PIXE Analysis of Heavy Metals in Soil Along East River

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Introduction

The goal of our current research in the Union College Ion-Beam Analysis Laboratory (UCIBAL) is to use the IBA technique of particle-induced X-ray emission (PIXE) [1] to analyze soil from key locations along the East River in Queens, NY. This project is based on research done in 2017 and 2018 by Sajju Chalise, in which it was noted that soil taken from Astoria Park had a much higher lead content than that taken from Gantry State Park, about 5080 meters away. A comparison of the X-ray spectra taken on the two samples is shown in Figure 1 [2].

It was suspected that the high lead content in the Astoria Park sample may be due to lead-based paint from the Hell Gate Bridge. As shown in Figure 2, the lead content reaches a peak at 0m, right at the Hell Gate Bridge. To determine if the high lead concentration is really associated with the bridge we collected and analyzed soil samples at smaller distance intervals around the bridge.

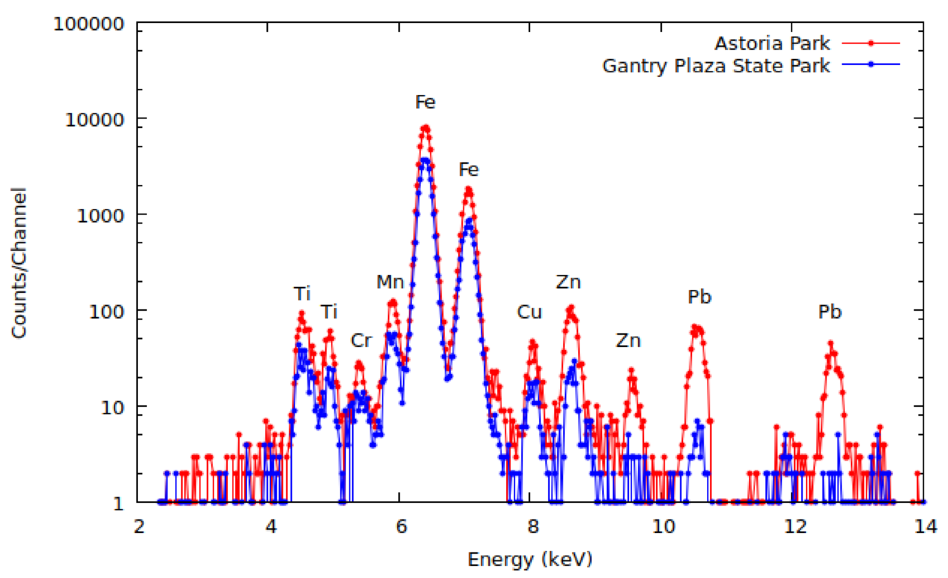

Figure 1: PIXE spectra of soil collected from Astoria Park compared to soil from Gantry State Park.

