Saucon Creek Watershed Heavy Metal Chemistry

Uncertainties and Hopes

Toby Broun

Introduction

- In 2011, the Lehigh Valley Planning Commission published a report on the state of the Saucon Creek watershed, which encompasses Hellertown, Lower Saucon, Coopersburg, Williams Township, Bethlehem, and Milford PA.
- This report revealed that Saucon Creek and its tributaries were impaired by sediment, which acts as an absorbent for numerous heavy metals: metals that have high densities and become toxic to humans and other organisms at low concentrations.
- Initial research within Saucon Creek's watershed revealed potentially-optimistic levels of heavy metals, but industrial or urbanized areas notably showcased greater heavy metal concentrations.

Research Objectives

- Two major sets of trials were performed for this specific inquiry alongside a larger water monitoring campaign.
- Initial Tests: Determine the extent to which the LVPC report’s discussion of the risk for heavy metal absorption by sediment remains valid.
- Follow-Up Tests: Determine the extent to which urbanized and industrialized zones are affected by heavy metal contamination and determine whether a correlation between land use and toxicity exists.

Context of Saucon Creek's Watershed

- A watershed is an area where water and precipitation collect and drain into a common body of water. Though Saucon Creek's watershed is quite extensive, the Lehigh Valley Planning Commission cited Saucon Creek's major tributaries as those concentrated within the Hellertown-Lower Saucon Area.
    - Saucon Creek mainstream
    - East Branch Saucon Creek
    - Silver Creek
    - Polk Valley Run
    - Black River
- Global heavy metal concentrations in river water have increased since the 1970s.
- All 4 heavy metals tested for in this experiment enter waterways via human activity at specific sites (point-source discharge), whether it be industrial or agricultural.
- Heavy metals are hydrophobic, meaning they are readily absorbed by sediment and remain there for long periods of time. However, they remain detectable on the surface of water for short periods of time if they are actively being deposited.

An Overview of Specific Quantities

- Water hardness (concentration of dissolved Mg and Ca) plays a substantial role in water chemistry, as it decreases acute heavy metal toxicity to organisms.
- Increases in water temperature increase heavy metal concentration.
- The EPA compiled standards for the concentration of each heavy metal (and other contaminants) considered chronically and acutely toxic to aquatic organisms:
    - Mercury–acute at 0.00145 mg/L, chronic at 0.00077 mg/L; Copper–acute at 0.00467 mg/L, chronic at 0.00145 mg/L; Zinc–acute and chronic values are one in the same (0.12 mg/L); Lead–acute at 0.065 mg/L, chronic at 0.012 mg/L
    - The EPA reports which established these criteria were based on a series of tests conducted on various vertebrate and invertebrate species
    - Invertebrate species tend to be more vulnerable and are susceptible to chronic and acute harm at lower levels of concentration

Material List

- 1 case of freshwater heavy metal and water hardness test strips
- 1 waterproof thermometer
- 1 timer
- 1 closable transport bag (important for maintenance of cool, dry conditions necessary for proper test tube storage
- 1 on-site recording device (iPhone, iPad, notebook, etc.)

General Procedure

1. At test site, dip water thermometer into water so that it is fully submerged. Record water temperature.
2. Open the test strip container and select one test strip from the container, being sure to avoid touching any of its reading points.
3. Set timer for 2 seconds in accordance with the recommended submersion time.
4. Dip the test strip into the water while starting the timer. Remove immediately once it goes off.
5. Shake excess water off the strip and compare its color readings to those on the case immediately, making sure to note water hardness as well as heavy metal concentration.
6. Screw the lid of the container back on tightly and do not open until next test. Place the container in a dry, sealed bag.
7. Repeat steps 1-6 for the remaining test sites.

Note: results will be measured on various scales for each metal. The possible scale values for Zinc are 0, 5, 10, 30, 50, and 100 mg/L; 0, 0.1, 0.2, 0.4, 1, 2, and 5 mg/L for Copper; 0, 0.005, 0.001, 0.0015, 0.03, and 0.05 mg/L for lead; and 0, 0.002, 0.005, 0.01, 0.02, 0.04, and 0.08 mg/L for mercury. Hardness is measured in mg/L as well, with potential values being 0, 25, 50, 100, 250, and 425 mg/L.

