The Mobility of Heavy Metals After Rain Events At Lehigh Gap Nature Center

Morgan Gallagher, Tori Wardamasky, George Yasko, Steve Peters

Background and History

The Palmerton Zinc Superfund site began as two zinc smelting plants owned by New Jersey Zinc Company, a company that contributed 33 million tons of slag and emitted heavy metals into the surrounding environment for nearly 70 years (EPA, 2007). Blue Mountain, an area within the Superfund site, has reported heavy metal concentrations in the soil as high as 1,300 ppm cadmium, 6,474 ppm lead, and 32,085 ppm zinc (Palmerton Citizens, 2003). The Lehigh Gap Nature Center (LGNC), Aquashicola Creek, and the Lehigh River were also impacted by the smelting of heavy metals. LGNC uses natural attenuation to decrease the concentration of metals in the environment. Natural attenuation allows the bioavailable heavy metal concentrations in the soil to decrease slowly over time, relying on naturally occurring physical, chemical or biological processes to bury and immobilize the hazardous elements.

Abstract

To assess the natural attenuation of the heavy metals present at LGNC, we established four sites and one control to measure the mobilization of elements (zinc, lead, cadmium, and arsenic) into the soil. We were particularly interested in the 24-hour period after a rain event and how this affected mobilization. We predicted that heavy rains would expedite the leaching and therefore produce an increased concentration of metals in the soil. We were also interested in how rain water mobilized soluble material off of plant tissue. We conducted our sampling throughout June, July and August of 2013 and analyzed our samples with Inductively Coupled Plasma (ICP) and Excitation Emission Matrix (EEM) to assess metal concentrations and sources of organic carbon.

Methods

To conduct sampling of the leached water, a shallow and deep lysimeter were installed at each of the four sites, and one lysimeter was installed at a control site. The shallow lysimeter was placed in the O-horizon, while the deeper lysimeter was placed in the B-horizon. The control lysimeter was buried beneath rocks rather than soil, which would have collected rainwater rather then leached water. The sample water was extracted out of the lysimeter by using a pump to draw the water out. The field filtered samples were used for ICP while the remainder of the samples (without filtering) was used for EEM analysis. To collect leaf exudates, leaf washes were performed. Leaves from established tree sites were rinsed with DI while still attached to the trees. The collected rinse water was both filtered for ICP and analyzed with EEM.

Mobilization Processes

Heavy metals in the soil can be mobilized by two physical processes. The first is mobilization due to heavy rain events. After a storm event, the elements above ground or in the shallow soils will be leeched down through the organic layer and B-horizon. This is where the second mobilization process will occur. Near or below the B-horizon, elements which include heavy metals, can be uptaken by tree roots. Here the metals are brought up into the leaves where they are stored with other nutrients. Eventually, when the trees drop their leaves, these metals exit as leaf exudates through decomposition and are deposited on the top soil.

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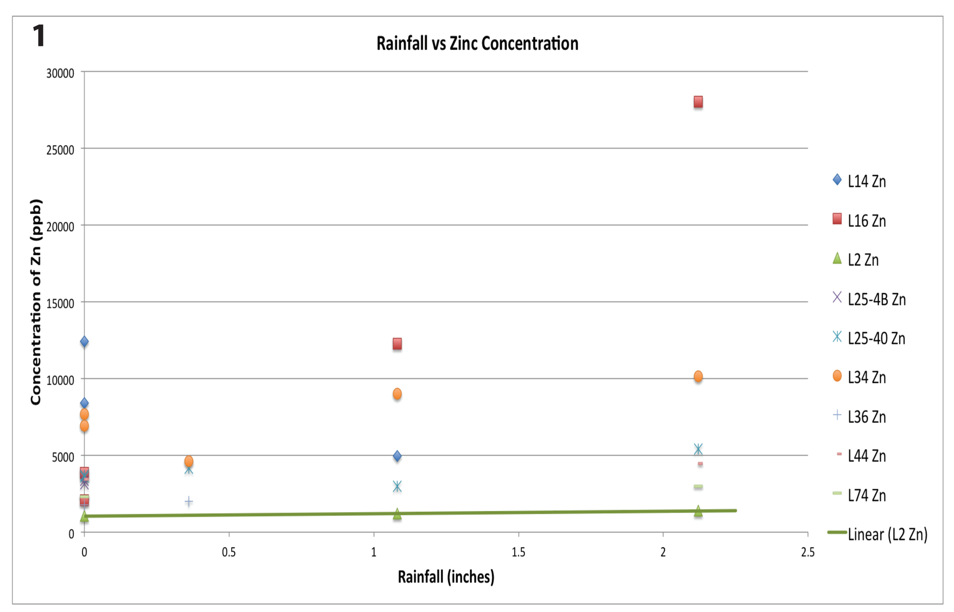