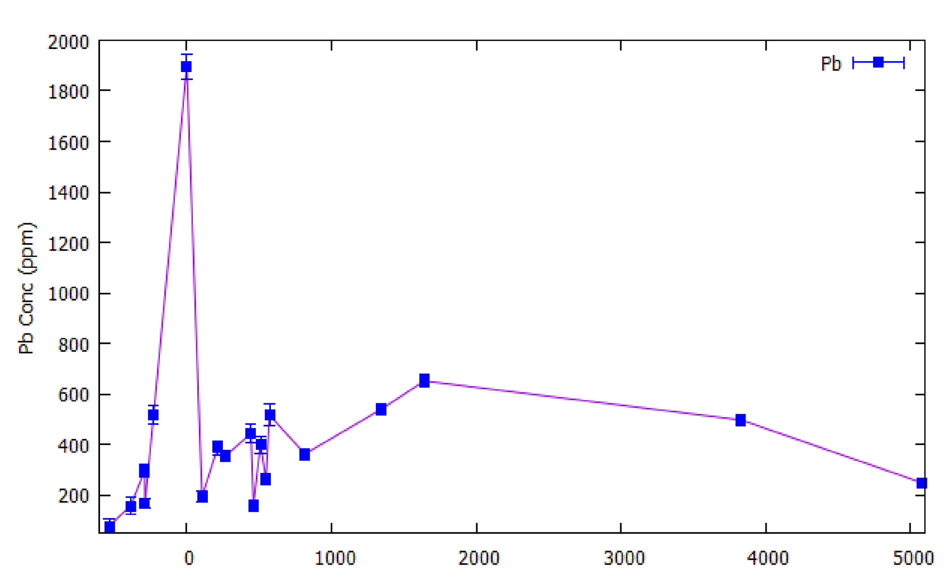

Figure 2: A plot of lead concentration in soil as a function of distance from the Hell Gate Bridge. Negative distance-values correspond to points on the north side of the bridge and positive values correspond to points on the south side.

It is worth noting the potential health risks presented by such a high lead content in soil. According to the CDC, lead-based paint is one of the main causes of lead poisoning in children. Even low levels of lead can result in decreased intelligence, impaired growth and development, and at higher levels it can lead to damage to the nervous system, kidneys, and reproductive system, and even death [3]. All of the lead concentration values in Figure 2 are well over the NYSDEC health-based standard for lead content in soil of 63 ppm [4], and the maximum value of 1897 ppm is over 30 times this standard. This presents a clear health risk, especially to children, who are likely to come into contact with this soil.

PIXE Analysis

We used a PIXE analysis setup to analyze our soil samples. PIXE analysis works by bombarding a sample with a beam of protons. A schematic for a basic PIXE setup used for thin targets is shown in Figure 3. When a proton interacts with the sample, it knocks out an inner shell electron and an outer shell electron falls in to take its place, as shown in Figure 4. The outer shell electrons' transition between energy shells results in the emission of X-rays, which are then measured by the detector. The energies of the X-rays can be used to determine which elements are present in the sample, and the number of X-rays emitted can be used to determine the concentrations of the elements.

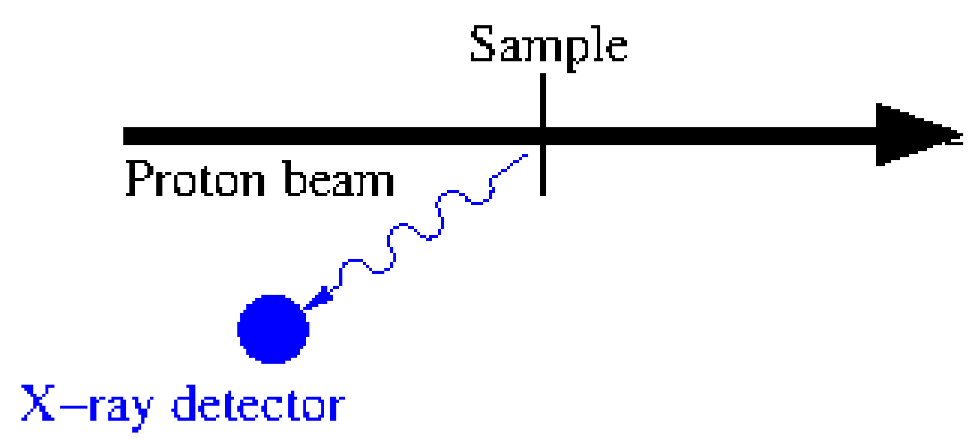

Figure 3: Schematic of a basic PIXE setup for a thin target.

