Determining PFAS Contamination From Firefighting Foam Using PIGE and PIXE

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Introduction

- Pollution is a serious problem on our planet, particularly environmental pollution.
- PFAS, or per- and poly-fluoralkyl substances, along with heavy metals like lead, are of particular concern
- The carbon-fluorine covalent bond of PFAS allows them to not only be resistant to water and oil, but also very persistent and damaging in the environment.
- Class B firefighting foams, which are used to suppress car and aircraft fires, or any highly flammable and high hazard liquid fires [1], contain PFAS, and thus runoff from these foams have become a serious issue.
- We investigated class B firefighting foams for the presence of PFAS by looking for fluorine, a key indicator of PFAS.

PIGE and PIXE

- **PIGE**, or proton-induced gamma-ray emission, is a form of nuclear reaction analysis and utilizes a high energy ion beam. Figure 1 above shows the process; in light elements, the proton can get close to the nucleus, putting it in an excited state, A*. Then the nucleus deexcites by emitting a gamma-ray with an energy characteristic of the nucleus the proton interacted with [2].
- **PIXE**, or proton-induced X-ray emission, is also nuclear reaction analysis using a high energy ion beam. As seen in Figure 2, it sends protons through the test material, and they lose energy by exciting electrons in the material, so the inner electrons are ejected, and the outers move in to fill the vacancies, and are accompanied by the emission of X-rays with a characteristic energy that identifies heavier elements in the material [3]

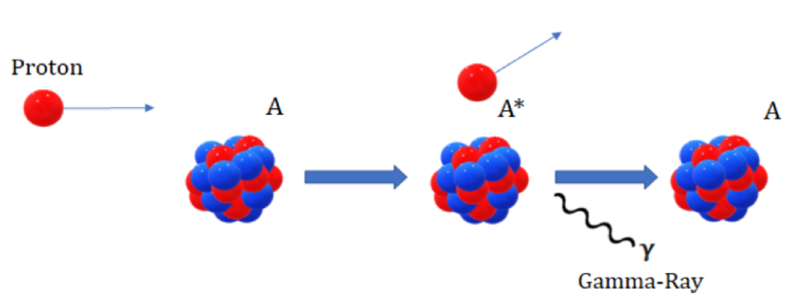

Figure 1: Schematic of PIGE process [2]

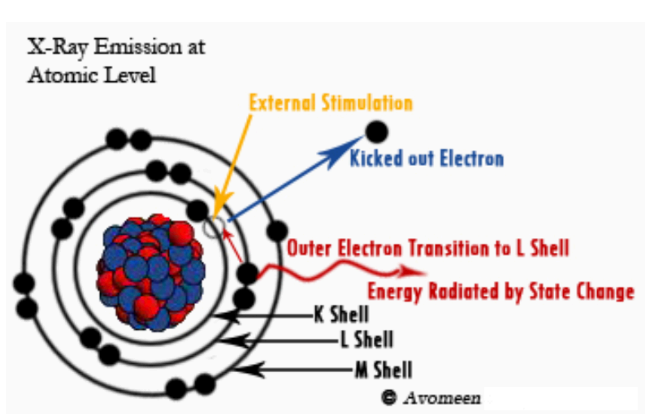

Figure 2: Schematic of PIXE process [4]

Experimental Method

- We investigated firefighting foams for fluorine and heavy metals using PIGE and PIXE by generating a 2.2 MeV proton beam using the 1.1 MV tandem Pelletron accelerator (Figure 3) in the Union College Ion Beam Analysis Laboratory (UCIBAL).
- Fluorinated standards with known concentrations were made by combining various masses of NaF with cellulose binder to form 0.5g pellets, and results of PIGE analysis on these pellets are shown in Figure 5.
- Figure 5 shows presence of fluorine (110 and 197 keV peaks)
- Wanted to confirm the presence of PFAS in firefighting foam sample obtained from Rotterdam Fire Facility, made targets of dried foam and cellulose binder, results of PIGE analysis shown in Figure 7.
- Next we wanted field samples; went to Rotterdam fire training facility and took 18 soil samples, map shown above in Figure 5.
- Soil was dried, sifted, and pressed into 0.5g pellets using polyvinyl as the binding agent.
- Performed both PIGE and PIXE on soil samples.

