PIXE Analysis on Artificial Turf

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Introduction

Crumb rubber is a recycled rubber product made primarily from used tires and is the cushion in artificial turf fields. Although synthetic turf has helped prevent discarding used tires in landfills, they pose a potential hazard regarding health to both humans and animals because they contain chemical additives including Zn, S, Pb, and polycyclic aromatic hydrocarbons (PAHs). Concerns over the safety of artificial turf fields have gained national attention due to the possibility of a link between increased cancer among athletes, especially soccer goalies [1]. The Environmental Protection Agency (EPA) has begun its own research regarding the health risks from exposure to crumb rubber in artificial fields [2].

Many high school and college campuses utilize artificial turf fields because they are low-maintenance and are a cost-effective alternative to natural grass fields. In recent years, there has been debate regarding the use of the crumb rubber infill due to the potential presence of heavy metals and carcinogenic chemicals, such as Pb and Br [3]. Our research aims to identify how prevalent these heavy metals, such as Pb, are in artificial turf infill and blade samples.

PIXE Analysis

To study artificial turf, we use Proton Induced X-Ray Emission (PIXE) spectroscopy, an ion-beam analysis technique facilitated by a 1.1-MV tandem Pelletron Accelerator at the Union College Ion-Beam Analysis Laboratory (UCIBAL). PIXE is well-suited to the study of artificial turf because it is a non-destructive and highly sensitive technique that can detect elements ranging from Na to U in thin or thick, solid or liquid samples.

The PIXE process begins when a 2.2 MeV proton beam interacts with inner shell electrons of the target atom and ejects an electron. X-rays with energies characteristic of the elements are emitted when an outer shell electron fills the inner shell vacancy (Figure 1) [4]. We measure these x-rays with an Amptek silicon drift detector. Concentrations of elements present in the sample can be calculated by

$$C_Z = \frac{Y_Z}{Y_t \cdot H \cdot Q \cdot \varepsilon \cdot T} \qquad \text{(Eq. 1)}$$

where C_Z is the concentration of element Z, Y_Z is the intensity of the principle x-ray line of element Z, Y_t is the theoretical intensity, H is an experimental constant determined by running a set of calibration standards, Q is the measured beam charge incident on a sample, ε is the efficiency of the detector, and T is the transmission through any filters or absorbers between the target and the detector.

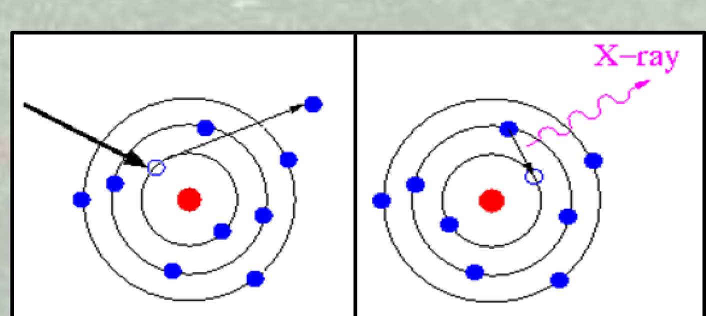

Figure 1 A schematic of the PIXE process. An incident proton ejects an election (left) and an outer shell electron de-excites to fill the vacancy (right).

Figure 2 A photograph of some artificial turf blades before being coated with Al on the left. On the right, 1g of loose crumb rubber infill and 1g of infill pressed into a pellet with ~1g of epoxy.

Experiment

SAMPLE PREPARATION

Artificial turf blades and rubber infill (Figure 2) were collected at high school and college campuses around the Capital District of New York State. We made 24 crumb rubber pellets from eight different fields by mixing 1g of rubber infill and 1g of 5-min epoxy. The rubber-epoxy mixture was placed in a mold and allowed to harden for at least an hour. The hardened pellet was sanded to expose the rubber infill.