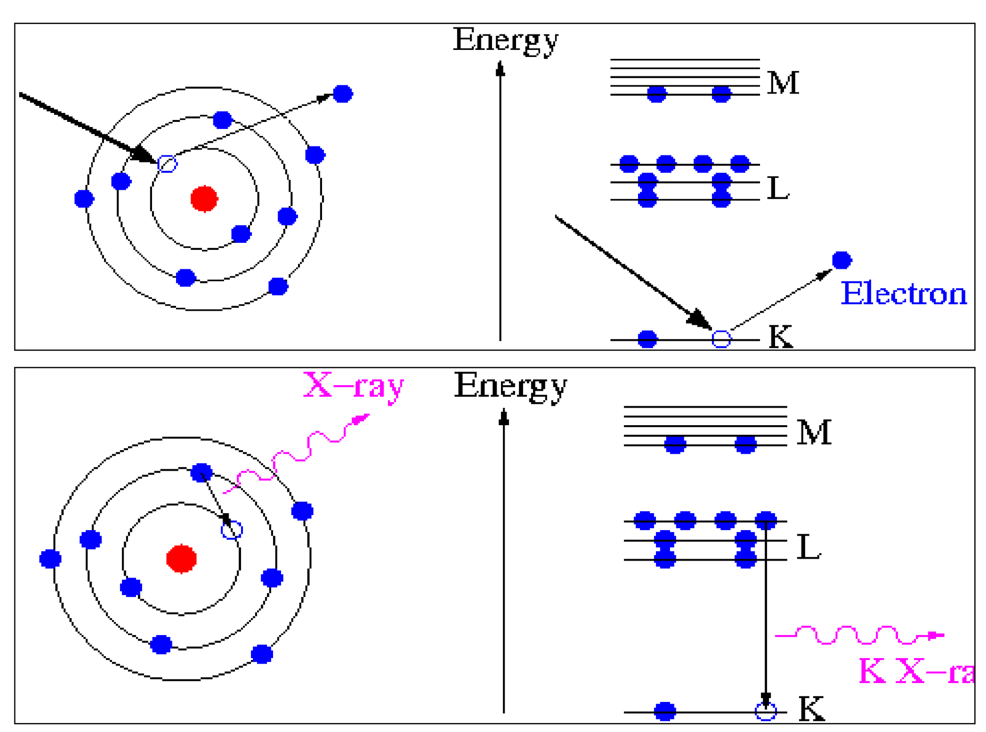

Figure 4: Diagram showing the process by which a proton knocks out an inner shell electron and the void is filled by an outer shell electron in PIXE analysis.

GUPIX

GUPIX for Windows, or GUPIXWIN, is a program used to analyze spectra from the PIXE data and calculate the concentrations of elements within the samples [5]. In GUPIX, the concentration, C_Z, of an element within the sample can be calculated using the formula

$$C_z = \frac{Y_z}{Y_t \cdot H \cdot Q \cdot \varepsilon \cdot T}$$

where Y_Z is the intensity of the principle X-ray line for element Z as determined from the fit to the spectrum, Y_t is the theoretical intensity determined in GUPIX, H is an experimental parameter determined by analyzing data from a set of standards, ε is the detector efficiency, and T is the coefficient for transmission through a filter or absorber between the detector and the target.

Sample Collection

On July 12, 2019, we collected our soil samples from along the East River. In order to determine with greater precision and accuracy the distances between each collection site and the Hell Gate Bridge, we used GPS coordinates from Google Maps, which gave a much more precise location and allowed us to plot the lead concentration as a function of distance with greater accuracy. Figure 5 shows an photograph of the Hell Gate Bridge.

After collection, the soil samples were dried, as shown in Figure 6, then sifted and mechanically shaken for 24 hours to produce a fine powder. Pellets were created by hydraulically pressing 0.5 grams of soil with a few drops of polyvinyl alcohol, then coated with a thin layer of Al in a vacuum evaporator. Figure 7 shows an photograph of the sifted soil samples in jars, as well as some of the pellets that were made from these samples.

Experiment

The PIXE experiments were performed using the Union College 1.1-MV Pelletron accelerator, shown in Figure 8. Proton beams of 2.2 MeV were fired at the sample and emitted X-rays were measured at an angle of 135° relative to the beam. using a silicon drift detector (SDD) after passing through a 56-μm thick Al filter. Figure 9 shows an image of 6 pellets attached to the target ladder, which was then placed at the center of the scattering chamber.

Figure 5: A photograph of the Hell Gate Bridge.

Figure 6: A photograph of a soil sample being dried using a heat lamp.

