

PIXE Analysis of Atmospheric Aerosol Samples Collected in the Adirondack Mountains



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Introduction

We have performed an elemental analysis of atmospheric aerosol samples collected at Piseco Lake in Upstate New York using proton induced X-ray emission spectroscopy (PIXE). This work is part of a systematic study of airborne pollution in the Adirondack Mountains. Of particular interest is the sulfur content that can contribute to acid rain, a well-documented problem in the Adirondacks.

PIXE Analysis

Proton induced x-ray emission (PIXE) is an Ion-Beam Analysis (IBA) technique in which a sample is bombarded with a proton beam that occasionally will knock out an inner shell electron in the sample [1]. Figure 1 shows a proton ejecting an electron from an atom. An outer shell electron fills the vacancy and in doing so, loses energy in the form of an X-ray as shown in Figure 2. Every element in the periodic table has characteristic X-ray energies associated with the element. The number of characteristic X-rays associated with a certain element corresponds to the concentration of that element in the sample. The concentration C_z of an element Z in the sample can be calculated using the equation

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

where Y_z is the intensity of the principle X-ray line for element Z , Y_t is the theoretical intensity per μC , H is an experimental constant determined by taking data on a set of standards, Q is the measured beam charge incident on the sample, ϵ is the intrinsic efficiency of the detector, and T is the coefficient for transmission through any filters or absorbers between the target and the detector.

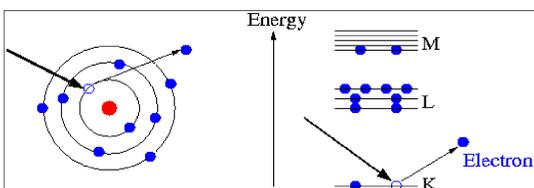


Figure 1: Diagram of the ejection of an inner shell electron by a proton.

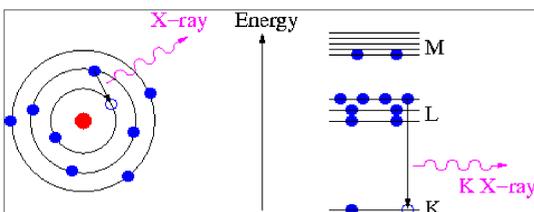


Figure 2: An X-ray is emitted when the vacancy is filled by an outer shell electron.

Sample Collection

The air samples were collected using a nine-stage impactor set up near Piseco Lake, which distributes the particulate matter onto Kapton Foils by particle size [2]. The impactor, which is shown in Figure 3, is attached to a vacuum pump that pulls air through the impactor at a flow rate of 1 L/min. Microscopic images of several impacted foils are shown in Figure 4. The Kapton foils are then used as targets in the particle accelerator. A photograph of the sampling system setup at Piseco Lake is shown in Figure 5.

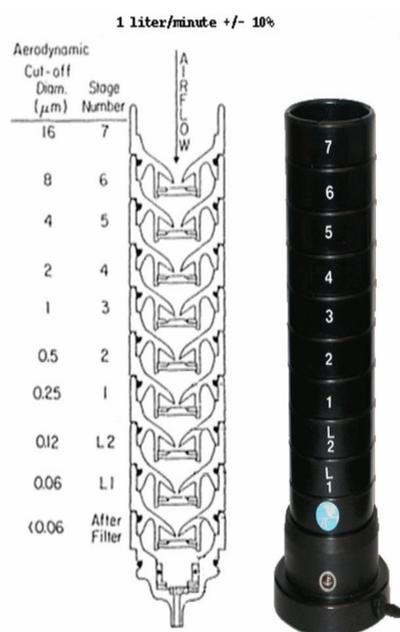


Figure 3: A schematic and photograph of the nine-stage cascade impactor.



Figure 4: Photographs of Kapton foils for PM-0.25, PM-0.5 and PM-4 (left to right).



Figure 5: A photograph of the nine-stage impactor set up near Piseco Lake.

Experiment

The PIXE experiments were performed using the Union College Pelletron Accelerator shown in Figure 6. 2.2-MeV proton beams with diameters of 1-2 mm and currents of 8-12 nA were incident on the samples. The emitted X-rays were detected in the scattering chamber using a silicon drift detector (SDD) after passing through a 76- μm thick Be filter. X-ray energy spectra were acquired for each sample and a set of standards [3].



Figure 6: A photograph of the Union College Pelletron Accelerator.

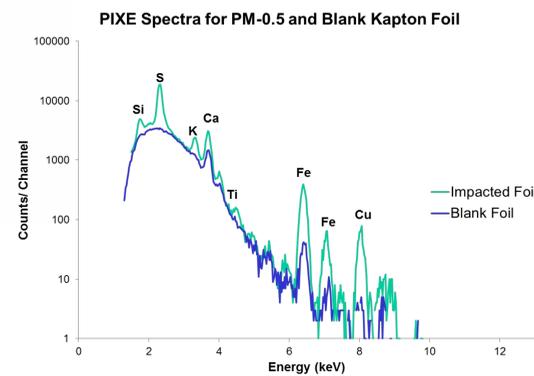


Figure 7: PIXE spectra comparing an impacted Kapton foil for PM-0.5 (Cyan) and a blank Kapton foil (Blue).

