Mercury Accumulation in Old Growth and Recently Clear-cut Forests in the Tephra Fall Zone of the 1980 Mount St. Helens Eruption

Andrew J. Buechel[1], Abir Biswas[1], David Burris[1], Kyle Krueger[1], Mariah Smith[1], Don Zobel[2], Joe Antos[3], and Dylan Fischer[1]

[1]Evergreen Biogeochemistry and Ecology Lab, The Evergreen State College, Olympia, WA. [2] Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oregon. [3] Department of Biology, University of Victoria, British Columbia, Canada; **Contact:** bueand07@evergreen.edu, biswasa@evergreen.edu

Introduction

- Mercury (Hg) is a toxic global pollutant capable of bio-accumulation up food webs
- The amount of Hg cycling in ecosystems has increased 2 to 5-fold since the industrial revolution.
- Atmospheric Hg is able to travel long distances from its emission source, to deposit to forest ecosystems and underlying soils via throughfall and litterfall.[1]
- Hg is typically retained in soils in association with organic matter, and Hg be re-emitted to the atmosphere via to solar irradiation and changes in soil temperature/moisture.[2,3]
- Soils in the Pacific Northwest are characterized as having high Hg storage, likely related to a combination of elevated atmospheric Hg deposition and to infrequent Hg loss via forest fires due in temperate rainforests in the region[5-7]