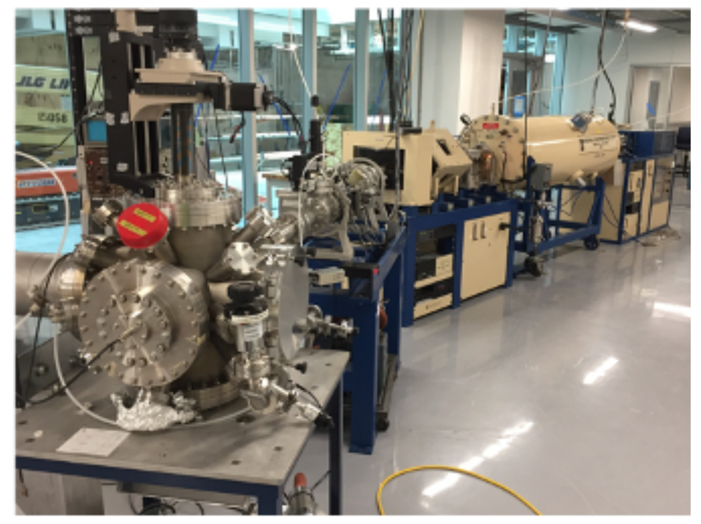

Figure 3: Photograph of tandem Pelletron accelerator in UCIBAL

Figure 4: Firefighting foam targets of varying concentrations of NaF and cellulose binder

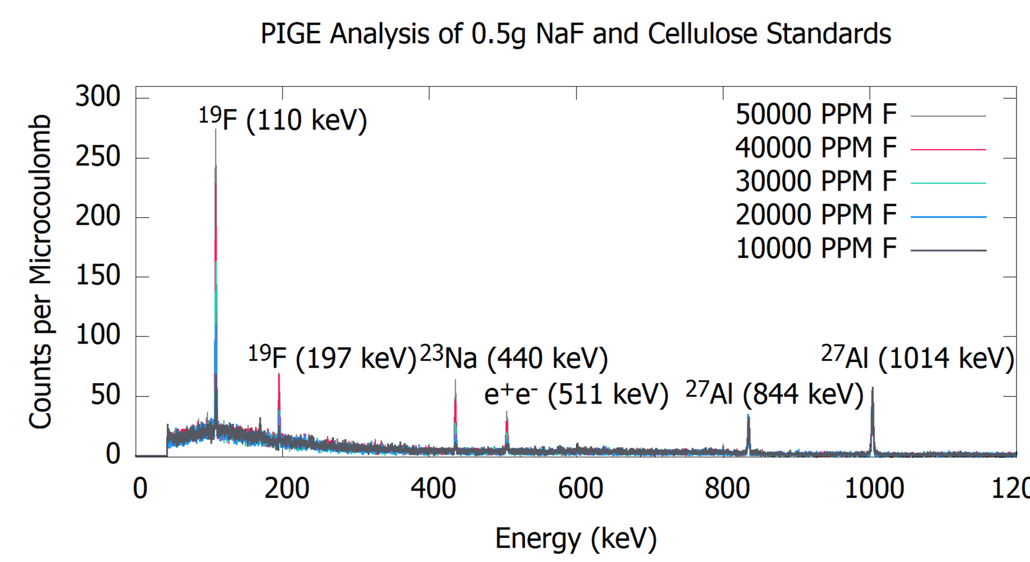

Figure 5: Normalized intensity vs gamma-ray energy spectra for NaF and cellulose standards