Preliminary Results

Figures 7 and 8 compare PIXE spectra for impacted Kapton foils for PM-0.5 and PM-2 (respectively) and a blank Kapton foil. The energy spectra were fitted with GUPIX software in order to determine the concentrations of each element present in the sample [4]. Figure 9 shows the concentrations of elements in the sample in mass per unit area. Significant concentrations of silicon through zinc were measured.

Figure 10 shows the concentrations of sulfur and copper as a function of particle size. The smaller the particle size, the longer the particle can remain suspended in the air. Because there are higher concentrations of sulfur and copper at low particle sizes, it is possible that the sulfur and copper originated from industry as far away as the Midwest and travelled via the prevailing winds to the Adirondacks. In contrast, there are higher concentrations of Si, K, Fe and P in larger particle sizes, as shown in Figure 11. This would suggest that these elements originated in the soil, as the particles would not remain suspended in the air very long due to their size. Figure 12 shows the concentrations of elements in stage 2 in mass per unit volume. When we compare Figure 12 to profiles from industry, coal combustion, motor vehicles, and soil, the high sulfur and copper concentrations are most likely characteristic of industry and coal combustion emissions [5].

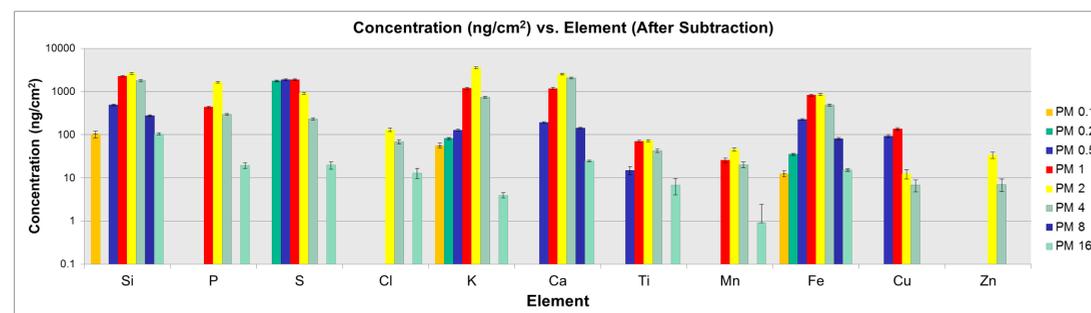


Figure 9: A bar graph of the concentrations of the elements in ng/cm^2 for various particle sizes.

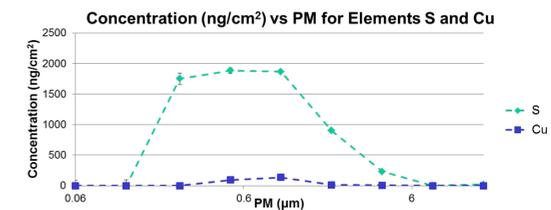


Figure 10: Scatter plot of the concentration of S and Cu in ng/cm^2 vs. PM in μm .

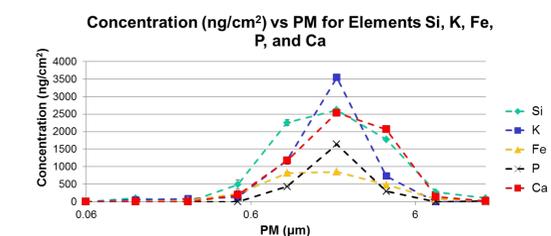


Figure 11: Scatter plot of the concentration of Si, K, Fe, P, and Ca in ng/cm^2 vs. PM in μm .

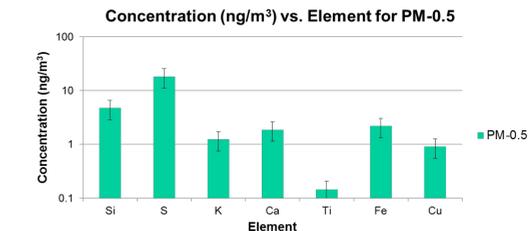


Figure 12: Bar graph of the concentrations in ng/m^3 of the elements in stage 2 only (PM-0.5).

References

- [1] Johansson, Sven, John Campbell, and Klas Malmqvist. *Particle Induced X-ray Emission Spectrometry (PIXE)*. New York, NY: John Wiley & Sons, 1995.
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- [3] MicroMatter Co., 18218 18th Ave. NW, Arlington, WA 98223, U.S.A.
- [4] GUPIX, the versatile PIXE spectrum fitting software, University of Guelph.
- [5] D.D. Cohen, G.M. Bailey and R. Kondepudi, Nucl. Instru. And Math. **B**, 218 (1996).

Acknowledgements

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