PIXE Analysis of Crematoria Emissions

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Introduction

Many communities have raised concerns about particulate mercury emissions from cremations that could have adverse health effects [1]. Amalgam fillings containing mercury were used in dentistry during the population boom. Now that cremations have become a widely accepted practice and many people with these fillings are being cremated, communities have become increasingly concerned about possible mercury poisoning through inhalation. In this experiment, we analyze aerosol samples from cremation exhaust to determine the concentration of inhalable mercury present.

PIXE

Particle Induced X-ray Emission (PIXE) is an ion beam analysis technique used to measure the concentration of a broad range of elements in environmental samples. A typical set-up uses a high energy proton beam incident on a sample to induce x-ray emissions (Fig. 1). The beam causes an inner shell electron to be ejected (Fig. 2). An electron of higher energy fills the vacancy and releases its energy by emitting an x-ray (Fig. 3). The emitted x-rays have unique energies that are characteristic to each element, and thus the composition of the target can be determined. The concentration of a particular element can be determined by

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

where Y_t is the theoretical x-ray intensity, Y_z is the sample x-ray intensity, Q is the charge collected, ε is the efficiency of the detector, T is the coefficient of transmission for x-rays through any absorbers between the target and the detector, and H is the experimental constant determined by running on standards [2].

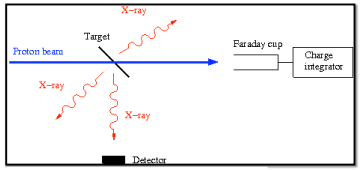

Figure 1. A diagram of a basic PIXE experimental set-up.

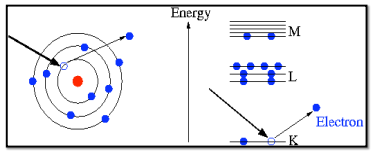

Figure 2. A diagram of the ejection of an inner shell electron by a proton.

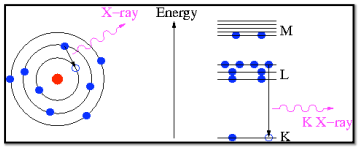

Figure 3. The emission of an x-ray as a higher shell electron fills the inner shell vacancy.

Sample Collection

We used the PIXE International Cascade Impactor (Fig. 4) [3] to collect aerosol samples on the roof of the crematorium at Vale Cemetery in Schenectady, NY. The impactor was placed one meter away from the cremation exhaust stack (Fig. 5). A vacuum pump drew air through the impactor's ten stages, each designed to collect different sized particles (Fig. 4). The Kapton impaction foils were weighed before and after the samples were collected. We also took magnified images of the impacted foils and measured the area of particulate matter deposited on each filter (Fig. 6).

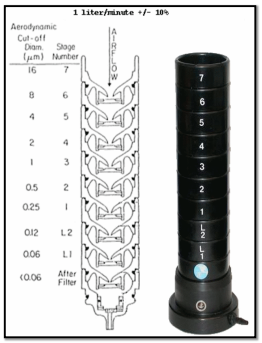

Figure 4. Schematic Diagram of the cross-section and a photograph of the International Cascade Impactor [3].

Figure 5. A picture of the cascade impactor on the roof of the crematorium Vale Cemetery. In Schenectady, NY.

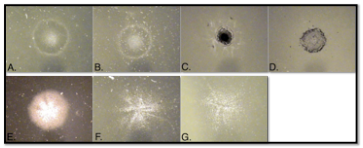

Figure 6. Photographs of the impaction foils after sample collection. Panels A-G are for Stages L1 to 5.

Experiment

The PIXE measurements were made using 2-MeV proton beams from the Union College Pellletron Accelerator (Fig. 7). Beams with currents of 5-10 nA were incident on the samples at the center of a small scattering chamber and the X-rays were measured with a silicon drift detector (Fig. 8). The beam current and total charge incident on the samples were measured using a Faraday cup. Data were also taken on a set of standards.

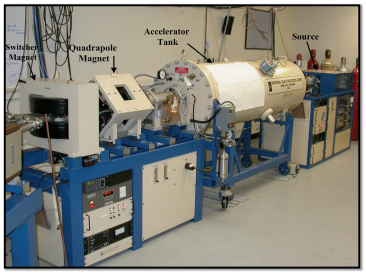

Figure 7. A picture of the Union College Pelletron Accelerator.

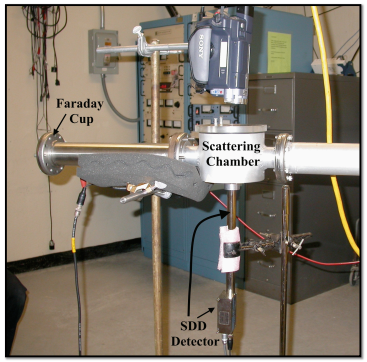

Figure 8. A picture of the PIXE chamber and Silicon Drift Detector.

Preliminary Results

Preliminary results are presented in Figures 9-11. Figure 9 shows a PIXE spectrum taken on an iron standard. Shown in Figures 10 and 11 are spectra taken on foils impacted with particles of size 0.5-1 microns and 2-4 microns, respectively. The red spectrum shown in the figures was taken on a blank Kapton foil. A number of elements from sulfur to bromine can be identified in the spectra, but there is no indication of the presence of mercury. The L-alpha X-ray from mercury has an energy of about 9.9 keV.

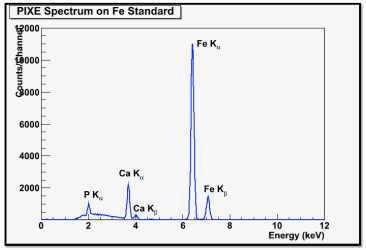

Figure 9. A PIXE spectra taken on an iron standard.

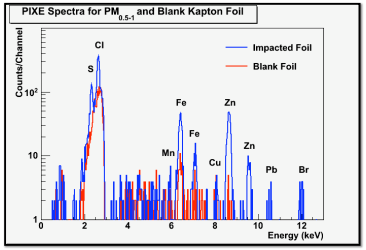

Figure 10. Pixe spectra taken on blank kapton foil (red) and a foil impacted with particulate matter between 0.5-1.0 micron in size (blue).

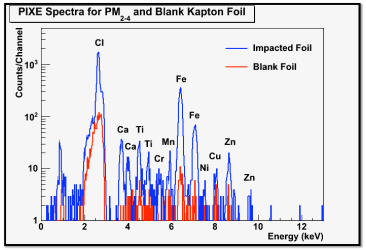

Figure 11. Pixe spectra taken on blank kapton foil (red) and a foil impacted with particulate matter between 2.0-4.0 microns in size (blue).

Future Work

We will take more detailed PIXE spectra and use GUPIX software [4] to perform a quantitative analysis to determine the concentration of all elements present and the upper limit of the possible mercury concentration.

References

[1] Summary of references on mercury emissions from crematoria. www.ejnet.org, November 3, 2008.

[2] Johansson, Sven, et Al. Particle-Induced X-ray Emission Spectrometry. John Wiley & Sons, Inc. New York. 1995.

[3] Pixe International. http://www.pixeintl.com/.

[4]. Gupix and Gupixwin. University of Guelph. http://pixe.physics.uoguelph.ca/gupix/main/.