Hypothesis – Initial Tests

- If the Saucon Creek watershed is tested for mercury, zinc, copper, and lead at sites across its major tributaries and along the main creek itself, then the concentration of each heavy metal as measured in mg/L will fall within at least chronically toxic levels, because heavy metal concentrations in freshwater bodies have risen globally and Saucon Creek and each of its major tributaries pass through areas of high human activity.

Heavy Metal Concentration in the Saucon Creek Watershed–Final Averages

	Test Site	East Branch Saucon Creek	Saucon Creek (Upstream of Polk Run)	Saucon Creek (Upstream of Lehigh River)	Black River	Silver Creek	Polk Valley Run
Heavy Metal Concentration (mg/L)	Hg	0	0	0	0	0	0
	Pb	0.015	0.015	0.015	0.015	0.015	0.015
	Zn	3.75	2.5	0	0	1.25	0
	Cu	0.05	0.075	0.05	0.075	0.075	0

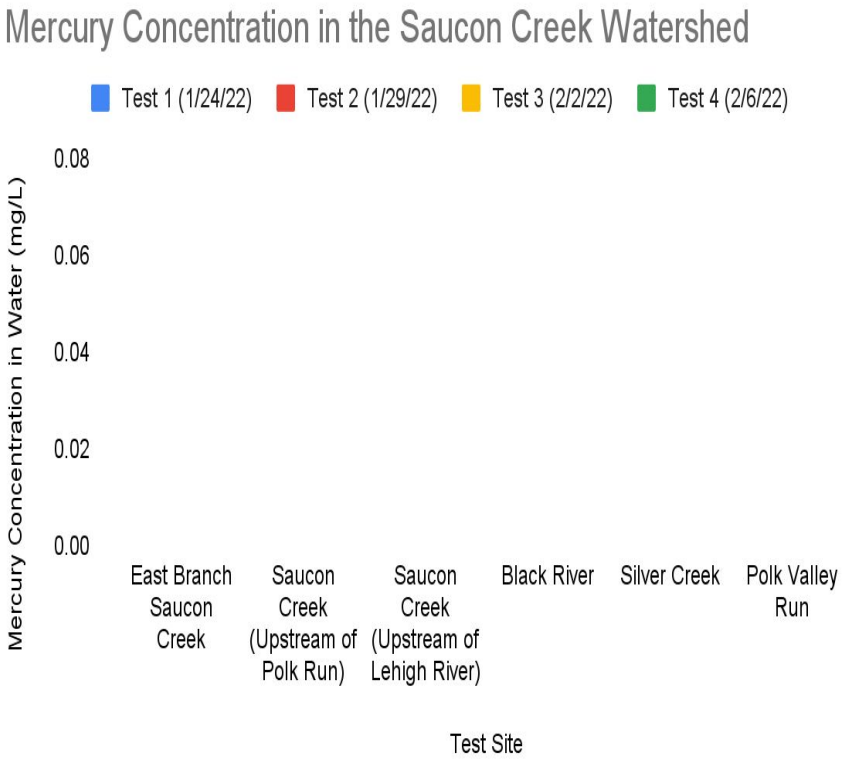