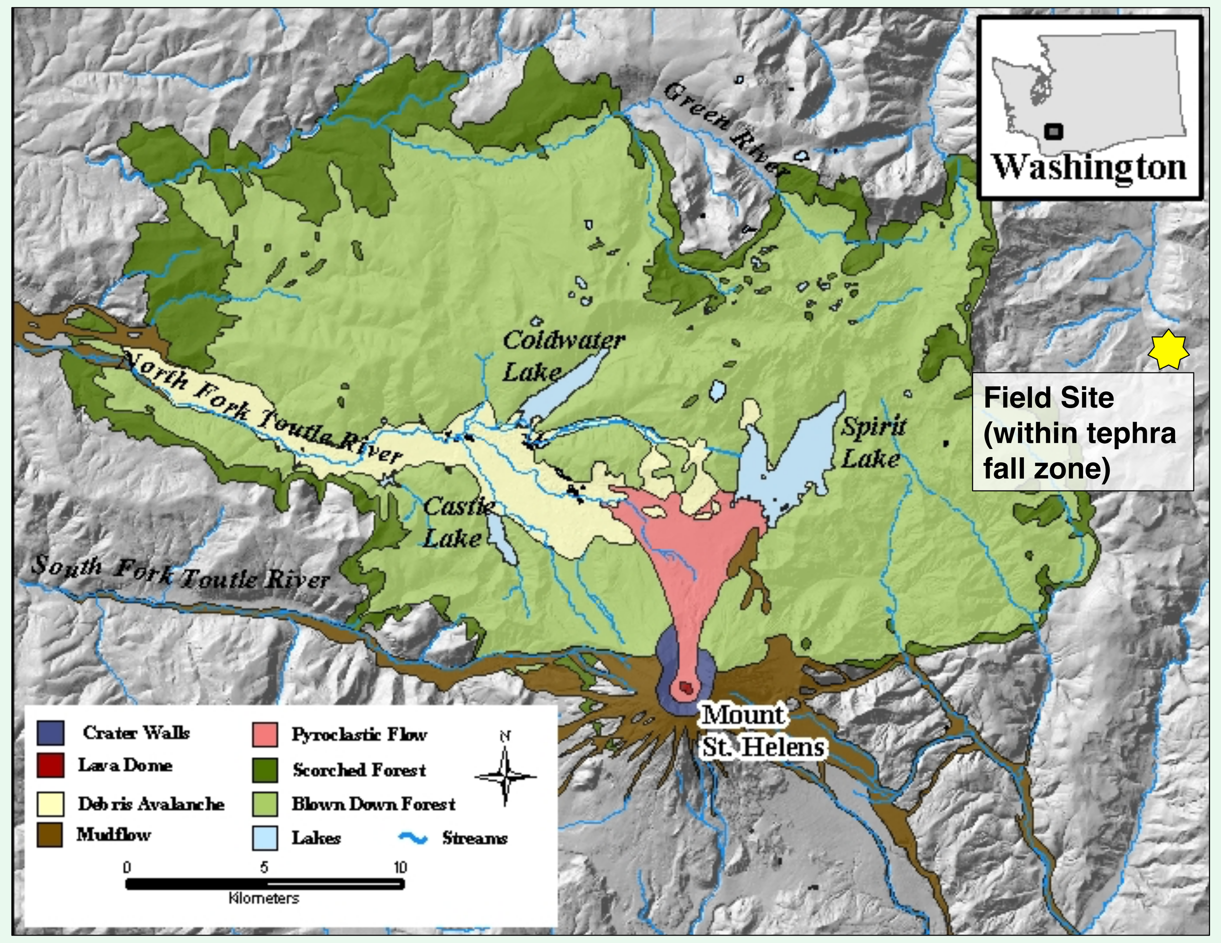


Figure 1. Map of disturbance zones at Mt. St. Helens. Field site located in ~ 15 cm tephra fall zone. Entirety of tephra fall zone goes beyond the borders of the image. Image borrowed from: USGS, modified by Abby Watt.