Figure 1 shows the concentrations of zinc sampled from the lysimeters. The green trendline represents the control site (L2).

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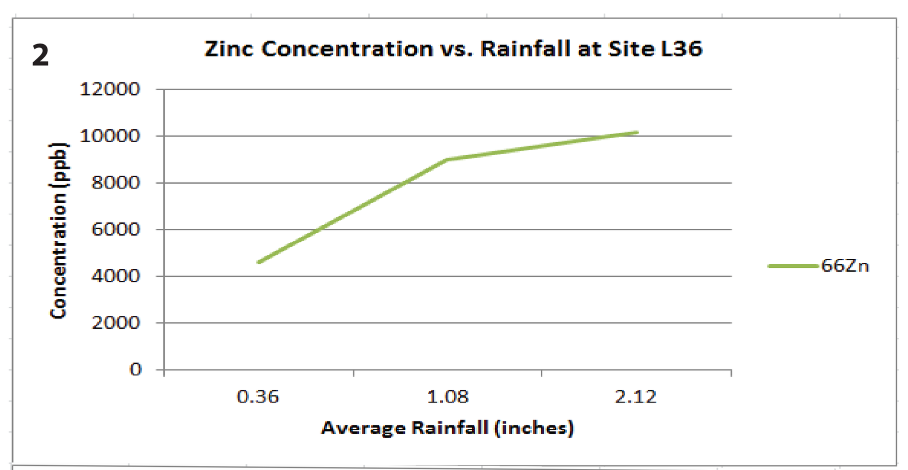

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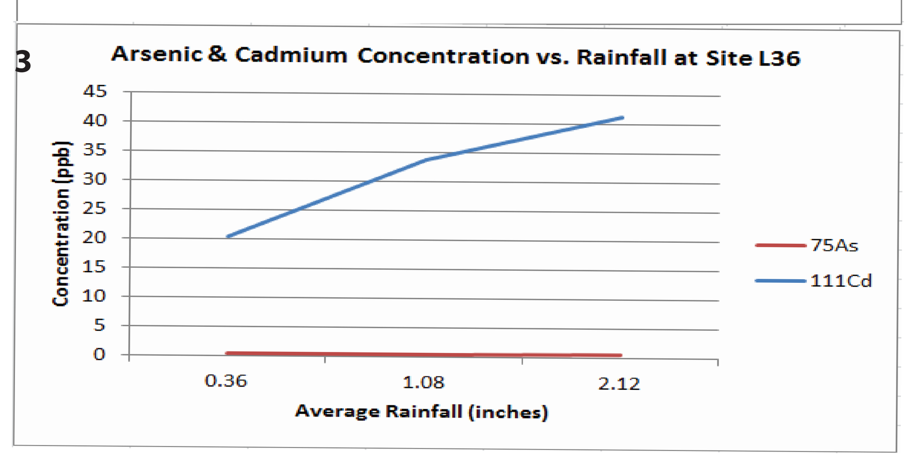

Figure 2 shows the relationship between zinc concentration and rainfall at Site L36 while Figure 3 shows the relationship with cadmium and arsenic. Total daily rainfall is positively correlated with concentration.