Water Hardness of Test Sites

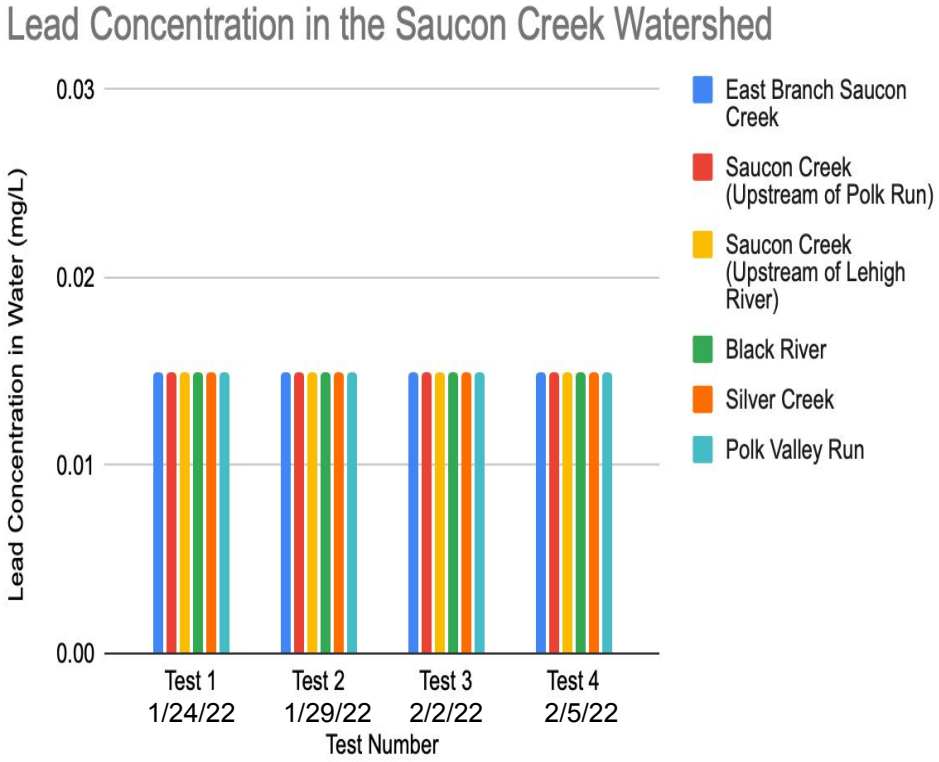
	Test Site	East Branch Saucon Creek	Saucon Creek (Upstream of Polk Run)	Saucon Creek (Upstream of Lehigh River)	Black River	Silver Creek	Polk Valley Run
Water Hardness (mg/L)	Test 1	100	100	100	100	100	100
	Test 2	100	100	100	100	100	100
	Test 3	100	100	100	100	100	100
	Test 4	100	100	100	100	100	100
	Final Average	100	100	100	100	100	100

Water Temperature Across Tests

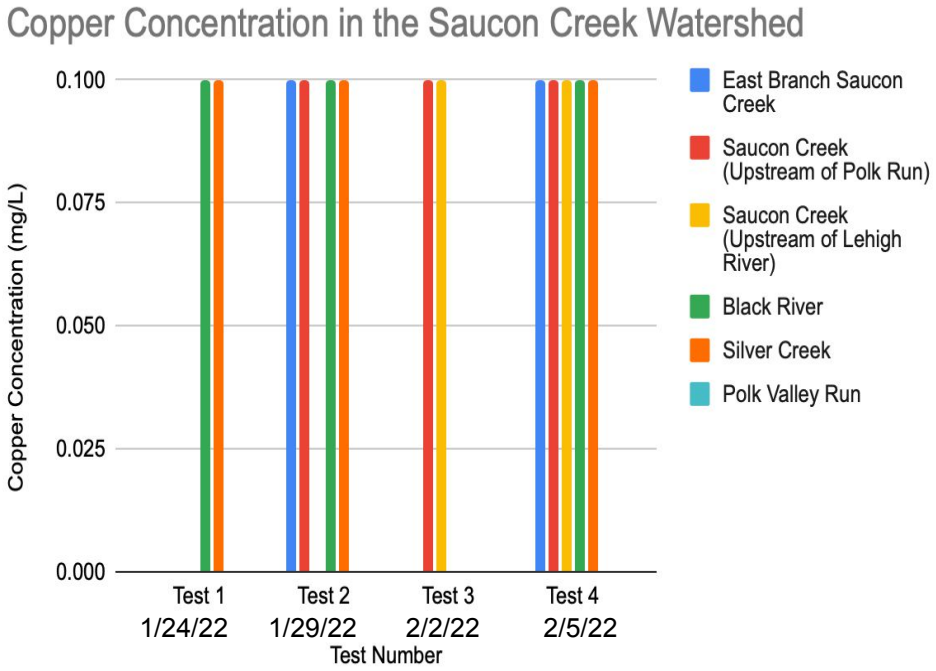
	Test Site	East Branch Saucon Creek	Saucon Creek (Upstream of Polk Run	Saucon Creek (Upstream of Lehigh River)	Black River	Silver Creek	Polk Valley Run
Water Temperature (Celsius)	Test 1 (1/24/22)	5.9	6.6	8.1	4.1	7.5	5.1
	Test 2 (1/29/22)	7.5	7.4	9.1	8.1	8.5	5.9
	Test 3 (2/2/22)	5.8	6.8	7.2	3.6	7.1	3.8
	Test 4 (2/5/22)	5.3	6.3	7.9	1.4	7.5	1.8
	Final Average	6.125	6.775	8.075	4.3	7.65	4.15

