays, chars and activated carbon, strong reductants, complexing agents

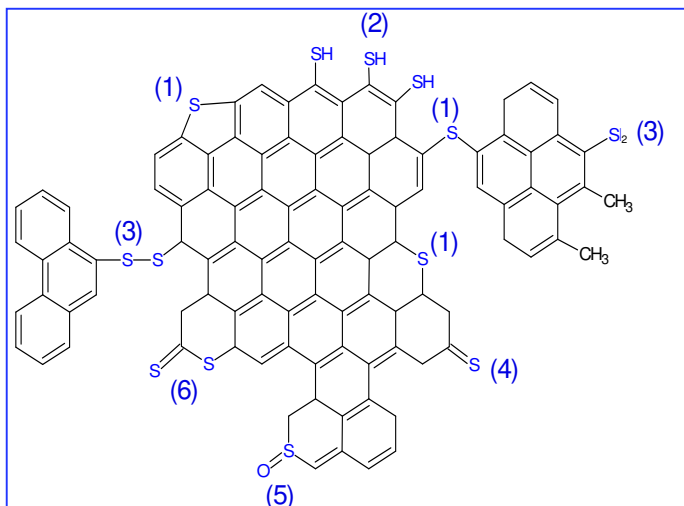
- Desirable physical properties
 - Large particle size distribution, macroporosity, nano-porosity
- Desirable chemical properties
 - High charge density, hydrophilic, hydrophobic, acidic, basic
- Concerns
 - High nutrient and trace element content
 - Microbial habitat & substrate
- Potential applications
 - Soil amendment, ex-situ reactors, in-stream reactors, in-situ reactive zones ...



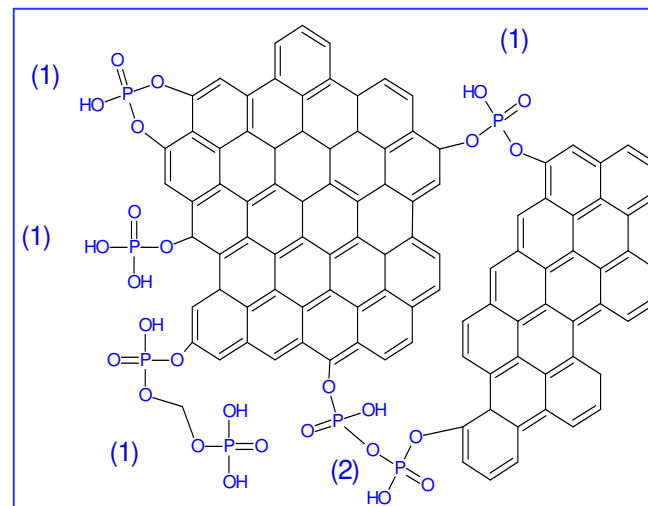
Oxygen-containing



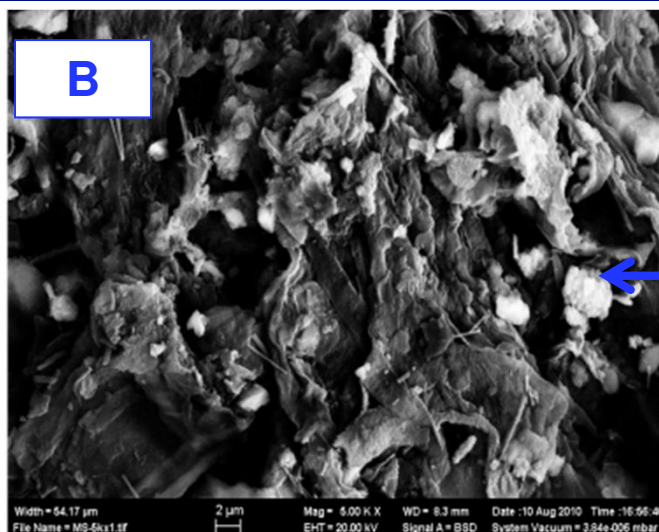
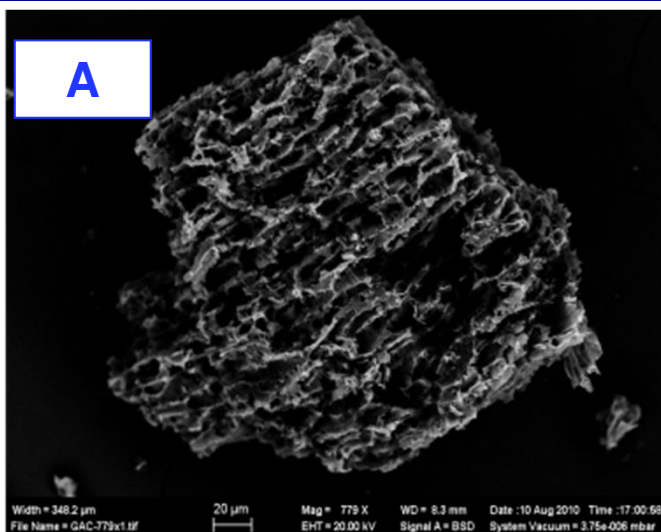
Nitrogen-containing



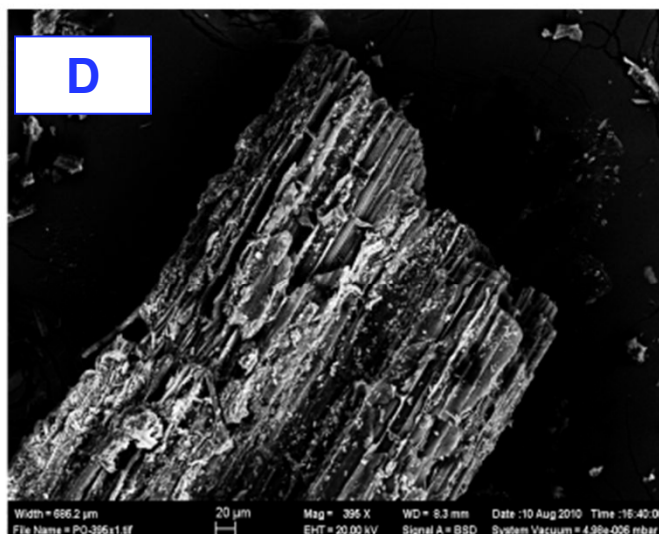
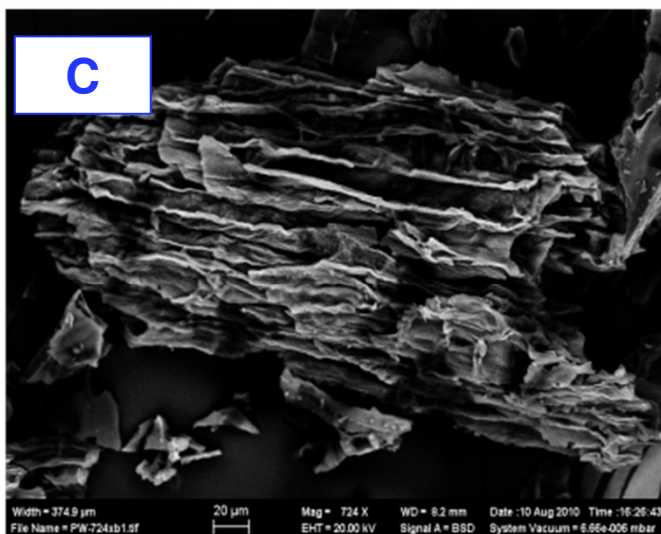
Sulfur-containing