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Figure 7 shows the process of removing water from the lysimeters using a vacuum flask and pump.

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Figure 9 demonstrates the leaf wash process

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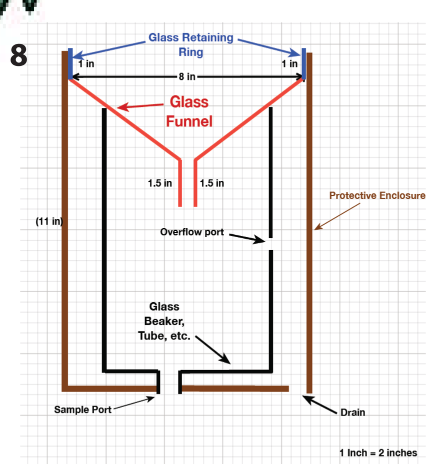

Figure 8 depicts a sketch of the lysimeters installed under the soil to collect water.

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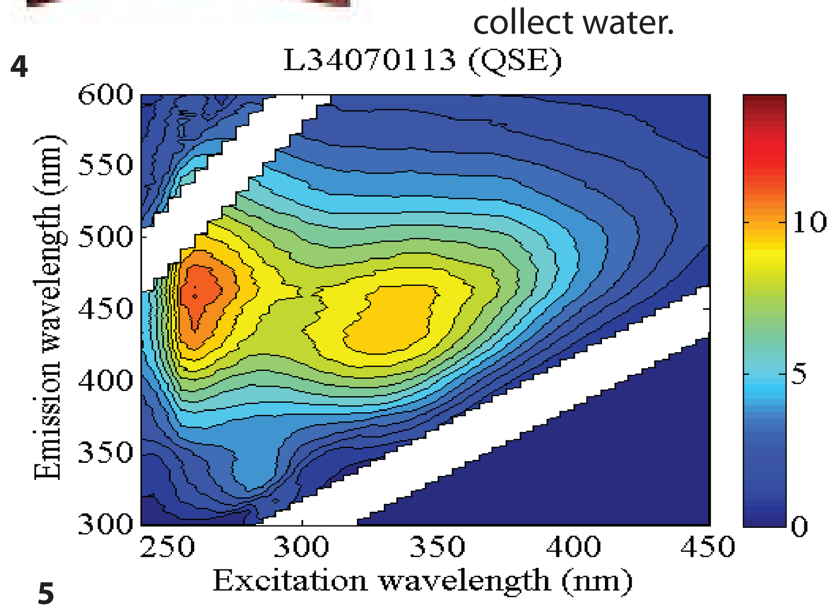

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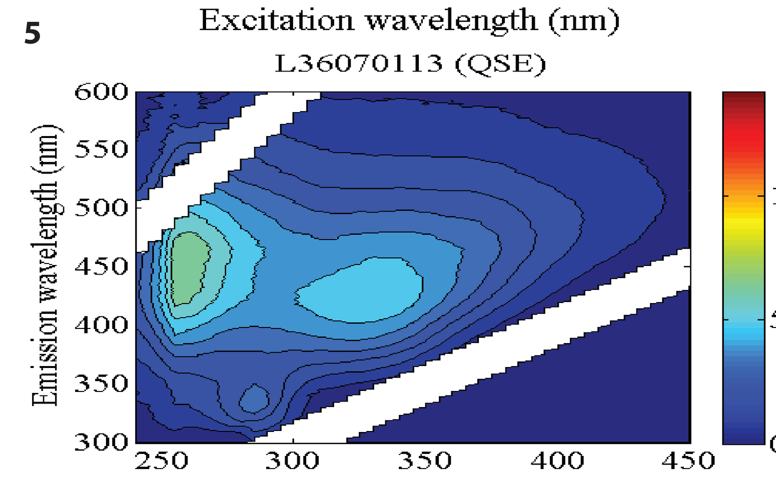

Figure 4 and Figure 5 represent the EEM analyses at O- and B- horizon lysimeters (L34 and L36 respectively) after a rain event. The figures show distinct peaks (A and C) in terrestrial humic material.