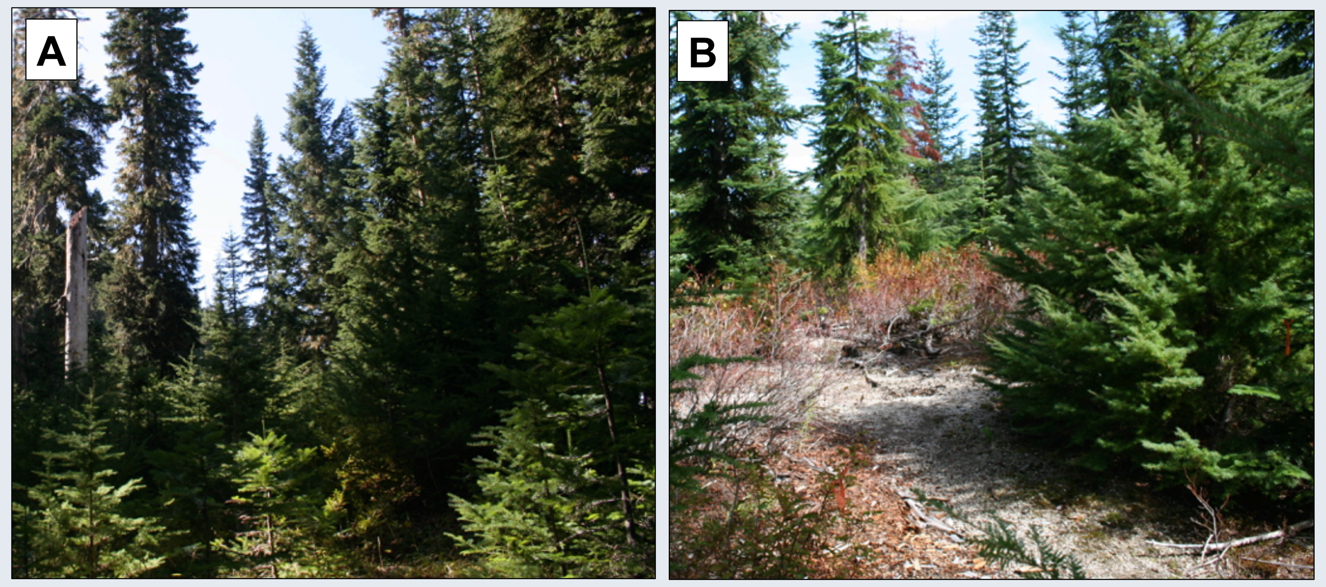


Figure 2. Old growth **(Panel A)** clear-cut **(Panel B)** sampling sites. Two previously established ~600 year old old growth sites were paired with two sites of similar elevation, that were clear-cut and replanted prior to 1980 eruption.

