Trace Elemental Composition & Concentration of Liquid Precipitation in New York Using PIXE

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Introduction/Motivation

Environmental pollutants from various sources, both natural and anthropogenic, have been found to deposit harmful elements into our environment. These pollutants are generally airborne and eventually find their way into the watershed and soils through rainfall. Plants and animals uptake these pollutants and in high enough quantities are toxic and known to have harmful effects on the human body [1]. Thus it is of great importance to be able to detect and accurately determine the amount of these harmful pollutants and in addition understand the deposition, transport, transportation and uptake of these elements by organisms in the ecosystem.

In order to identify the specific elements found in aerosol, liquid precipitation or soil samples, and thus determine their concentrations, an ion-beam analysis will be performed. There are four main ion-beam analysis techniques, shown in Figure 1, and for our experiment in particular, the non-destructive, highly sensitive, and accurate ion beam analysis technique of Proton Induced X-ray Emission Spectroscopy (*PIXE*) will be performed. *PIXE* is the gold standard in ion-beam analysis and is especially well suited for the analysis of environmental materials[2 - 4] and the *PIXE* process is shown in Figure 2.

Liquid precipitation samples have been collected from Clifton Park and Cold Spring Harbor (both in New York State) and a 1.8-*MeV* beam of protons, generated by an accelerator shown in Figure 3, will used to produce characteristic x-ray spectra. Spectra of x-ray intensity versus x-ray energy will be collected and a *PIXE* analysis will be performed. The presence and concentration of selected trace elemental pollutants will be determined and preliminary results will be presented. Future studies will be performed to further explore the possible sources of these pollutants. In particular an elemental map showing the distribution of elements as a function of geographic area will be created.
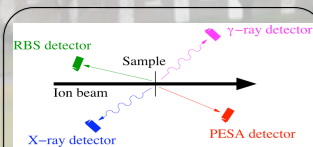

Figure 1- Schematic showing the 4 simultaneous IBA techniques and in particular the *PIXE* process.
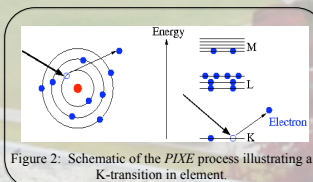

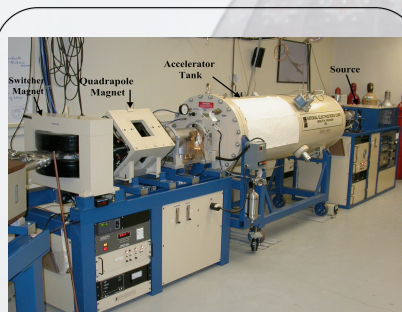Figure 2: Schematic of the *PIXE* process illustrating a K-transition in element.

Figure 3: Photograph of Union College's 1.0-MV tandem electrostatic Pelletron particle accelerator used to generate the 1.8-*MeV* proton beam that will be used to facilitate the *PIXE* process.

Experimental Procedure

Rainwater and snow samples were collected from Clifton Park, NY and Cold Spring Harbor, NY, each season spanning a full year from June 2009 – 2010. Following the method of Ghorai et. al.,[5] approximately *200-mL* of liquid precipitation samples were slowly evaporated, in acid-washed glass, at approximately 70-80°C until *1-mL* of the sample remained. This *1-mL* was deposited onto an approximately *12-μm* thin Mylar film, shown in Figure 4, and further dried in a vacuum desiccator. X-rays produced by the incident proton beam were collected by a silicon drift detector and the resulting spectra of intensity versus x-ray energy were analyzed using GUPIX[6], thus allowing for the determination of the trace elemental composition and concentration of the sample. In order to calibrate GUPIX [6] a set of Micromatter standards [7] were used as shown in the top of Figure 4. The concentrations of these standards was used to normalize the concentrations of the elements found in rainwater.
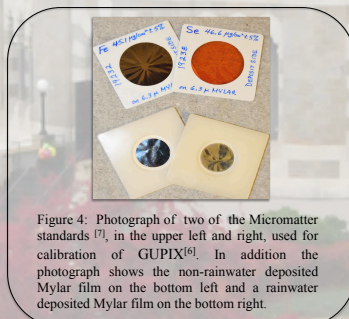

