

Introduction

There has been considerable concern in recent years that artificial turf may be unsafe [1]. We are performing PIXE and PIGE analysis of artificial turf blades and in-fill samples to search for possibly toxic substances. The samples are bombarded with proton beams from the 1.1-MV Pelletron tandem accelerator and the emitted X-rays and gamma-rays are measured with Si drift and CdTe detectors, respectively.

Previous Work

Some preliminary measurements were performed using an external beam facility which allows us to analyze samples that cannot be put into the vacuum chamber.



Figure 1: A photo of a square of 7.5 micron thick Kapton foil used for the window of the external beam facility.



Figure 2: A photo of a 2.2 MeV proton beam in air.

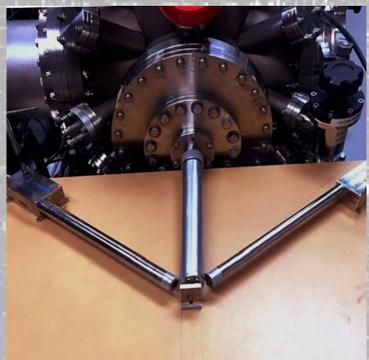


Figure 3: A photo of the external beam facility showing the beam pipe, target holder, and detectors.

Samples



Figure 4: A photo of a clump of turf infill.



Figure 5: A photo of the different color turf blades coated in gold and palladium to keep them from charging when the samples were bombarded with the proton beam.

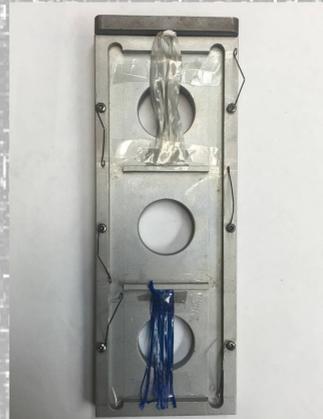


Figure 6: A photo of our target ladder. The samples are taped onto it and then put into the vacuum chamber for data collection.

Calibration

Data were taken on a set of six Micromatter [2] thin standards to determine the energy calibration and solid-angle (H-factor) of the detector, and the thickness of the Al absorber placed in front of the detector to attenuate low energy X-rays. The spectra were analyzed with GUPIX [3].

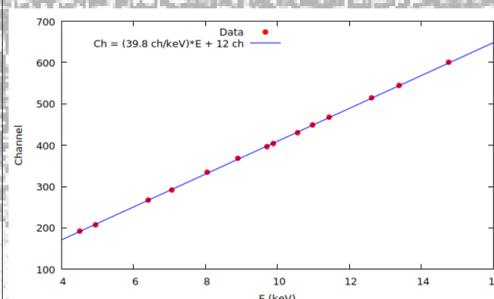


Figure 7: A plot of channel number versus energy for peaks in the X-ray spectra taken on thin standards. The line is a fit to the data.

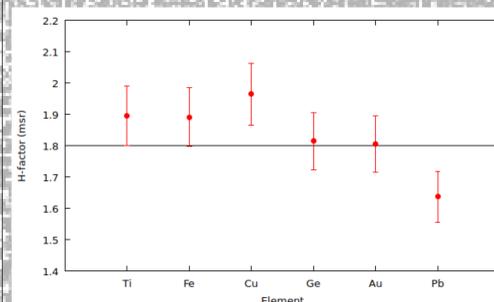


Figure 8: A plot of the H-factor versus element. The H-factor is the ratio of the known concentration of the thin standard to the measured concentration determined from a fit to the spectrum using GUPIX with $H = 1$. The thickness of the Al absorber is adjusted to remove any element dependence of the H-factor. The H-factor and Al absorber thickness were determined to be 1.8 ± 0.1 msr and 78 ± 1 micron.