Phosphorus-containing

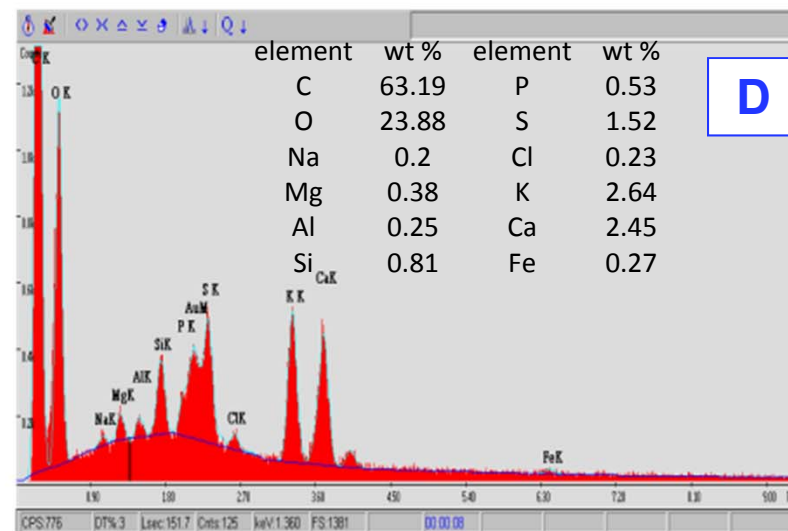
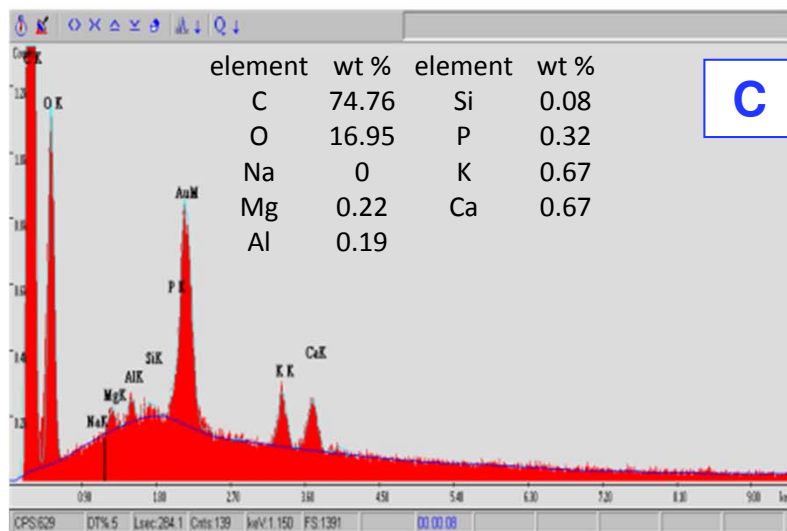
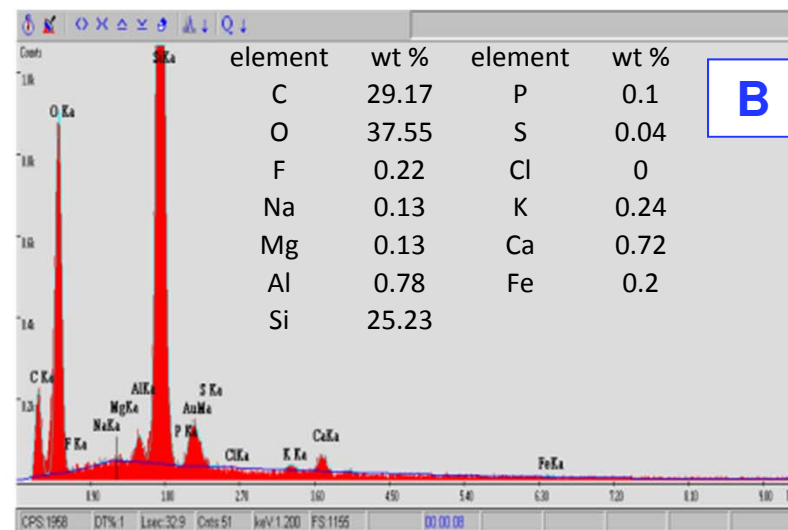
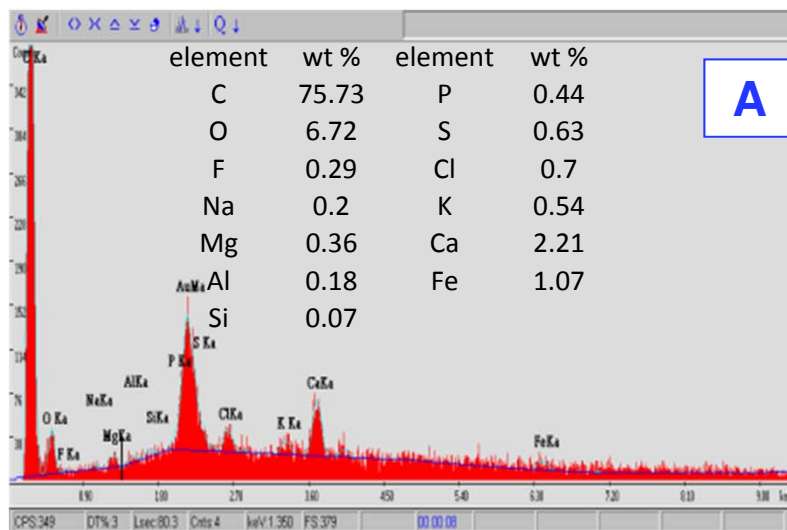