Figure 4: Photograph of two of the Micromatter standards [7], in the upper left and right, used for calibration of GUPIX[6]. In addition the photograph shows the non-rainwater deposited Mylar film on the bottom left and a rainwater deposited Mylar film on the bottom right.
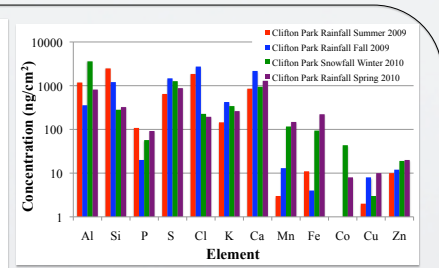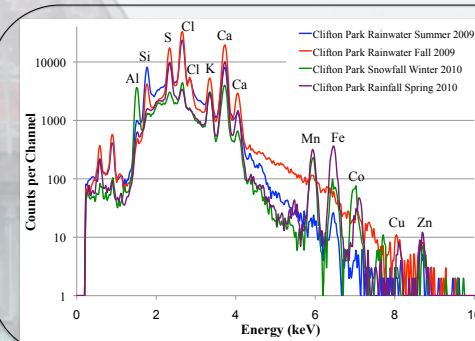

Figure 5: PIXE spectra of liquid precipitation data for Clifton Park, NY, spanning the seasons from June 2009 – June 2010 accompanied by the variation in elemental concentration (in ng/cm²) as seen by season.
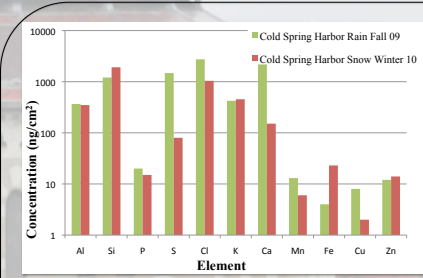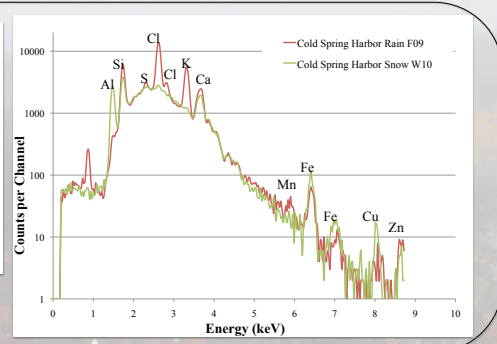

Figure 6: Variation in elemental composition (in ng/cm²) for liquid precipitation in Cold Spring Harbor accompanied by the PIXE spectral data ranging from the fall 2009 – winter 2010 seasons.

Preliminary Results

We have successfully developed a technique to analyze liquid precipitation samples for their elemental composition. Figures 5 & 6 show the raw data collected by the x-ray detector for Clifton Park and Cold Spring Harbor, and are displayed as the intensity of the x-rays as a function of their energy. We see that there are clear variations in concentrations of the trace elements by geographic area. Figure 5 shows data collected by over a span of four seasons. We see some variation in the concentration among the elements, such as Mn, Fe, and Co while others like S, Ca, and Zn remain relatively constant. Comparing with Figure 6, it appears that the samples farther from the ocean exhibit a greater concentration of light elements. It is interesting to note the presence of Co in the Clifton Park spectra, though more analysis is needed as to reproducibility and a cause. In Figure 6 we note that most elemental concentrations are relatively constant, but large differences are seen in some elements, such as S, Ca, and Fe.

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