Preliminary Results

We have performed a thick target PIXE analysis of the turf infill and blade samples to measure the concentrations of heavy metals. The relative concentrations of the metals in the blade samples are indicative of the pigments used to color the blades. Significant concentrations of iron and zinc were measured in all of the infill samples tested, and bromine was detected in a few. The highest level of bromine measured was 1500 ± 200 ppm (0.15%). We believe the bromine is from brominated flame retardants in some of the crumb rubber used as infill.

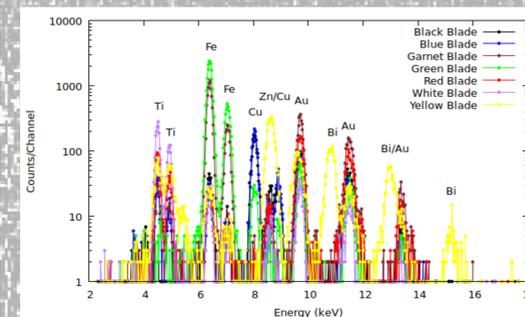


Figure 9: A comparison of PIXE spectra taken on blade samples of different colors.

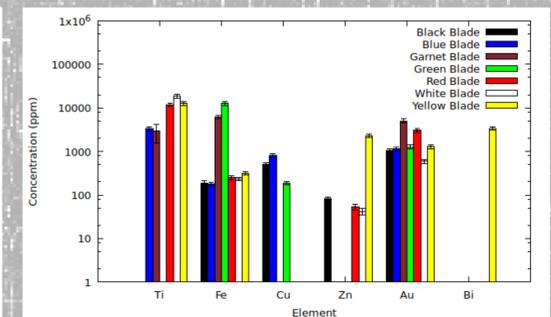


Figure 10: A bar graph of the concentrations of metals measured in the blade samples.

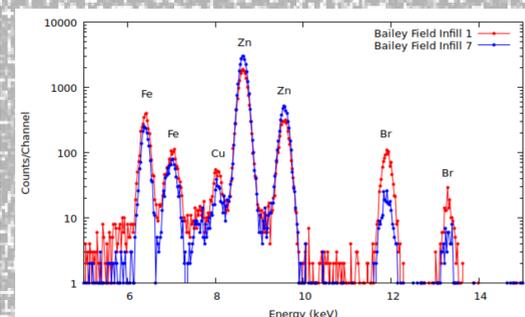


Figure 11: A comparison of PIXE spectra taken on two infill samples that contain significant concentrations of bromine.

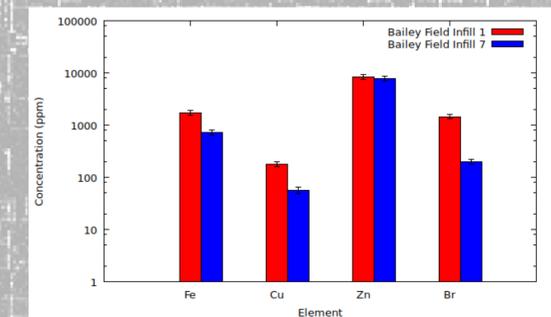


Figure 12: A bar graph of the concentrations of metals measured in two infill samples with significant amounts of bromine.

Future Work

Going forward, we plan to collect and analyze many more samples from different fields and turf manufacturers. We also plan to do more research to try to identify possible sources of the observed bromine.

References

- [1] Are synthetic playing surfaces hazardous to athletes' health? The debate over 'crumb rubber' and cancer, David Wharton, *Los Angeles Times* (2016). <http://www.latimes.com/sports/la-sp-artificial-turf-debate-20160229-story.html>.
- [2] Micromatter, Unit #1, 8333 - 130th Street Surrey, BC V3W 7X4, Canada. <http://www.micromatter.com/>
- [3] GUPIX, the versatile PIXE spectrum fitting software, University of Guelph.

Acknowledgements

We would like to thank the Union College Undergraduate Research Program, and the Union College Department of Physics and Astronomy for their support as well as extend a special thanks to John Sheehan for his help in designing and building the external beam facility.