Silica
mineral



scanning electro microscope images of Hg treated material

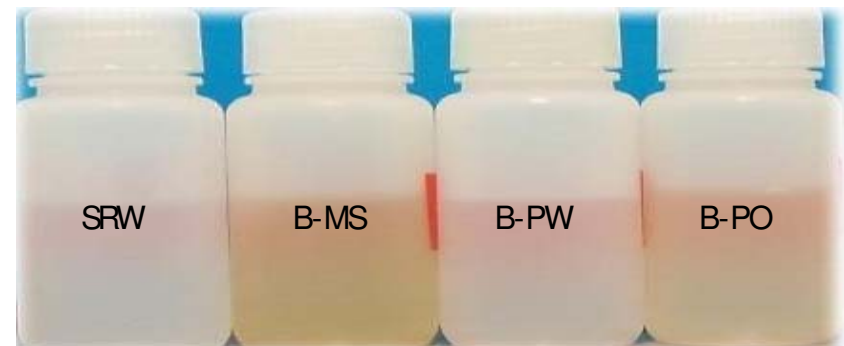
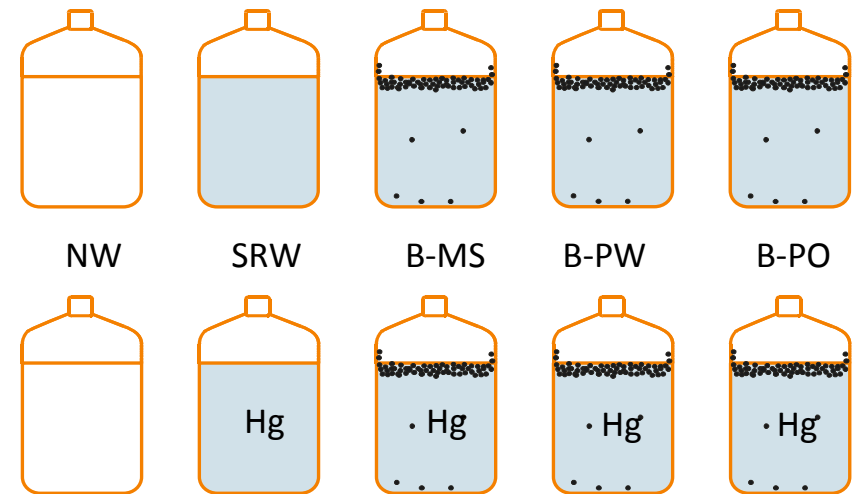
- A. Granular activated carbon B. mushroom biochar
- C. pine woodchip biochar D. poultry biochar



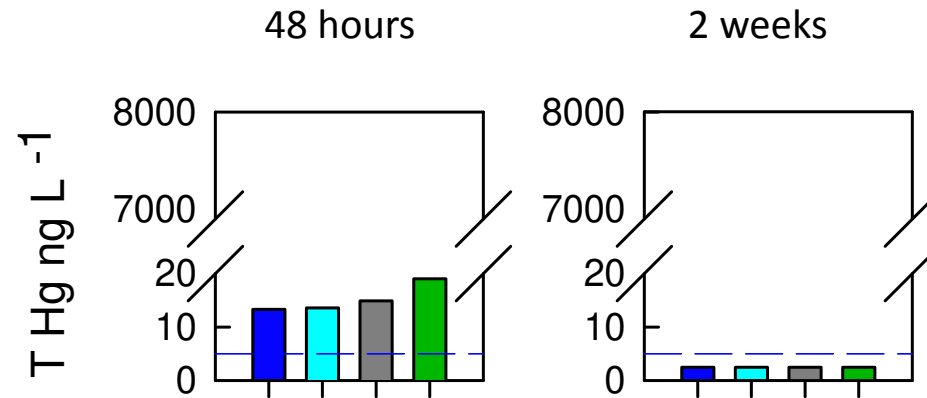
EDX material elemental peaks images

A. Granular activated carbon. B. Mushroom biochar
C. Pine wood chip biochar D. Poultry biochar

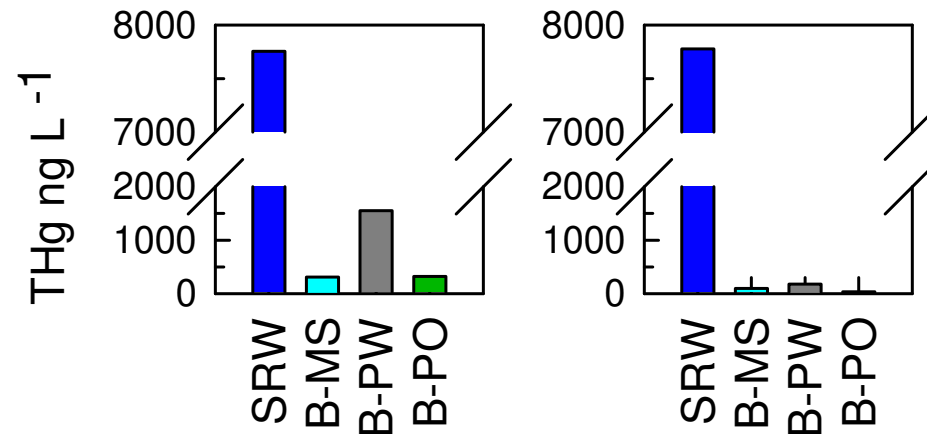
- Evaluate
 - Hg removal
 - Nutrient and trace element release
- Experiments
 - Hg-spiked SRW
 - 9000 ng L⁻¹ Hg