Methods

Field Work

- Soil cores were collected at two paired old growth and clear-cut sites.
- Cores were characterized in the field and segmented into distinct horizons: organic, crust, and tephra.

Analysis

- Soil was air dried, sieved, and homogenized in the lab prior to analysis for Hg and C.
- Total concentrations of Hg were determined by thermal decomposition and cold vapor atomic absorption spectrometry (CV-AAS) using a Nippon MA-3000 (Nippon Instruments, Japan).
- Replicate analysis of standard reference material, NIST 1575a (pine needle) were within ± 10% of certified value.
- Analysis of C was conducted by loss on ignition (LOI; at 500 °C for 5 h).

Hypothesis

The presence of the old growth canopy should result in increased atmospheric mercury accumulation in soil compared to paired sites clear-cut prior to the eruption.

Figure 3. Newly developed soil on top of volcanic ash (tephra and crust) from 1980 Mount St. Helens eruption.

Horizons

Organic: Representative of all new inputs/soil format-Ion following the eruption.

Crust: Fine volcanic ash that created an "imperme-able" layer.

Tephra: Coarser volcanic ash initially deposited from erupt-ion that has since weathered. (Depth of tephra not pictured)

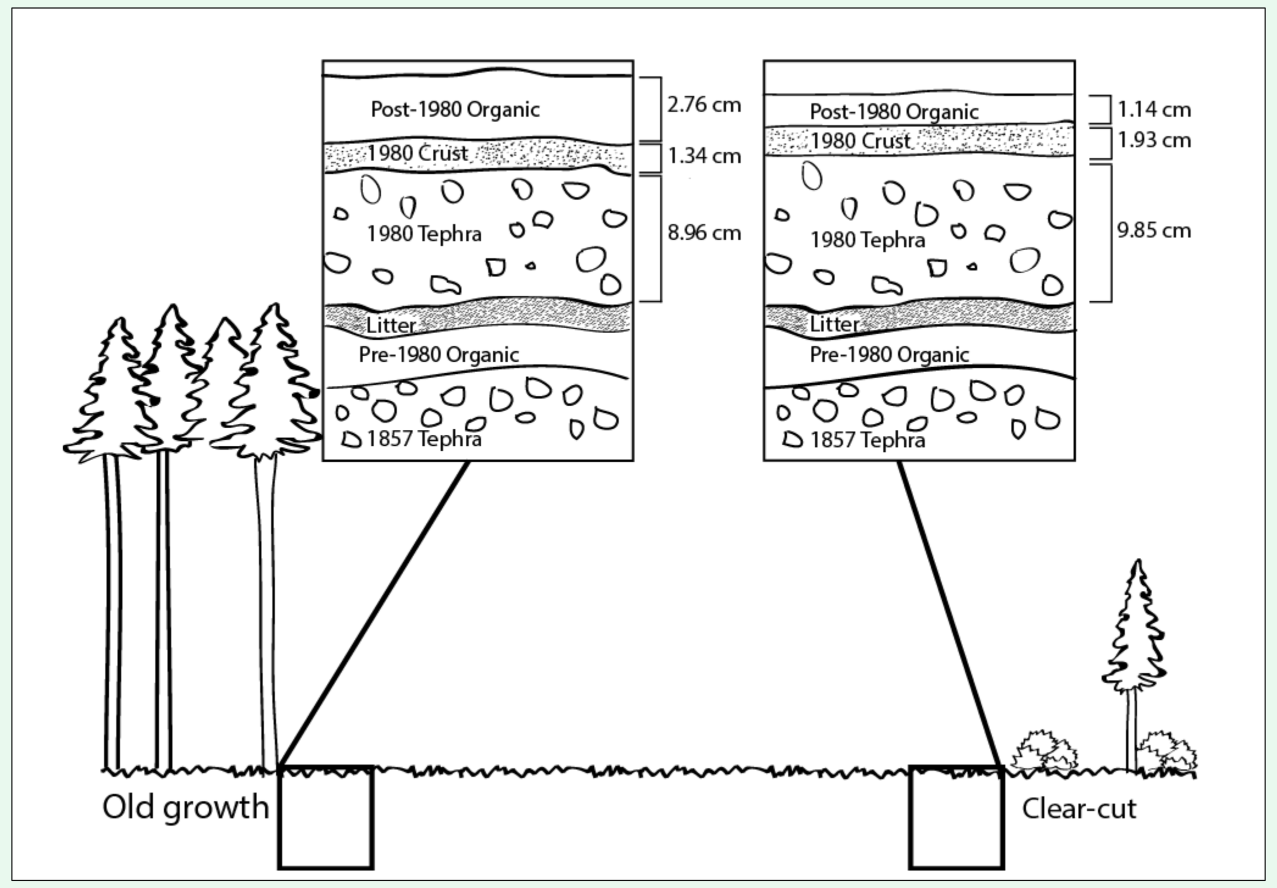


Figure 4. Schematic of soil development on Mount St. Helens tephra at old growth and clear-cut sites. Note greater depth of organic horizon in the old growth plots.

Results

Table 1. Mercury (Hg) concentrations, % Carbon, and Hg storage in soil horizons at Old Growth and Recently Clear-Cut sites. There were no significant differences between low elevation and high elevation old growth and clear-cut sites, thus the data was pooled.

Site	# of Cores	Horizon	[Hg] (ng Hg g^{-1})	OG:CC* (ng Hg g^{-1})	C (%)	Hg storage in O horizon (g Hg ha^{-1})	Hg storage (g Hg ha^{-1})
Old Growth	39	Organic	88.28 ± 46.87	p <0.01	15.37 ± 6.98	7.79 ± 5.33	18.60 ± 6.85
		Crust	16.17 ± 5.31	p <0.01	1.46 ± 0.90		
		Tephra	6.59 ± 3.98	p <0.01	0.64 ± 0.78		
Clear-cut	45	Organic	26.59 ± 15.48		6.48 ± 3.97	1.42 ± 1.12	8.86 ± 4.69
		Crust	8.05 ± 3.82		1.62 ± 1.18		
		Tephra	4.44 ± 2.98		0.61 ± 0.40		

*Denotes a significant difference was observed between the Hg concentrations of old growth and clear-cut in that horizon