Results and Discussion

Two processes can remobilize metals in the soil: plant decomposition and large rain events. Figure 1 depicts a graph of average rainfall versus zinc concentration found in the nine different lysimeters. The control, L2, was buried underneath rocks, while the other eight lysimeters were buried underneath soil (either the O- or B-horizon). As expected, the zinc concentrations found in the lysimeters buried in soil were higher than the ones found in the control. The control site was not surrounded by vegetation and was not exposed to the soil so the water was not able to leach the metals from its surroundings.

The decomposition of leaf litter releases organically-bound nutrients into the soil. A shallow lysimeter would measure the amount of decomposing soil carbon and associate metals contributed by the O-horizon. A deeper lysimeter would measure the net contribution to groundwater from metals already present in the deeper layers of soil. Figure 4 shows the EEM for site L34, one of the shallow lysimeters buried beneath the O-horizon. The L34 EEM has distinct A and C peaks, which are indicators of terrestrial humic. The A and C peaks for the Figure 5 L36 EEM have a much lower intensity since this lysimeter is buried underneath the B-horizon, not the rich, organic layer. We also found that the metal concentrations in the shallow lysimeters were higher than the ones found in the deeper ones, an indicator that the water is leaching the metals primarily from the decaying organic matter in the O-horizon, and not the metals already present in the B-horizon.

Figures 2 and 3 show arsenic, cadmium, and zinc concentrations versus rainfall at site L36. As the average rainfall increases, so do the metal concentrations in the lysimeter water. When shallow soils are inundated during precipitation events, the water will mobilize metals in the shallow soil water and eventually groundwater. During a large heavy rain event we would expect to see a positive correlation between average rainfall and metal correlation.

During a rain event, water can mobilize soluble materials off of plant tissue. In order to mimic this process, we experimented with our leaf wash procedure. However, the results from the leaf wash process were inconclusive and we believe that this method is not the best way to imitate actual rainfall events.

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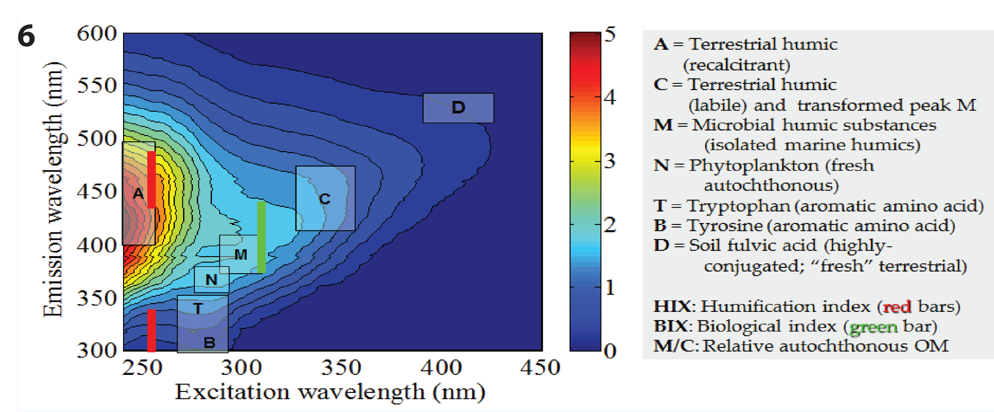

Figure 6 shows the MATLAB output of an EEM analysis with the peaks and their associations

Acknowledgments: Funding for this project was provided by the EI-STEPS Summer Research Program, the Department of Earth and Environmental Sciences, and the Lehigh Earth Observatory (LEO). Rain data for LGNC was provided by Bruce Hargreaves. Thank you to our advisors, Steve Peters and George Yasko, for their continuous guidance and support. We would also like to thank Rachel Henke for her laboratory and field assistance.