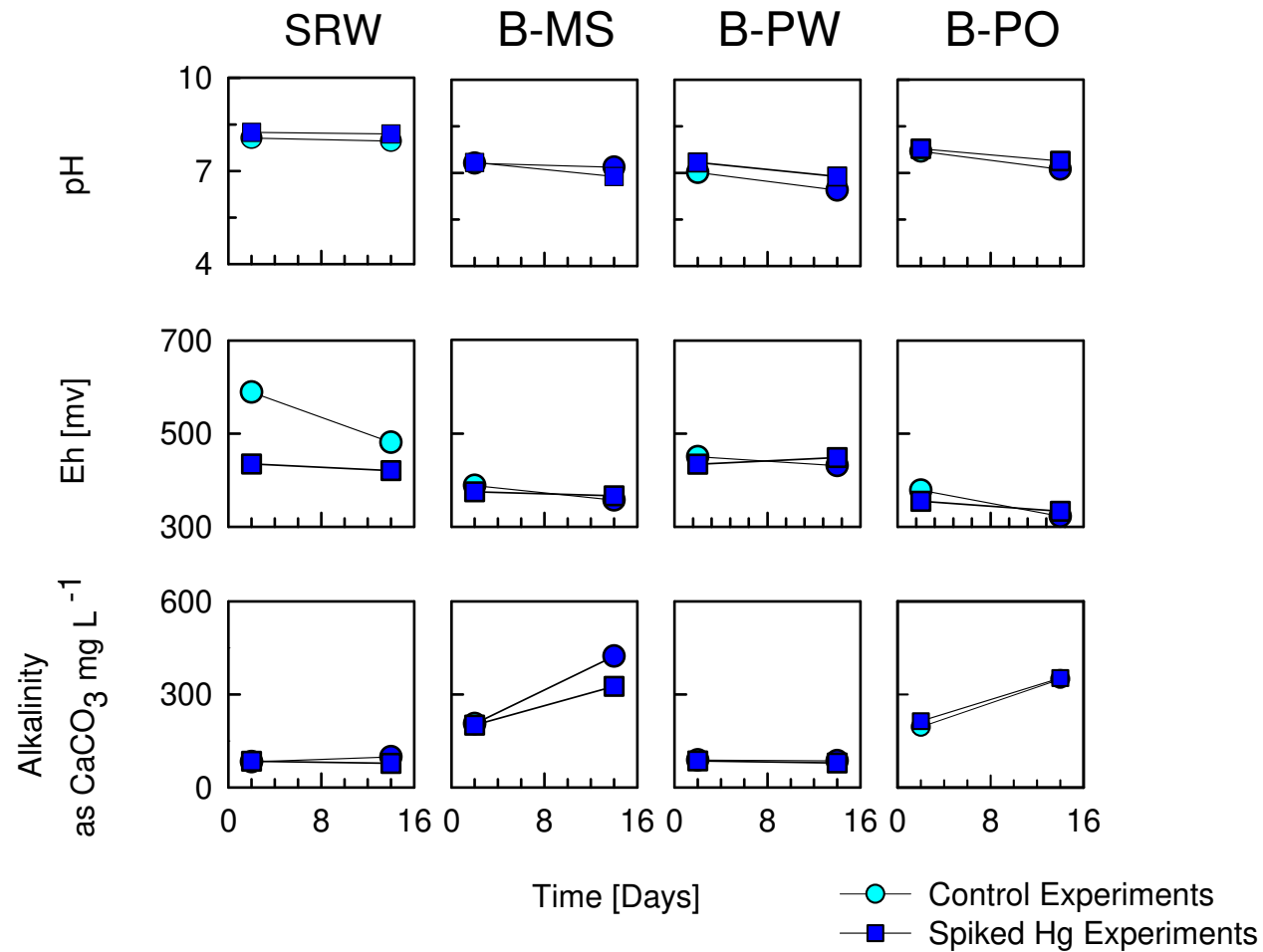
Control Experiments



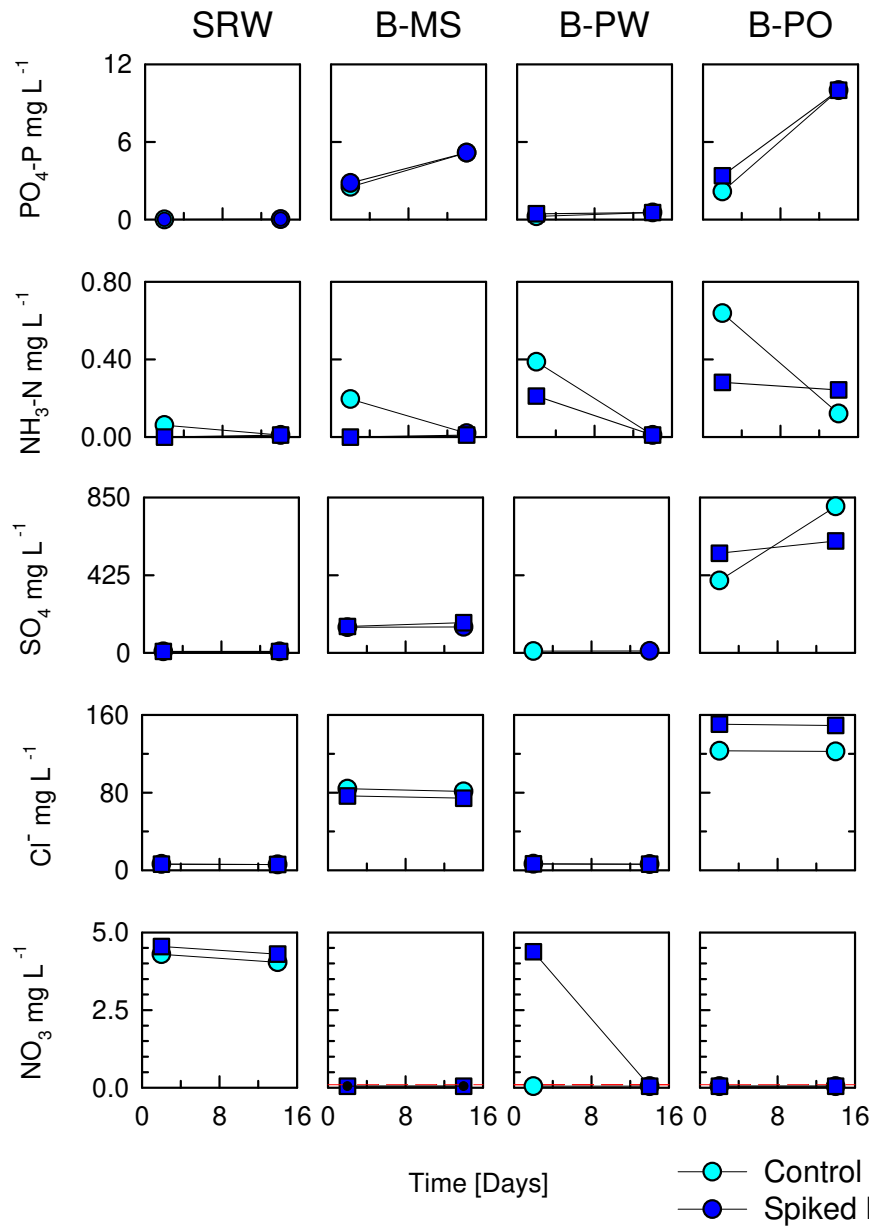
Hg Spiked Experiments



- Greater than 95% removal of Hg from South River water at 2 weeks for all biochar samples