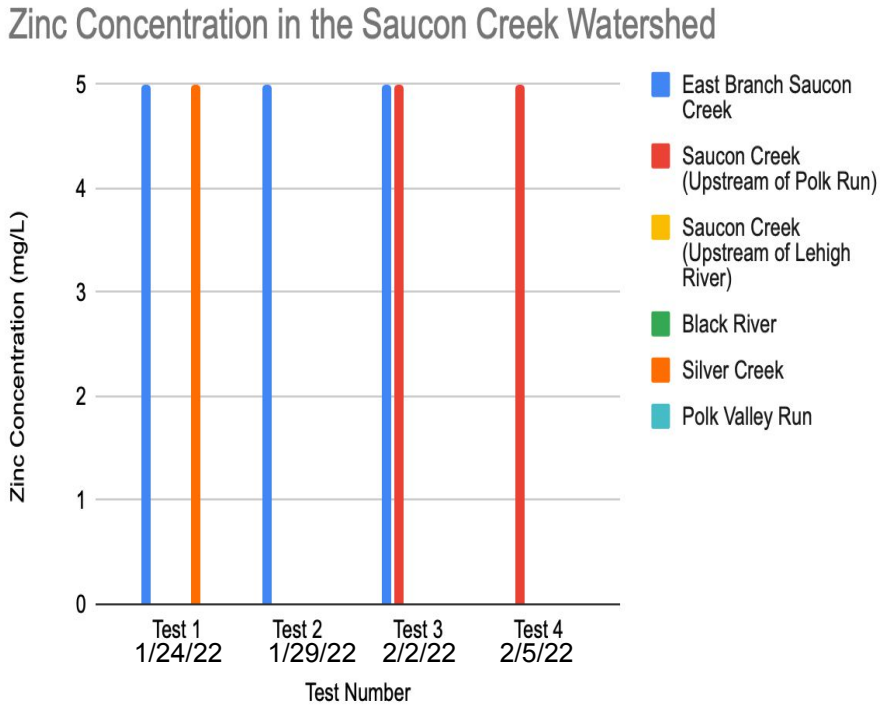
Test 1-4 Graphs–Mercury and Lead





Test 1-4 Graphs–Copper and Zinc

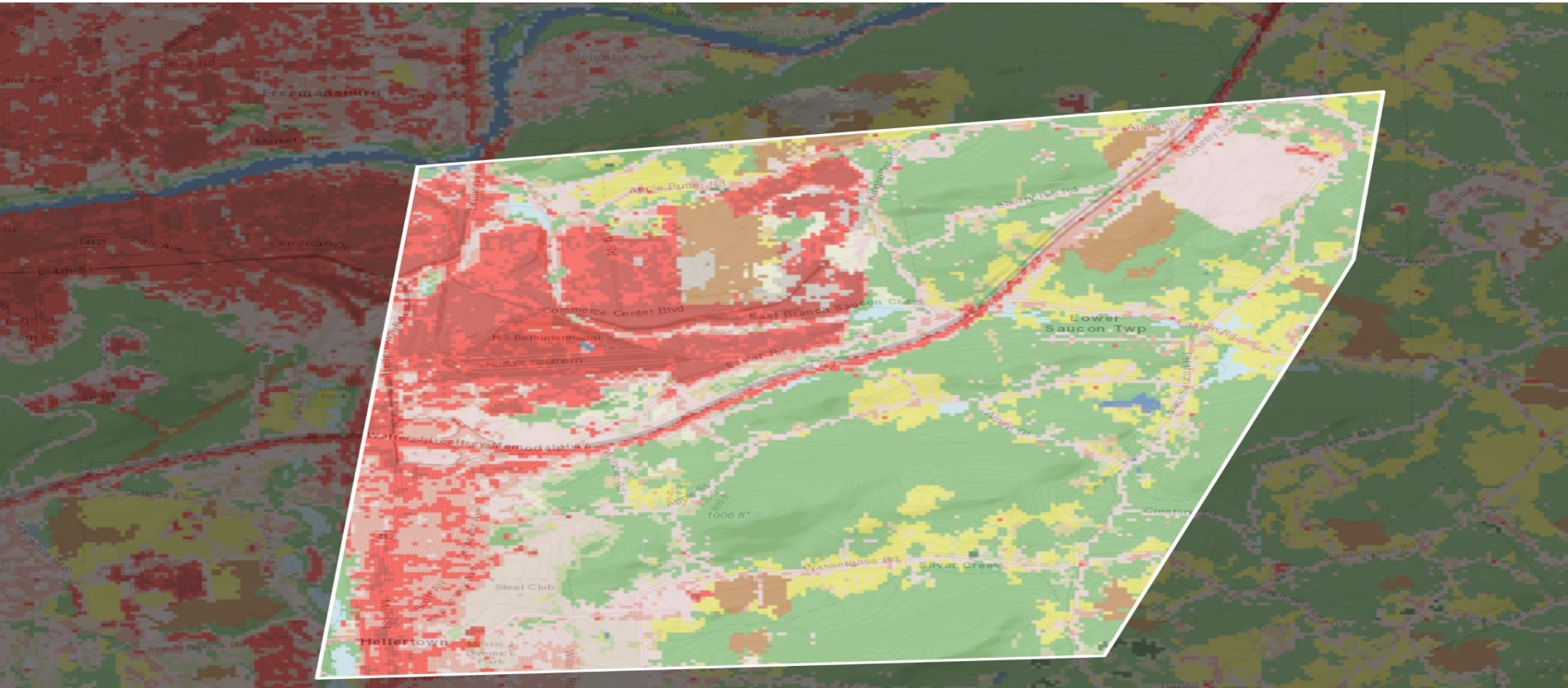




Hypothesis – Follow-Up Tests

If the most concerning tributaries within Saucon Creek's watershed are isolated for further testing, then industrialization/high development of land will be positively correlated with heavy metal toxicity, because runoff stemming from industrial and domestic products has consistently served as a concerning discharged source since the initial planning commission report, and further runoff since then has likely worsened the extent of that.