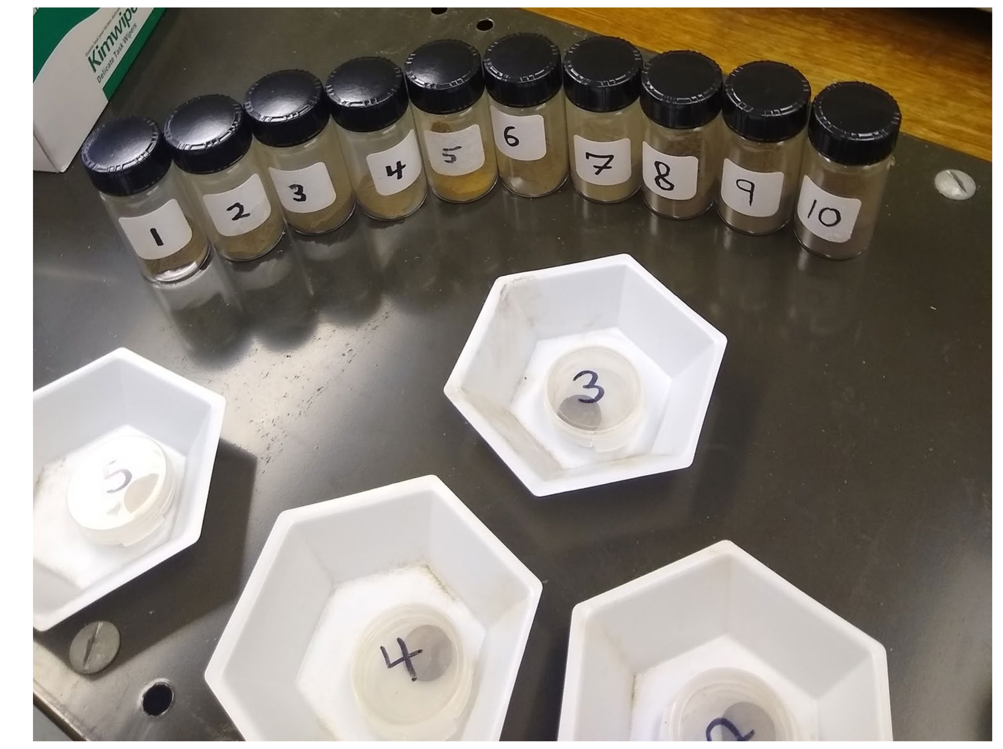

Figure 7: A photograph of soil samples in jars and pellets prepared from these samples.