The turf blade samples were prepared by finding loose collection of blades. Since the turf blades are made of plastic, they charge when exposed to the proton beam. To prevent charging, we coated the blades with a thin layer of aluminum using a Denton Vacuum Evaporator.

PIXE

To identify the elemental composition of the artificial turf blades and infill, the pellets and the blades were bombarded with a 2.2 MeV proton beam for 10min before integrating the charge for 5min (Figure 3). This process was repeated three times and to determine the total charge, Q, in Eq. 1, we multiplied the total integrated charge by two.

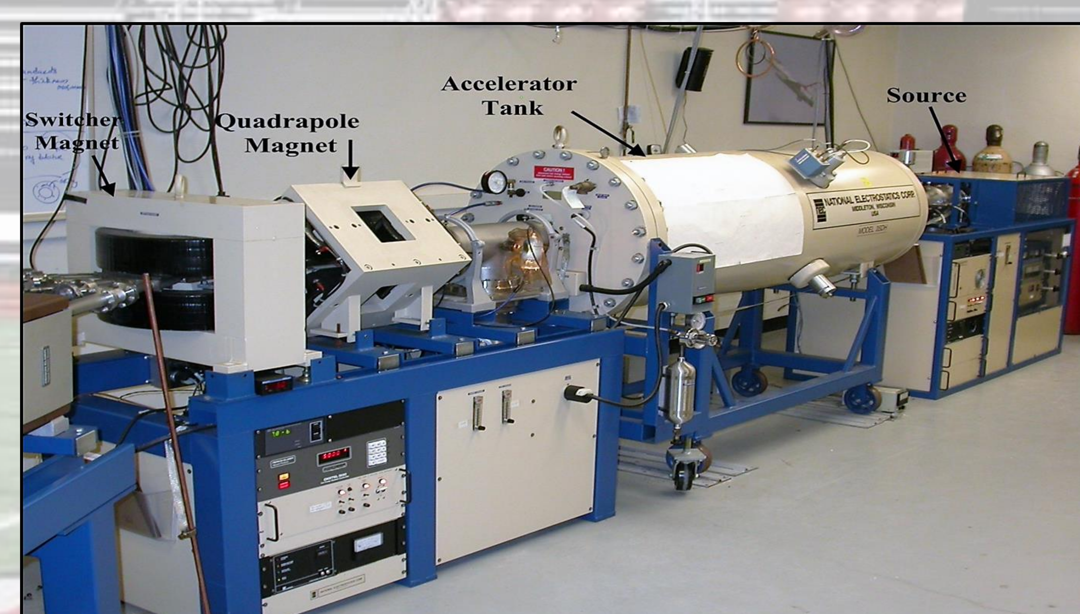

Figure 3 A photograph of the UCIBAL 1.1-MV tandem Pelletron Accelerator.