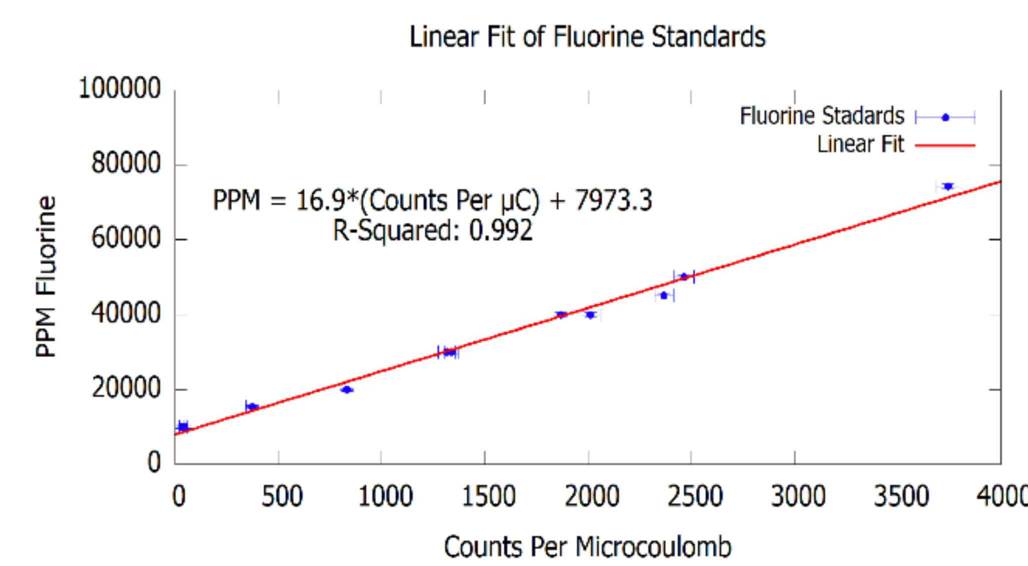

Figure 6: Linear fit for 11 NaF and cellulose standards ranging from 10000 to 75000 ppm

No.	Samples at location
1.	1,2,3,4,5,6,7,12
2.	8
3.	9,11
4.	13
5.	14
6.	10
7.	15
8.	16,17
9.	18

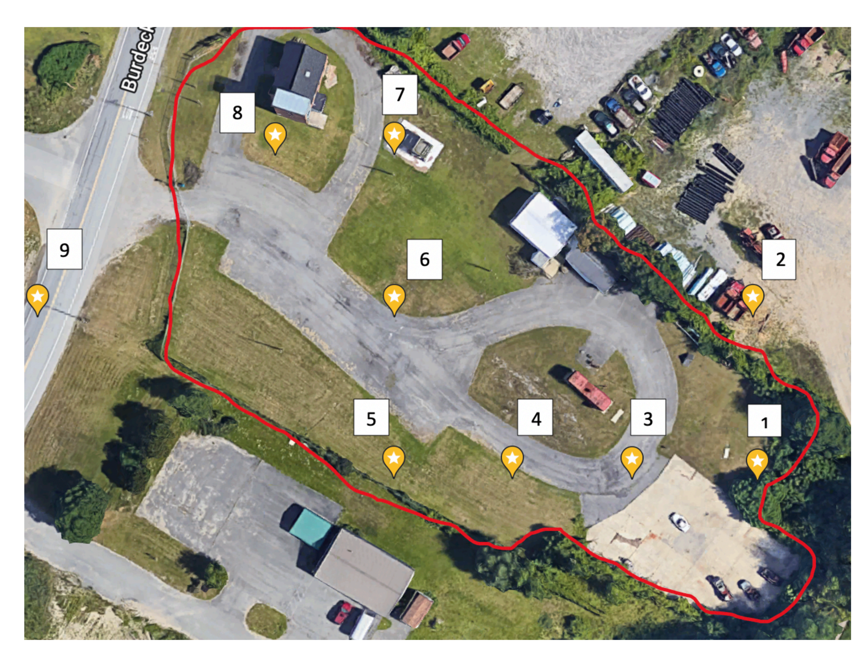

Figure 7: Map of collected samples area

References

[1] "Basic Information on PFAS." *EPA*, Environmental Protection Agency, 6 Dec. 2018, www.epa.gov/pfas/basic-information-pfas.

[2] "Development of a System to Screen for PFAS Chemicals using PIGE at Union College", Colin Langton, et. Al, Union College Summer Research Poster, 2019, http://minerva.union.edu/vineyarm/research/langton_poster_ceu_2019.pdf.