Model My Watershed Software Outline of Focus Watershed

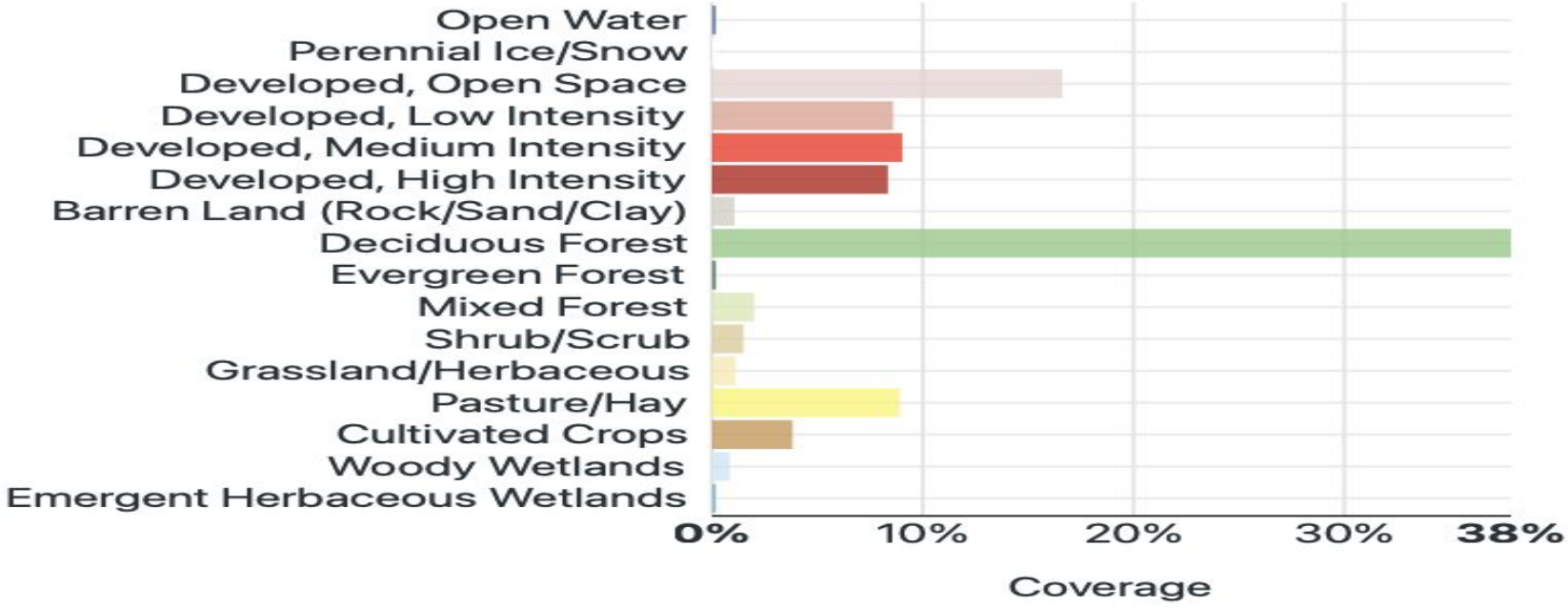


Key and Graph

Land Use/Cover 2019 (NLCD19)

Related Layer: Land Use/Cover 