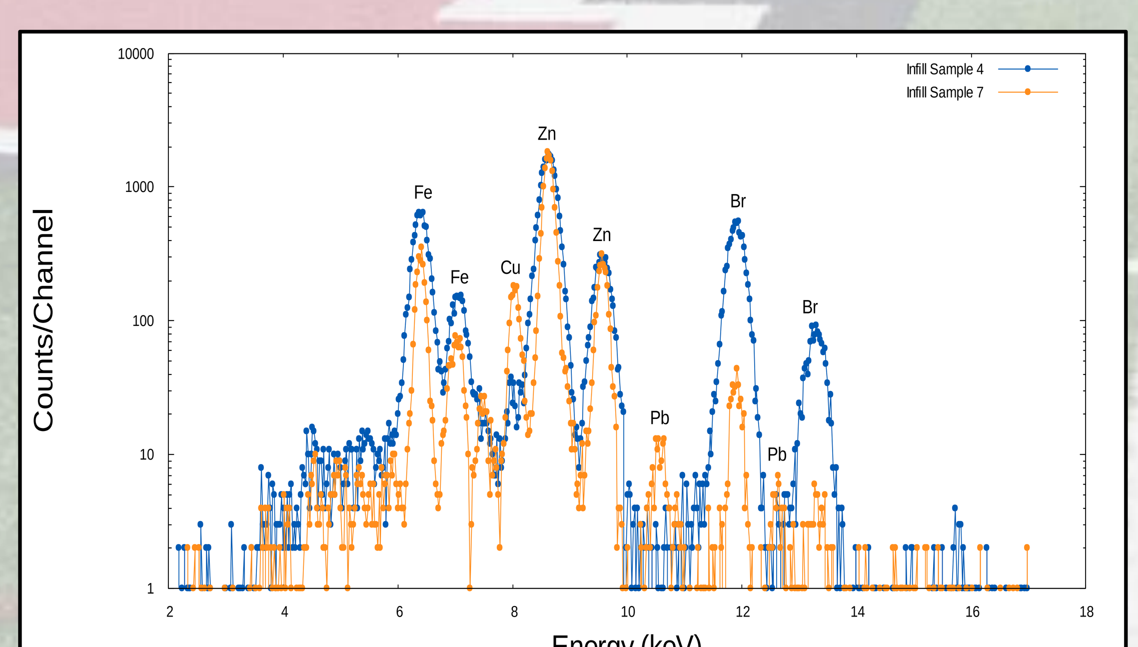

Figure 4 X-ray energy spectra of turf infill samples showing detectable amounts of Br and Pb.

Results and Discussion

The concentrations of the elements present were determined by using GUPIX [5]. To calculate concentrations using equation 1, several parameters need to be determined, namely the solid angle of the detector, H, and the thickness of our aluminum filter, T, that was used to block low energy x-rays. To determine these values, we performed a PIXE analysis on a set of single element thin target standards. The results of this analysis yield $H = (1.98 \pm 0.02) \times 10^{-3}$ sr and $T = 80 \pm 4$ µm.

INFILL

Figure 4 shows the x-ray energy spectra for two crumb rubber infill samples that show elevated levels of Zn, Br, and Pb. Analysis on the 24 crumb rubber infill samples showed that there were significant amounts of Zn and Fe in all of the infill samples with smaller amounts of Cu, Ti, Co, and Ni. In over half of our samples, measurable amounts of Br or Pb were detected. The highest concentration of Br in a sample was 1500 ± 100ppm whereas the highest amount of Pb was 110 ± 20ppm. Figure 5 is a bar chart showing the concentrations (ppm) for the infill samples that contained Br and Pb.