[3] "Particle-Induced X-Ray Emission and Rutherford Backscattering." *Ceric*, 17 Sept. 2020, https://www.ceric-eric.eu/lab-instrument/particle-induced-x-ray-emission-and-Rutherford-backscattering/.

[4] "Proton Induced X-Ray Emission (PIXE) Analysis White Paper." Avomeen, https://www.avomeen.com

Results

- From Figure 5 a relationship was developed between the known concentration of the NaF standards and the normalized intensity of gamma-rays for the 110 keV peak, and this is shown in the plot in Figure 6.
- Figure 8 shows a clear presence of fluorine in the fire foams.
- Figure 9 is the raw spectrum data for the PIGE run on sample 1. We can see a small but clear peak at 110 keV, indicating that fluorine is indeed present in the sample.
- Figure 10 is the raw PIXE spectrum for sample 16, and this shows a clear presence of lead.

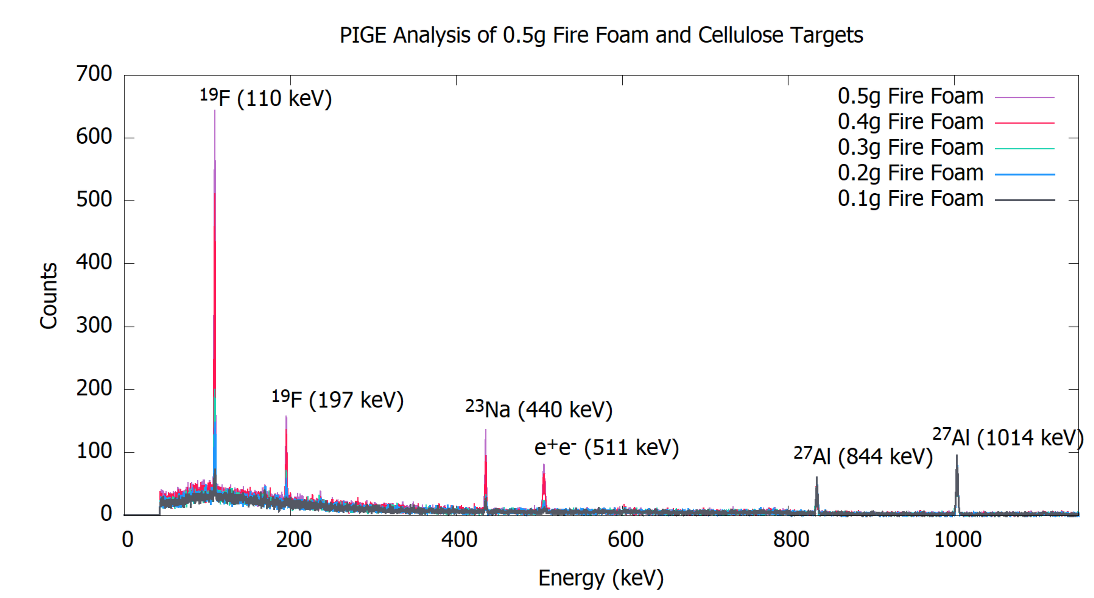

Figure 8: Normalized intensity vs gamma-ray energy spectra for firefighting foam targets