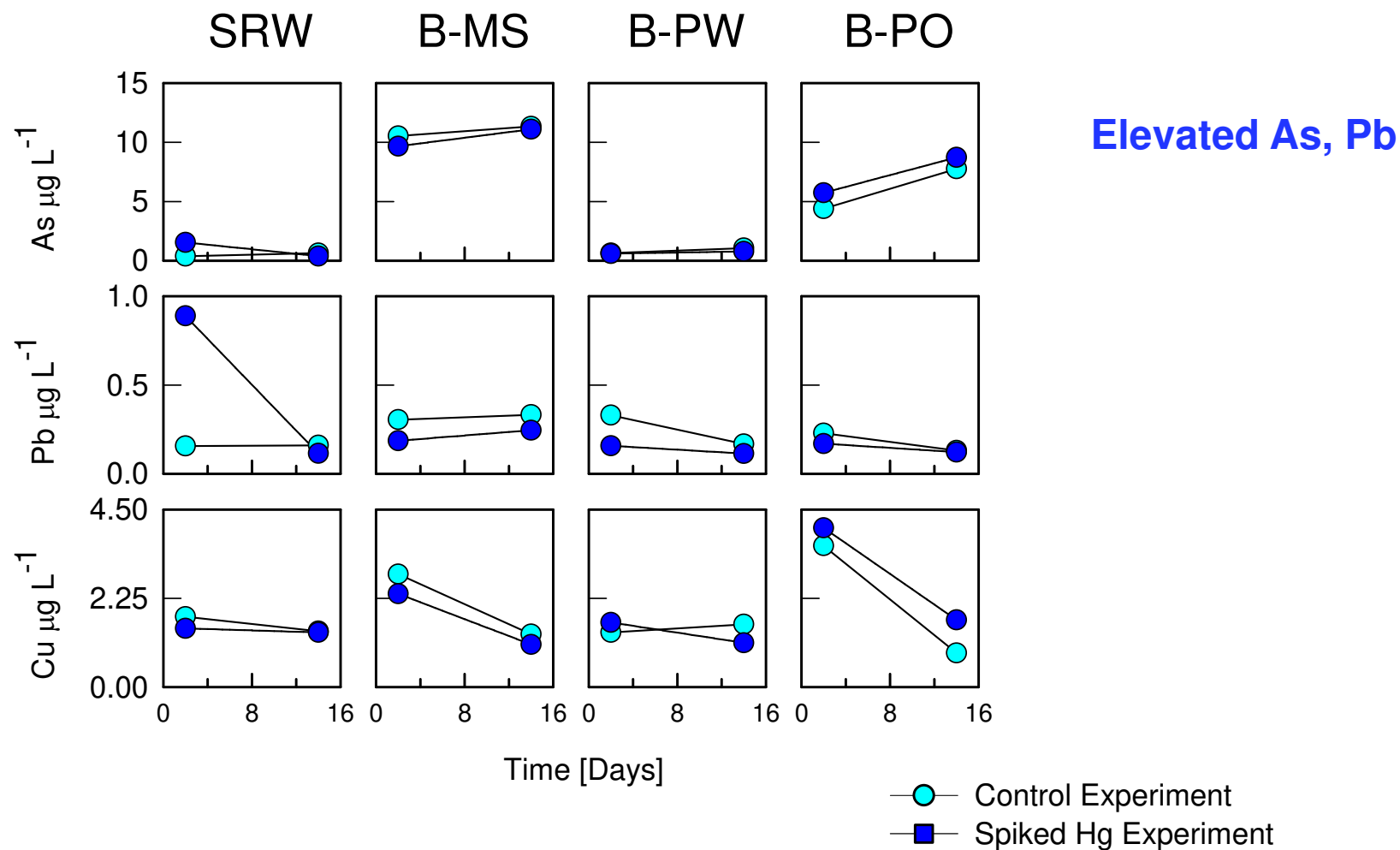


Water Chemistry

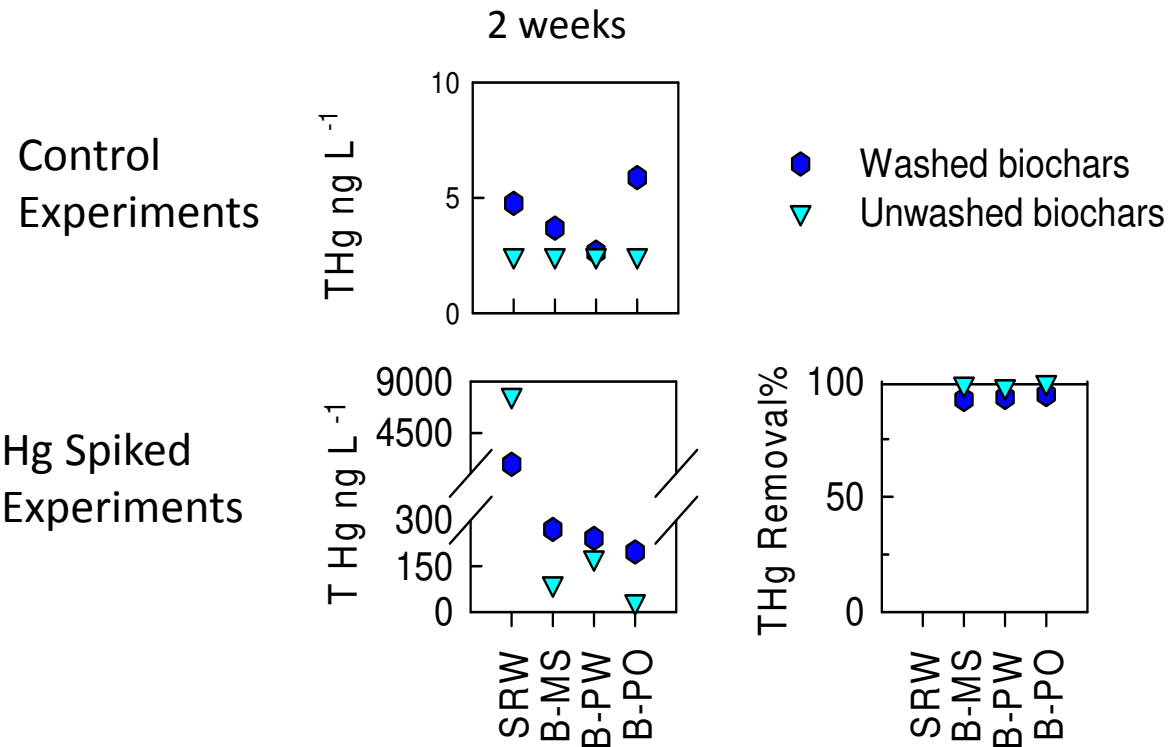


**Elevated phosphate,
sulfate, chloride**

Anions and Nutrients