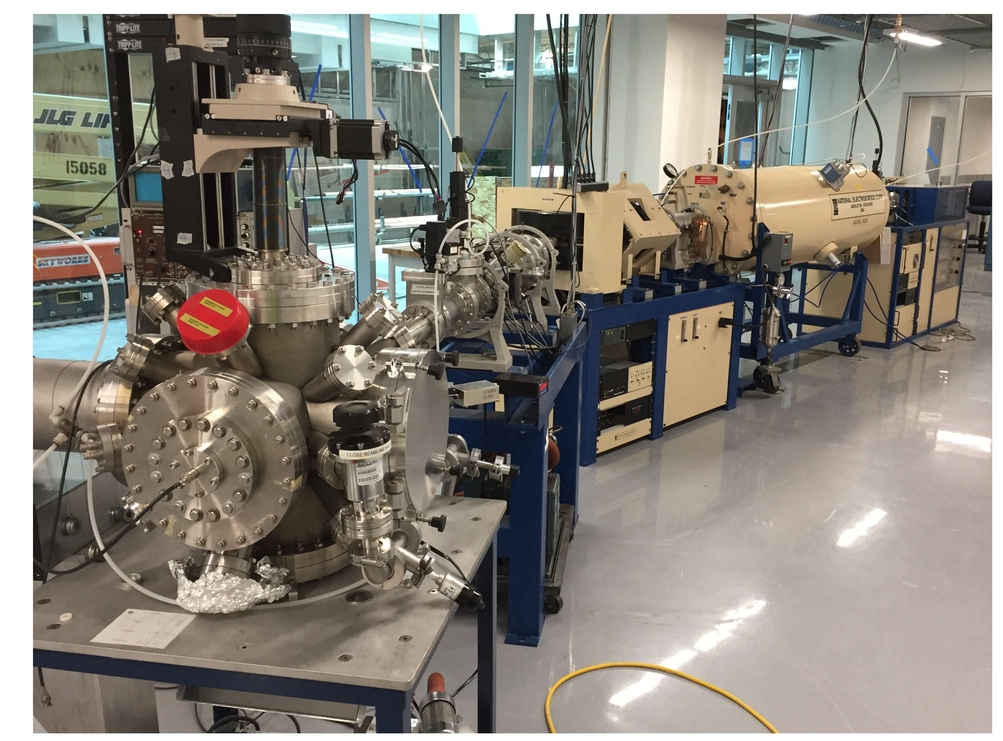

Figure 8: A photograph of the Union College Pelletron accelerator.

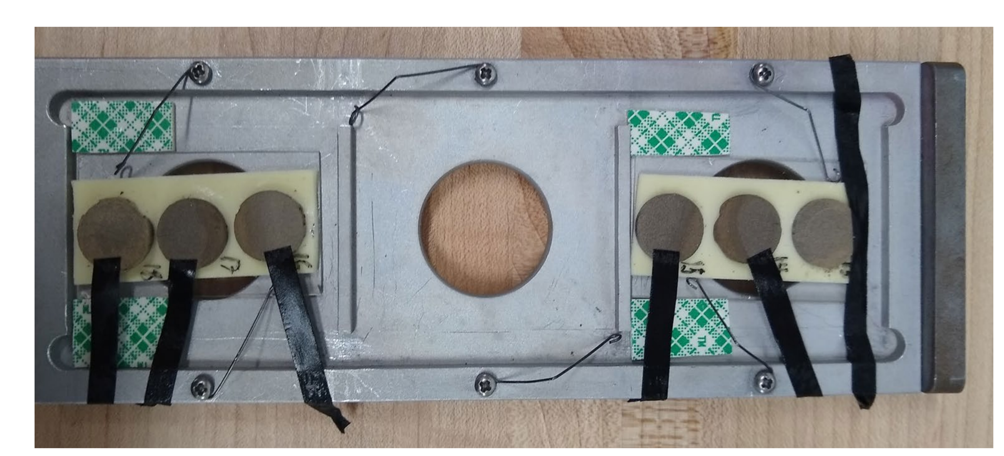

Figure 9: A photograph of 6 pellets attached to the target ladder.

Preliminary Results

According to our data, the lead concentration in the soil appears to be much higher at points closer to the Hell Gate Bridge. This supports the assertion that the high lead content is caused by the lead paint used on the bridge. Figure 10 shows one of the new PIXE spectra for the soil collected at Hell Gate Bridge. Figure 11 shows a plot of lead concentration vs distance from the bridge. Negative distance values correspond to points on the north side of the bridge and positive values correspond to points on the south side.

Future Work

We plan on collecting more soil samples from the south side of the bridge at various distances in order to affirm that the data follows the same trend. We also plan on collecting soil from the other side of the river under the bridge.