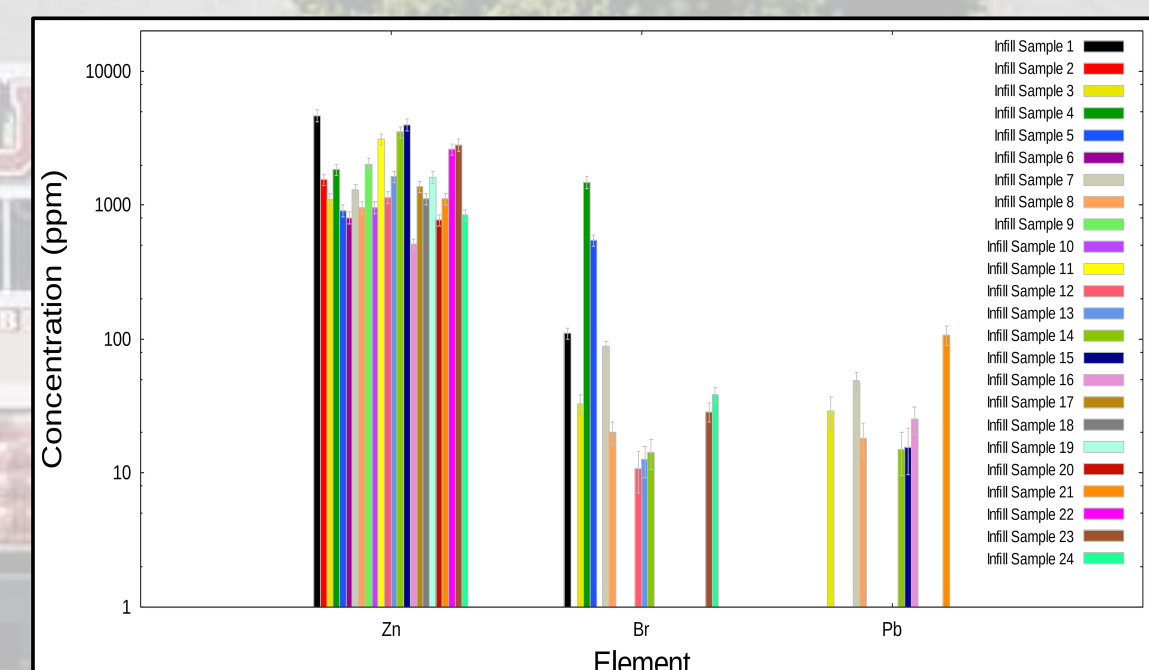

Figure 5 A bar chart of the concentrations in ppm for elements Zn, Br, and Pb in the crumb rubber samples.

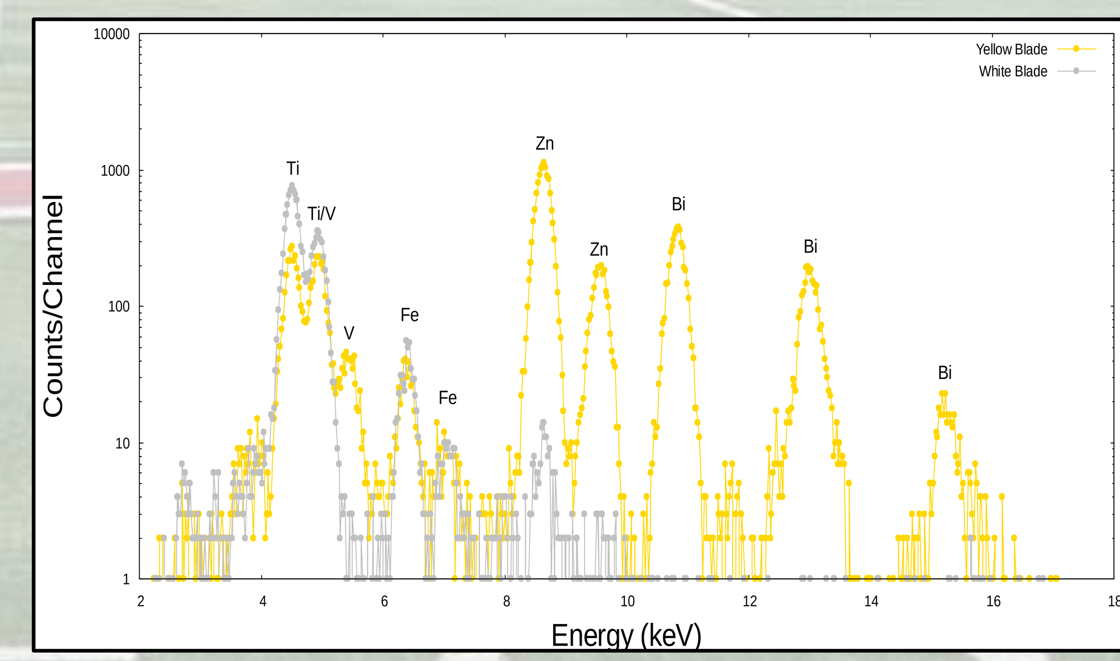

Figure 6 X-ray energy spectra of a yellow and white turf blade. The yellow blade shows trace amounts of V and Bi.