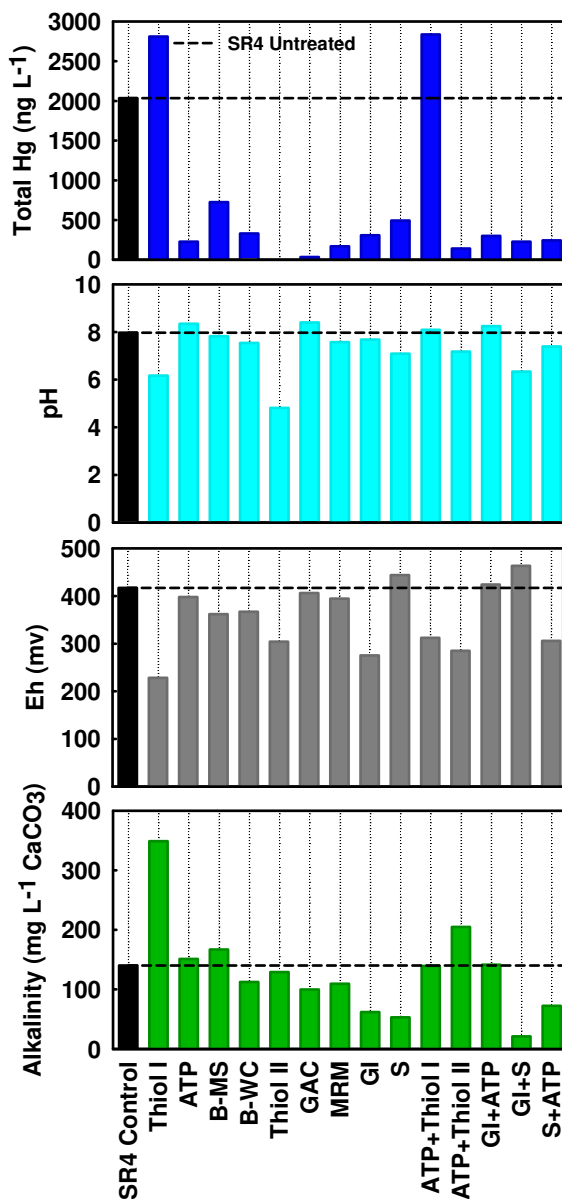


Trace Elements

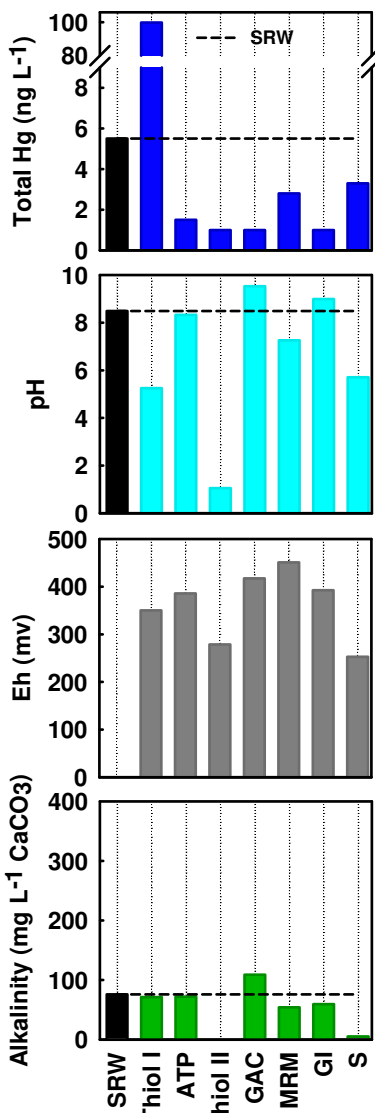


- **Greater than 92% Hg removed from South River for all washed biochar samples at 2 weeks**