2019 (NLCD19) ✖ Turn off

Source: National Land Cover Database (NLCD 2019) ℹ



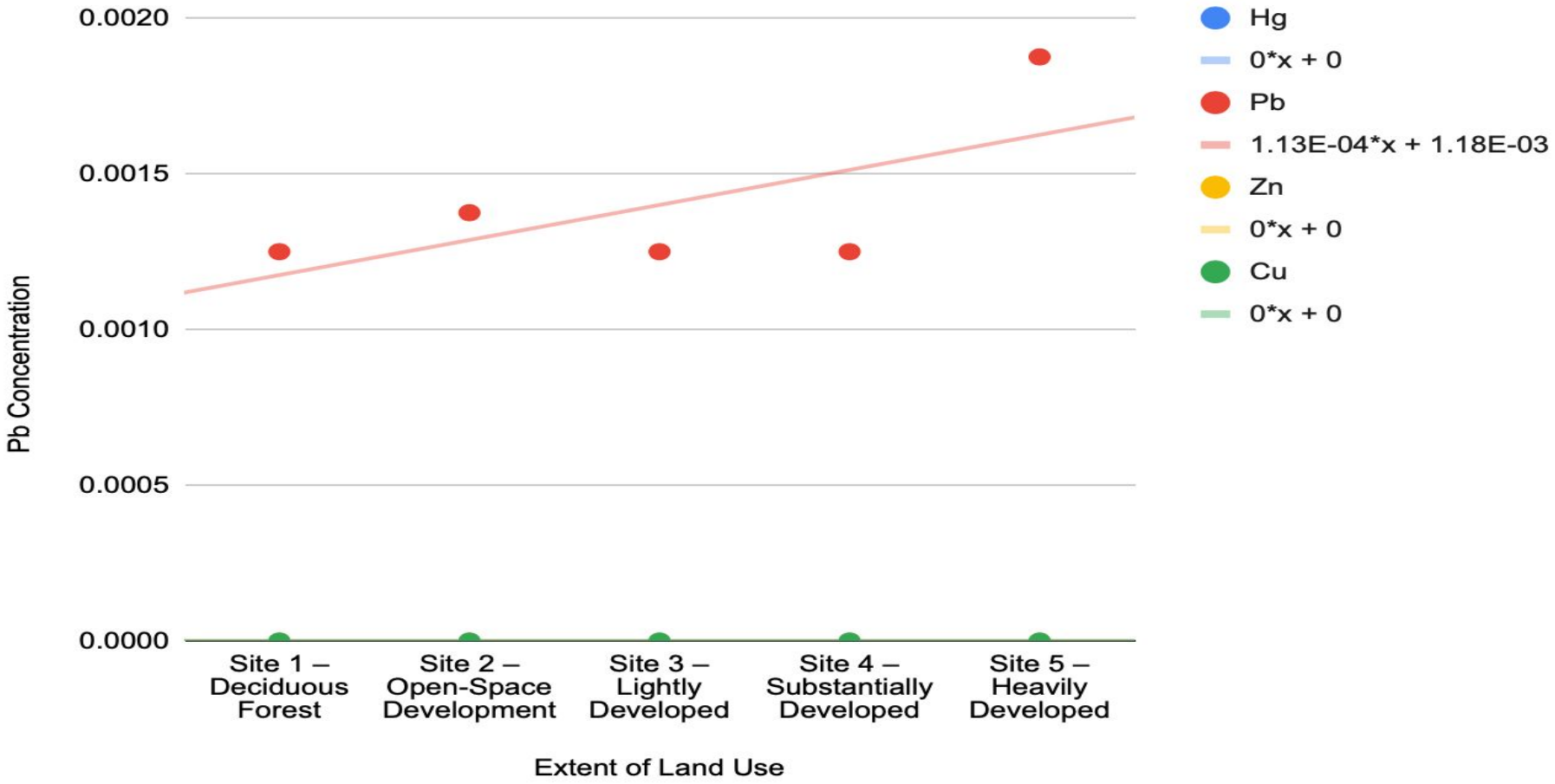
Preliminary Warm-Water Tests–Final Averages