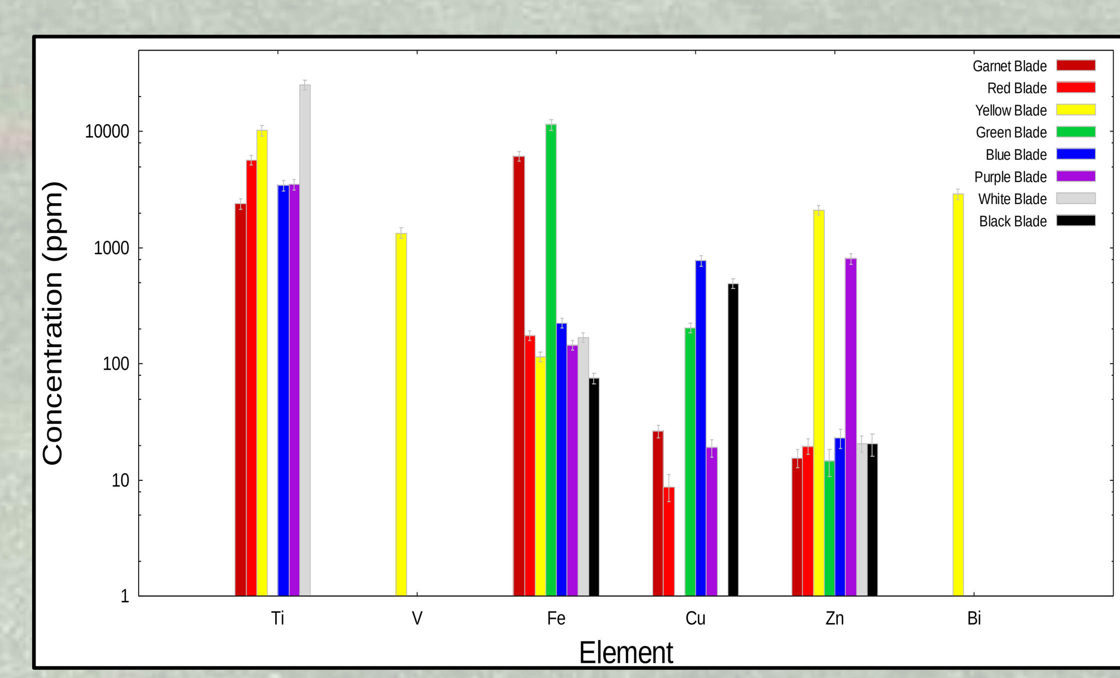

Figure 7 A bar chart of the concentrations in ppm for elements Ti, V, Fe, Cu, Zn, and Bi in our artificial blade samples.

High concentrations of Zn are seen in all of our samples. Our highest results for Zn are 4700 ± 470ppm which exceeds the residential standard of 2200ppm stated by the New York State Department of Environmental Conservation [6]. Tires contain 1-2% by weight of Zn and in high concentrations may be hazardous when inhaled or ingested [7].

Our research thus far shows that most measurable Pb levels are below 110 ± 20ppm, although no level of Pb is ever really safe. According to the EPA, Pb is considered hazardous in soil when it exceeds 63ppm in unrestricted areas [6]. Even though we find Pb levels well below the EPA limits for soil, there should be cause for concern that Pb is present in the turf at any level.

The elevated levels of Br may be due to brominated flame-retardants used on tires. However, a study also found Br in their tire samples that may be due to the use of a bromobutyl polymer [8], which is a combination of butyl rubber and Br used to make the rubber more durable [9]. More research will need to be conducted to determine the origin of the Br in the infill.

BLADES

Figure 6 shows the x-ray energy spectra for two artificial turf blades. Analysis of the blade samples found significant concentrations of Fe, Zn, and Ti, with trace amounts of Cu, as can be seen in Figure 7. Br and Pb were not detected in any of the blade samples. The yellow blade showed high amounts of V (1300 ±100ppm) and Bi (2900 ±300ppm). The detectable amounts of V and Bi are due to the compound bismuth vanadate, which is a known bright yellow pigment.

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