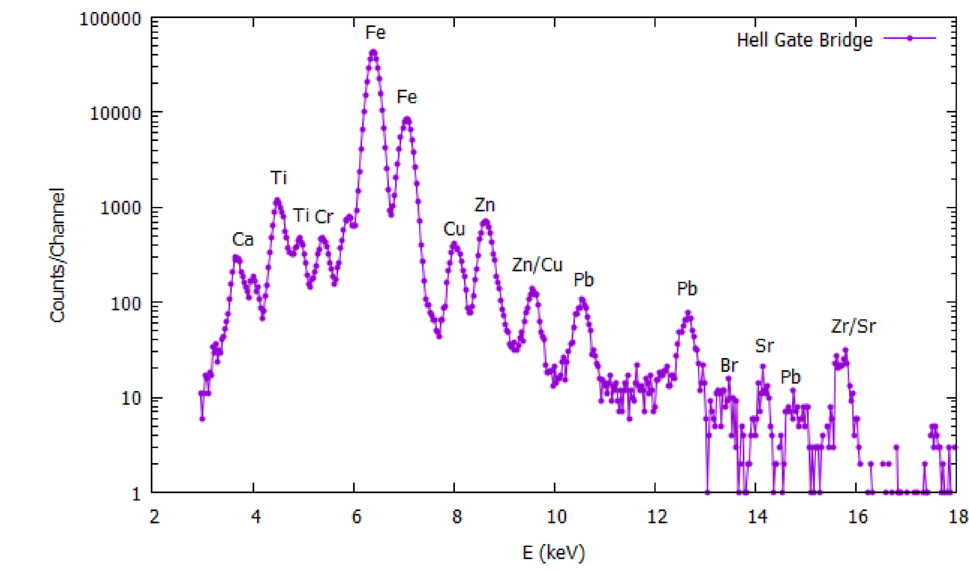

Figure 10: PIXE spectrum of soil collected from directly under the Hell Gate Bridge.

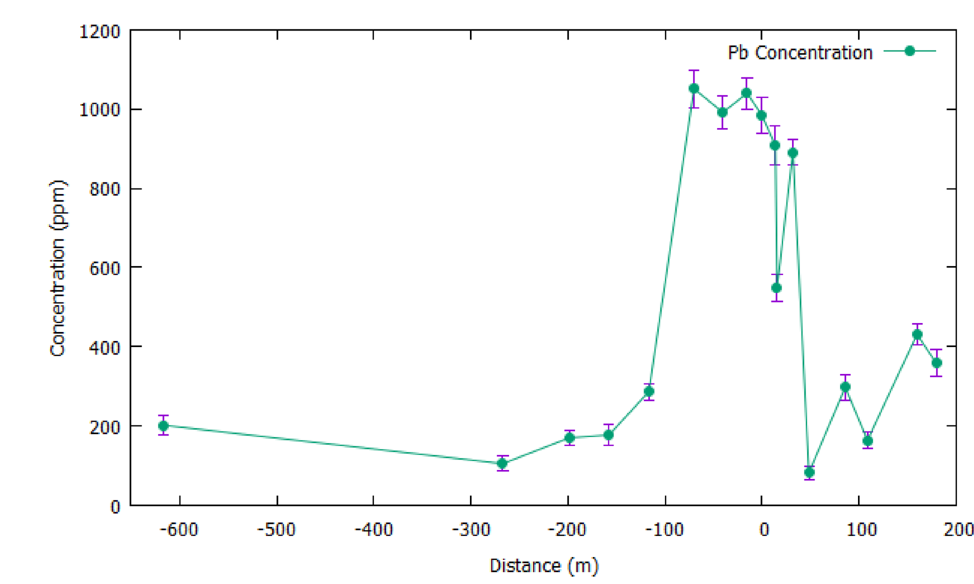

Figure 11: Plot of the lead concentration vs distance from the Hell Gate Bridge.

References

[1] PIXE International Corporation, P.O. Box 2744, Tallahassee, FL 32316 USA, http://pixeintl.com/.

[2] Chalise, Sajju, et al. "Proton Induced X-Ray Emission (PIXE) Analysis to Measure Trace Metals in Soil Along the East River in Queens, NY." Minerva.union.edu, Union College, 2017, minerva.union.edu/vineyarm/research/chalise_dnp_poster.pdf.

[3] "Lead Poisoning in Children." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 15 Feb. 2011, www.cdc.gov/healthcommunication/toolstemplates/entertainmented/tips/LeadPoisoningChildren.html.

[4] New York State Department of Environmental Conservation, 6 NYCRR Part 375, Environmental Remediation Programs, Table 375-6.8 (b), 14 Dec. 2006, https://www.dec.ny.gov/docs/remediation_hudson_pdf/part375.pdf.

[5] GUPIX, University of Guelph, Ontario, Canada, pixe.physics.uoguelph.ca.

Acknowledgements

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