Treated SR4 Sediment



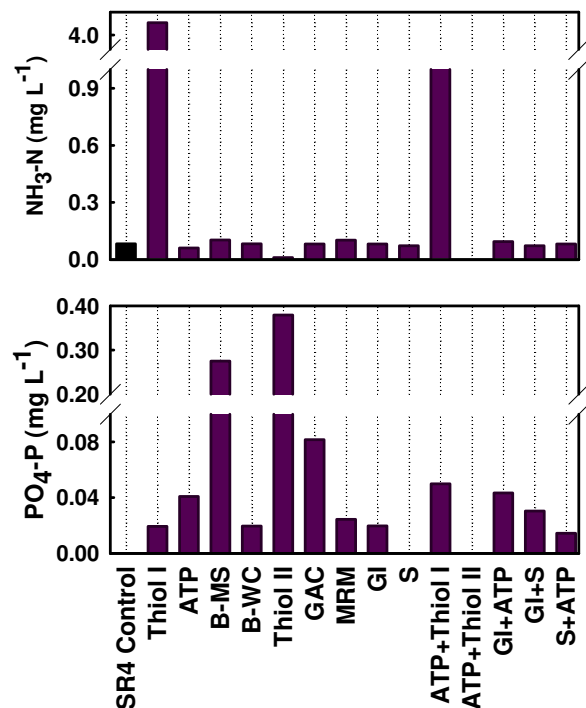
Controls - no sediment

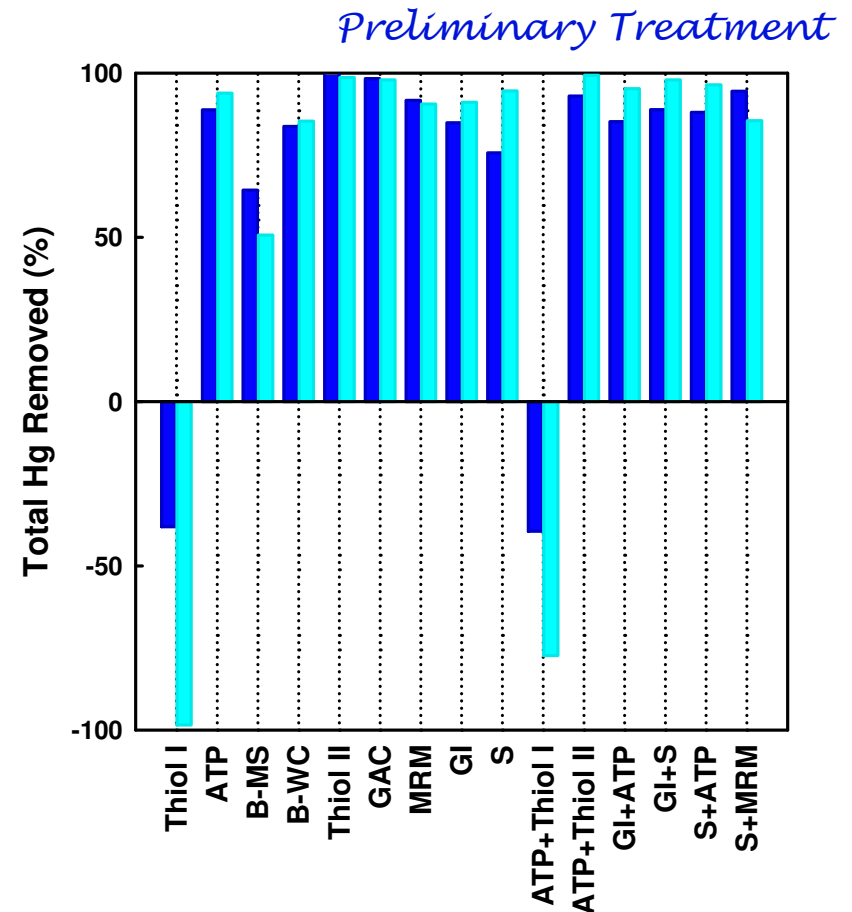
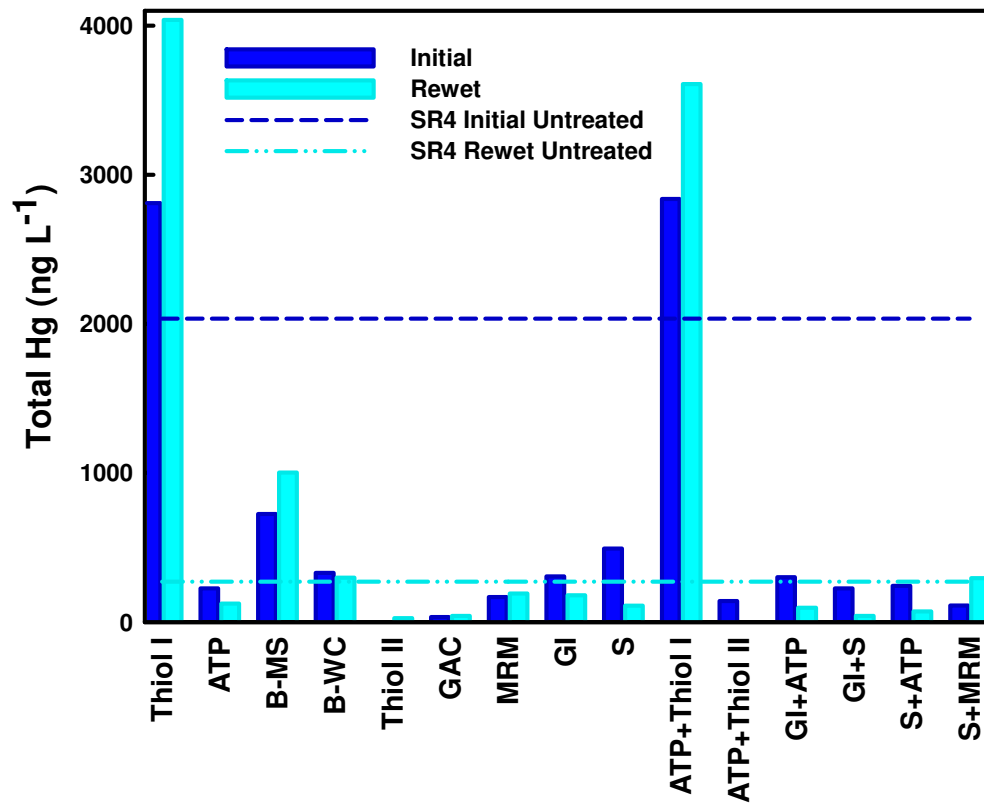