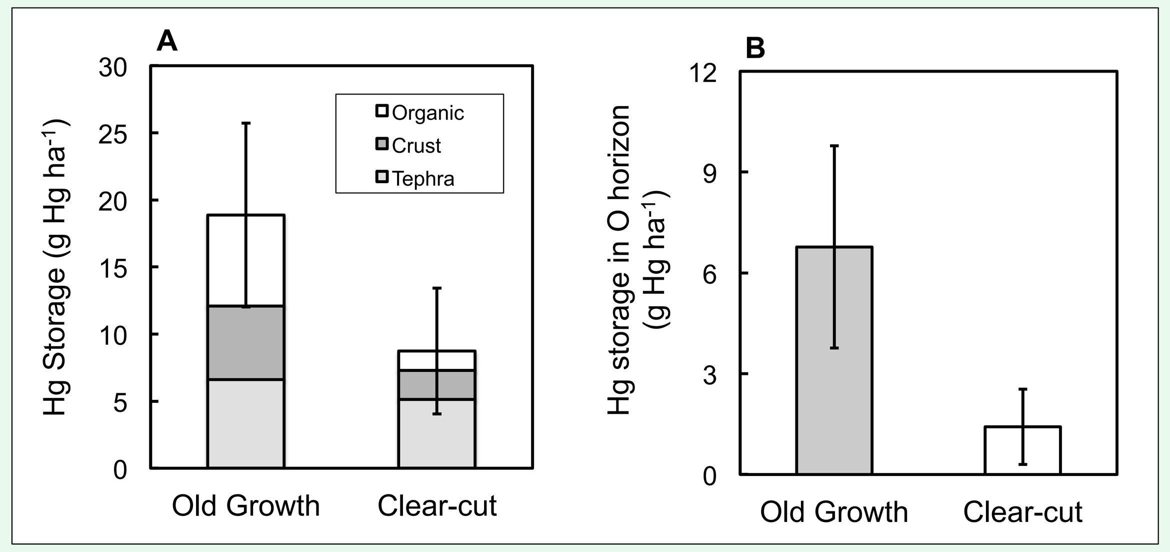
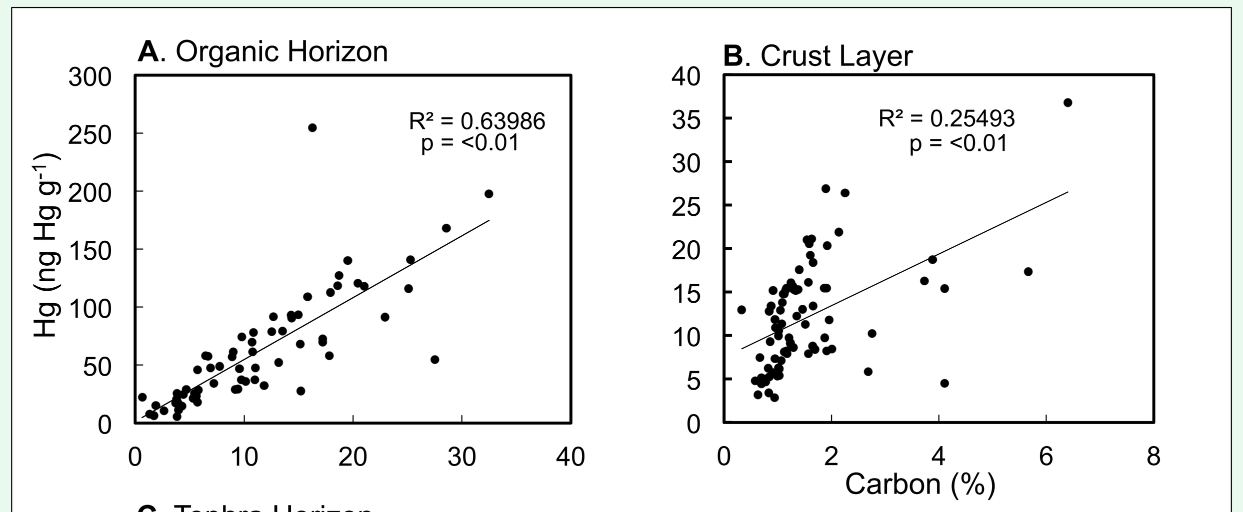


Figure 5. (Panel A) Total Hg storage in the soil profiles (incl. organic, crust, and tephra horizons) at Old Growth and Recently Clear-Cut sites. Error bars reflect the aggregate of standard deviations for all 3 soil horizons. **(Panel B)** Total Hg storage in just the organic horizon of soil at Old Growth and Recently Clear-Cut sites. Error bars reflect standard deviation of O horizon measurements. Two outliers (Hg concs. ± 3X standard deviation from the mean) were not considered in statistical tests.

- The difference between the old growth and clear-cut sites was clearer and more significant when considering Hg storage in the O horizon alone (p=<0.01*).



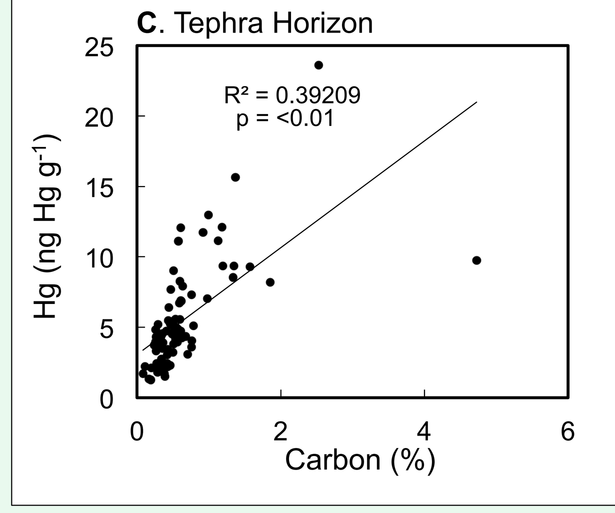


Figure 6. Linear Regression models between soil Hg concentrations as a function of soil C (%) for the Organic Horizon **(Panel A)**, the Crust Layer **(Panel B)** and the Tephra Horizon **(Panel C)**. There was a significant relationship between % Carbon and Hg concentrations in all 3 soil layers; accounting for up to 64% of observed Hg in the organic, 25% in the crust, and 39% in the tephra horizon.