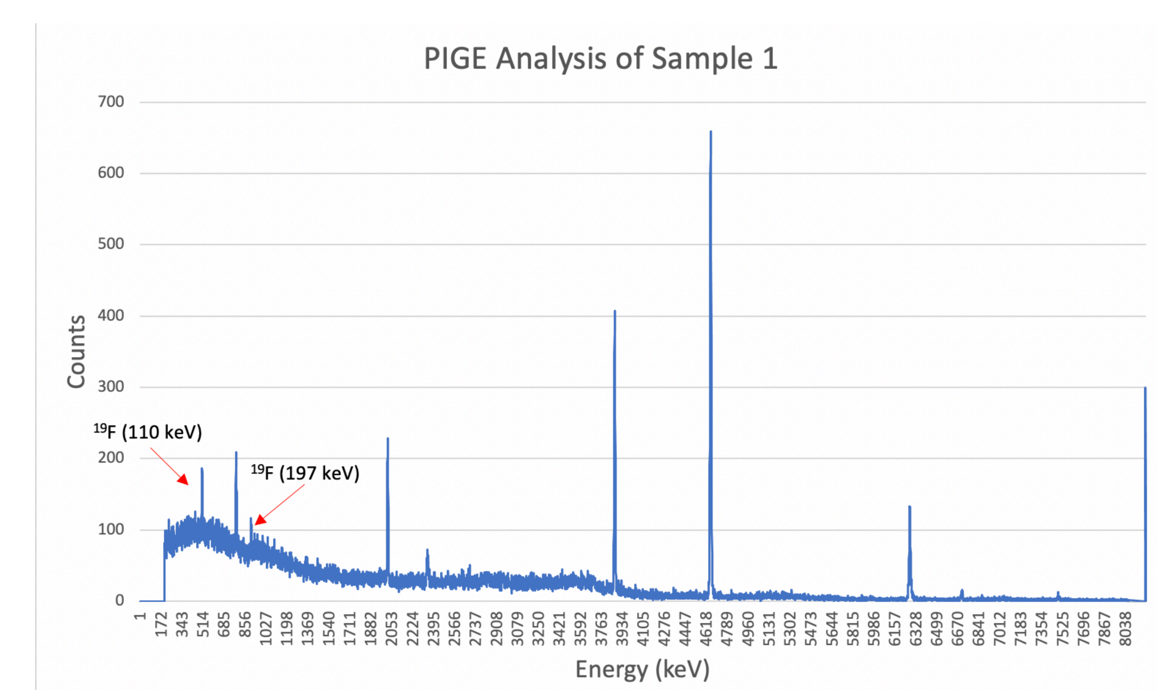

Figure 9: PIGE spectrum for sample 1 showing presence of fluorine

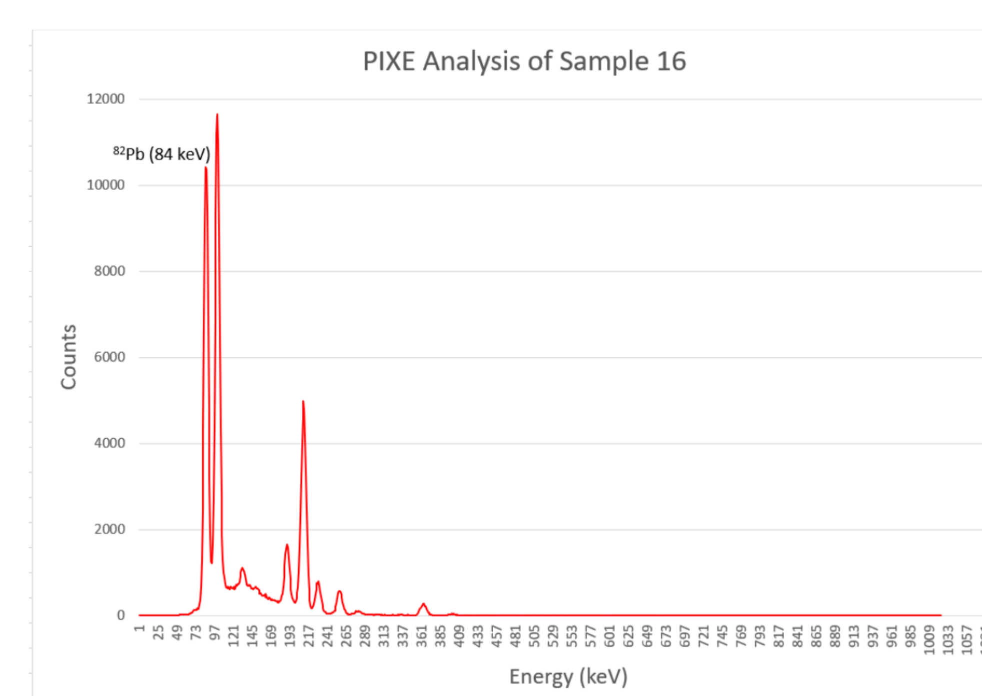

Figure 10: PIXE spectrum for sample 16 showing presence of lead

Acknowledgements

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