Test Site	East Branch Saucon Creek	Saucon Creek (upstream of Polk Run)	Saucon Creek (upstream of Lehigh River)	Black River	Silver Creek	Polk Valley Run
Hg	0	0	0	0	0	0
Pb	0.015	0.015	0.015	0.015	0.015	0.015
Zn	0	0	0	0	0	0
Cu	0.033	0	0	0	0	0

Pb Concentration in Threatened Watershed Zones

	Test Site	Site 1 – Deciduous Forest	Site 2 – Open-Space Development	Site 3 – Lightly Developed	Site 4 – Substantially Developed	Site 5 – Heavily Developed
Heavy Metal Concentration (mg/L)	Hg	0	0	0	0	0
	Pb	0.00125	0.001375	0.00125	0.00125	0.001875
	Zn	0	0	0	0	0
	Cu	0	0	0	0	0

Pb Concentration vs Extent of Land Use



Conclusions on Both Trials

- Both the initial and follow-up trials' hypotheses were partially correct.
    - The average concentration values obtained for two heavy metals, copper and zinc, were above the EPA's set values for chronic and acute toxicity to aquatic organisms in five of six waterways. Polk Valley Run never displayed evidence of copper or zinc.
    - Follow-up trials revealed a positive correlation between the extent of land use and heavy metal (specifically Pb) concentration and the extent of land use. However, this was not universally true.
- Overall, the results demonstrate the need for greater concern about sediment contamination; however, the situation is not as dire as the hypothesis implied. Most contaminated site: East Branch Saucon Creek.
- Water hardness remained constant at 100 mg/L (considered hard but not very hard water); temperature remained constant.
- Possible sources of error: failure to read test strips properly, failure to conduct multiple sub-tests for each main test, failure to store test strips properly.
- Very promising progress in the reduction of heavy metals was made between trials DESPITE RISING TEMPERATURES, implying a major breakthrough in that area.
    - However, this could potentially owe itself to disparities in the extent of evaporation OR TO ABSORPTION BY SEDIMENT
- Results present of follow-up trials presented a somewhat optimistic reality but serve as a firm reminder about the essence of mindful land use.