- Thiol I control ~ 100 µg L⁻¹
- Thiol II control pH <1

- Thiol I has elevated NH₃
- B-MS & Thiol II have elevated PO₄³⁻

Treated SR4 Sediment



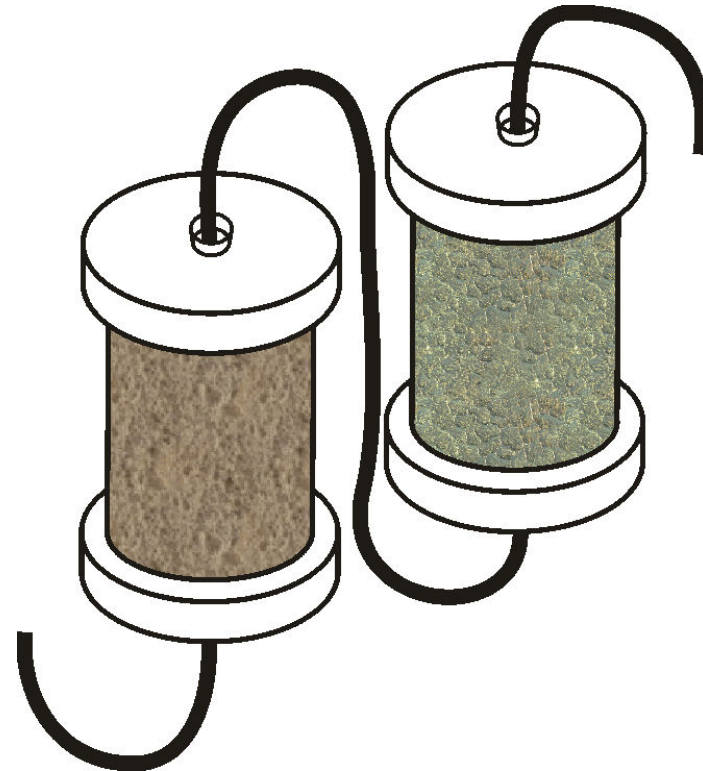


Rewetting of Treatment Batch Tests

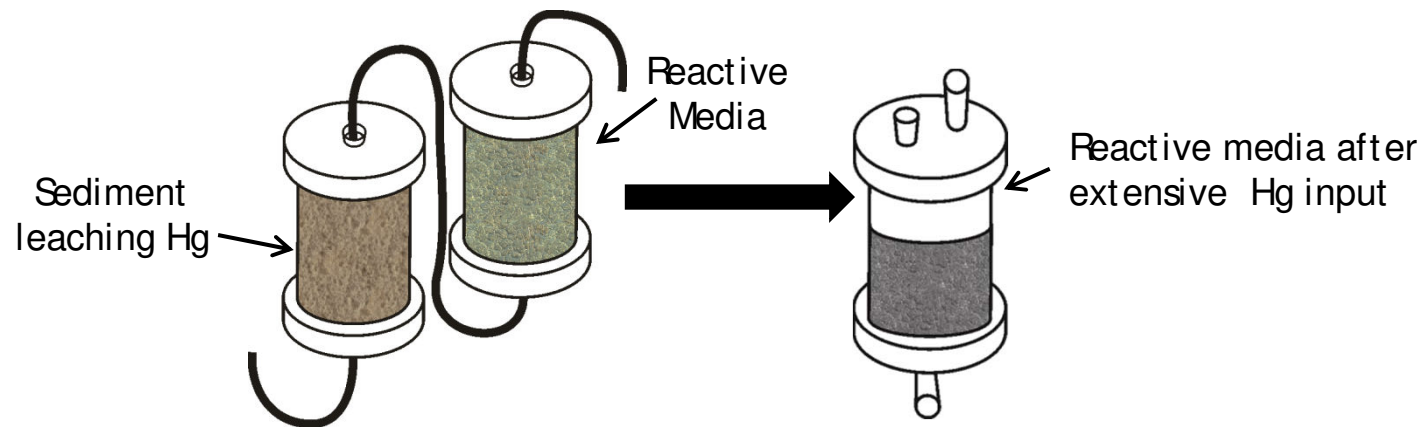
- Reacted aerobically for 33 days
- Added second aliquot of SRW to each batch
- Batches reacted for 14 days before resampling

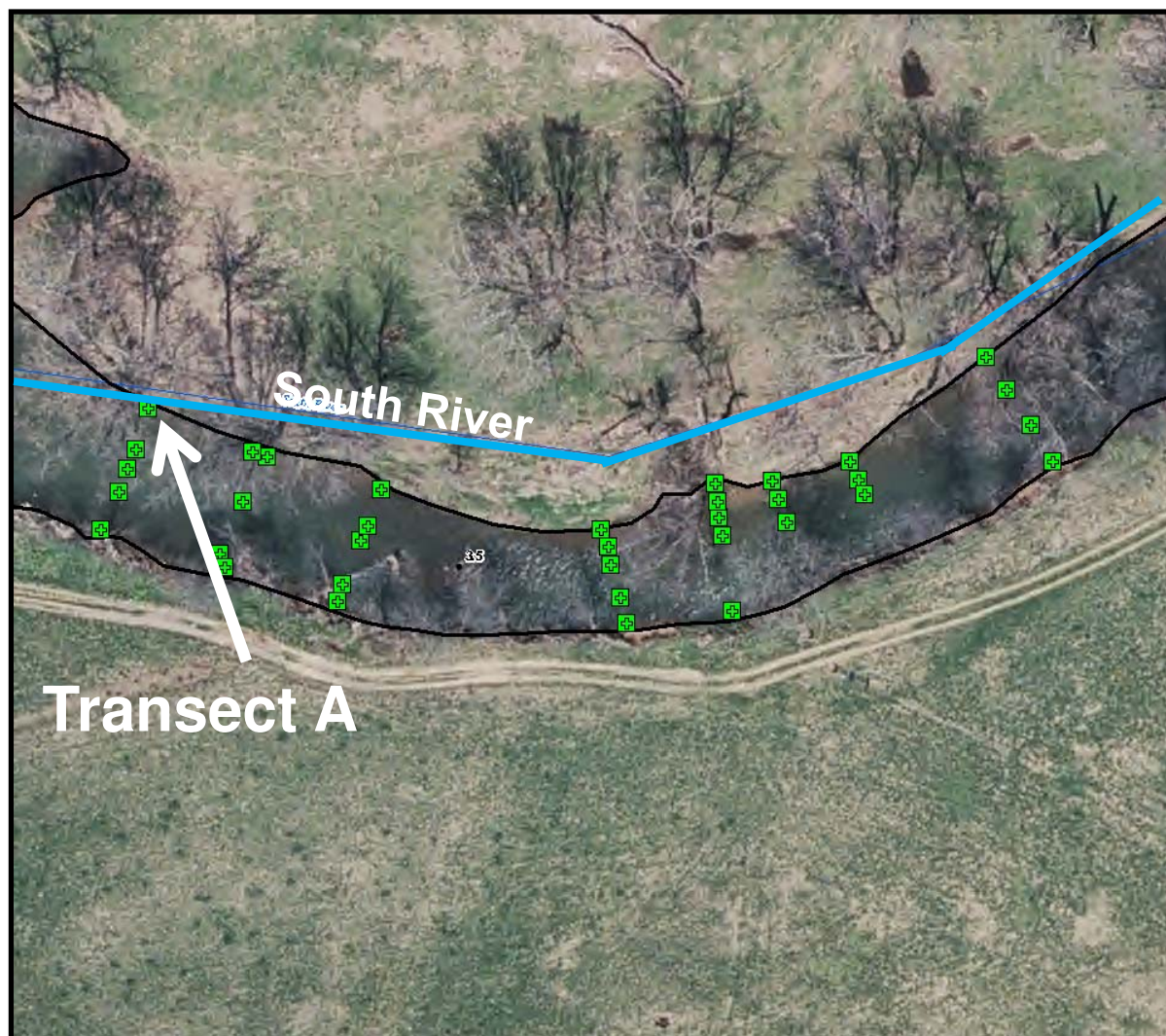
- Chemical extractions and synchrotron studies indicate large leachable fraction (2-3%)
- Remaining fraction is in the form: amorphous HgS
- Amorphous HgS present in unsaturated zone
- Both dissolved and colloidal fractions can be transported through bank sediments
- Effective Hg removal from SR water using all biochar types
- Co-blending of reactive media resulted in good treatment

- Treat bank porewater under flowing conditions
 - GAC
 - Biochar
- Dissolve reagents in influent solution (flocclulants)
 - Thiol Compound
- Blend reactive media into sediment and monitor leaching



- Humidity Test Cells
 - Assess Hg release from treatment media under enhanced weathering conditions and aging





- 2nd Riverbank Transect
- Floodplain Soil

Acknowledgements

Funding

DuPont

Natural Sciences and Engineering Research Council of Canada

Advice

R. Landis, N. Grosso, J. Dyer and E. Mack (DuPont)

Thank you