Discussion

- Overall, Hg accumulation was significantly greater at old growth sites than clear-cut sites **(Table 1, Fig. 5)**.
  - This observation is consistent with old growth canopy size resulting in increase atmospheric Hg scavenging and Hg transfer to the soil via throughfall and litterfall
- Carbon storage in the O horizon was over 3 times greater in the old growth sites than the clear-cuts. Carbon storage in old growth and clear-cut sites O horizon averaged 23.82 and 6.16 kg C m^2 respectively.
- Mercury as a function of soil C demonstrated a significant linear relationship within all horizons **(Fig. 6).**
  - Soil C was the best predictor for Hg concentrations in the O horizon **(Fig. 6 Panel A)**.
- The range of soil Hg concentrations at these sites are consistent with values observed in other mountainous ecosystems remote from anthropogenic sources.[6]
- Tephra concentrations were significantly lower than those observed immediately following the eruption (8 ppb), especially in the clear-cut sites, indicating that removal of Hg via weathering is also occurring.
- The storage values we observed suggests that our sites proximity to Mount St. Helens, a natural source of Hg, does not result in increased soil Hg accumulation.

Figure 7: Old growth overlooking a previously clear-cut forest in the tephra fall zone NE of Mount St. Helens

References

1. Obrist, D; Johnson D; Lindberg, S. **(2009)** Mercury concentrations and pools in four Sierra Nevada forest sites, and relationships to organic carbon and nitrogen. *Biogeosciences,* 6, 765-777.
2. Skyllberg, U.; Xia, K.; Bloom, P.; Nater, E.; Bleam, W. Binding of Mercury(II) to Reduced Sulfur in Soil Organic Matter along Upland-Peat Soil Transects. *Journ. Environ. Qual.* **2000.** 29(3), 855-865.
3. Mazur, M.; Mitchell, C.; Eckley, C.; Eggert, S.; Kolka, R.; Sebestyen S.; Swain, E. Gaseous mercury fluxes from forest soils in response to forest harvesting intensity: A field manipulation experiment. *Sci. Tot. Environ.* 496 2014, 496, 678–687.
4. Yu, X.; Driscoll, C.; Warby, R.; Montesdeoca, M.; Johnson, C. Soil mercury and its response to atmospheric mercury deposition across the northeastern United States. *Ecol. Applic.* **2014** 24(4), 812-822.
5. Obrist, D.; Johnson, D.; Lindberg, S.; Luo, Y.; Hararuk, O.; Brancho, R.; Battles, J.; Dail, D.; Edmonds, R.; Monson, R.; Ollinger, S.; Pallardy, S.; Pregitzer, K.; Todd, D. Mercury Distribution Across 14 U.S. Forests. Part I: Spatial Patterns of Concentrations in Biomass, Litter, and Soils. **2011** *Environ. Scien. Tech.* 45, 3974-3981.
6. Szopka, K.; Karczewska, A.; Kabala, C. Mercury accumulation in the surface layers of mountain soils: a case study from the Karkonosze mountains, Poland. *Chemospher,* **2011**, 83, 1507-1512.
7. Lin, C.; Shetty, S.; Pan, L.; Pongprueksa, P.; Jang, C.; Chu, H. Source attribution for mercury deposition in the contiguous United States: Regional difference and seasonal variation. *Jour. Air Waste Manag. Assoc.* **2012**, 62, 52-63.

Acknowledgements

The authors would like to thank The Evergreen State College firstly for the opportunity to carry out this study as well as the Science Support Center and its staff for their help. This study was made possible by funding from The Evergreen State College's Summer Undergraduate Research Fellowship.