Potential Topics for Further Research

- Research of the amount of heavy metals already present in sediment across the watershed could improve the understanding of the extent of the damage already done to the sediment.
- A quantification of sediment loads present in each stream relative to national standards could give insight as to the current state of the watershed.
- Investigating the species aquatic life present in the watershed and determining whether the acute and chronic toxicity values are applicable to any of those species could provide a better understanding of the level of threat faced from heavy metal concentration.

References

Saucon Creek TMDL Alternatives Report - Lvpc.org. 2011, http://www.lvpc.org/pdf/sauconCreekTMDLAlternativesReport.pdf.

“Sediment-Associated Contaminants Active.” Sediment-Associated Contaminants | U.S. Geological Survey, https://www.usgs.gov/mission-areas/water-resources/science/sediment-associated-contaminants.

Zhou, Qiaoqiao, et al. “Total Concentrations and Sources of Heavy Metal Pollution in Global River and Lake Water Bodies from 1972 to 2017.” Global Ecology and Conservation, Elsevier, 23 Jan. 2020, https://www.sciencedirect.com/science/article/pii/S2351989419309357.

Shah, Akesh. “HEAVY METAL IMPACT ON AQUATIC LIFE AND HUMAN HEALTH – AN OVER VIEW“. https://conferences.iaia.org/2017/final-papers/Shah,%20Alkesh%20-%20Heavy%20Metal%20Impacto%20on%20Aquatic%20Life%20and%20Human%20Health.pdf https://sjrr.domains.unf.edu/5-5-metals/.

References Cont.

State of the River Report for the Lower St. Johns River Basin, https://sjrr.domains.unf.edu/5-5-metals/.

Frogner-Kockum, Paul, et al. “Impact of Climate Change on Metal and Suspended Sediment Concentrations in Urban Waters.” Frontiers, Frontiers, 1 Jan. 1AD, https://www.frontiersin.org/articles/10.3389/fenvs.2020.588335/full.

“Water Treatment Solutions.” Lenntech Water Treatment & Purification, https://www.lenntech.com/processes/heavy/.heavy-metals/heavy-metals.htm.

Ambient Water Quality for Lead - Epa.gov. United States Environmental Protection Agency, 1980 https://www.epa.gov/sites/default/files/2019-02/documents/ambient-wqc-lead-1980.pdf.

Aquatic Life Ambient Freshwater Quality Criteria—Copper. United States Environmental Protection Agency, 2007 https://www.epa.gov/sites/default/files/2019-02/documents/al-freshwater-copper-2007-revision.pdf.

References Cont.

Water Quality and Discharge of Streams in the Lehigh River Basin- USGS. 1969, https://pubs.usgs.gov/wsp/1879h/report.pdf.

“National Recommended Water Quality Criteria - Aquatic Life Criteria Table.” EPA, Environmental Protection Agency, https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table.

“Hardness of Water Completed.” Hardness of Water | U.S. Geological Survey, https://www.usgs.gov/special-topics/water-science-school/science/hardness-water.

Zitko, V, and W G Carson. “Mechanism of the Effects of Water Hardness on the Lethality of Heavy Metals to Fish.” Chemosphere; (United Kingdom), 1 Jan. 1976, https://www.osti.gov/etdeweb/biblio/7086599.

“Water Temperature.” Environmental Measurement Systems, 23 Jan. 2019, https://www.fondriest.com/environmental-measurements/parameters/water-quality/water-temperature/.

References Cont.

Ricks, Damon. “The Impact of Lead Water Pollution Toxicity on Aquatic Organisms.” Emerging Researchers National ERN Conference, https://emerging-researchers.org/projects/12999/.

“USE OF COPPER IN MARINE AQUACULTURE AND AQUARIUM SYSTEMS.” FA165/FA165: Use of Copper in Marine Aquaculture and Aquarium Systems, https://edis.ifas.ufl.edu/publication/FA165.

Skidmore, J. F., and Search for more articles by this author. “Toxicity of Zinc Compounds to Aquatic Animals, with Special Reference to Fish: The Quarterly Review of Biology: Vol 39, No 3.” The Quarterly Review of Biology, 1 Sept. 1964, https://www.journals.uchicago.edu/doi/abs/10.1086/404229?journalCode=qrb.