

PIXE Analysis of Bone Cut with Hacksaw Blades

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Abstract

Forensic anthropologists use various methods to determine the type of weapons used in cases involving a dismembered body. For this study PIXE (particle-induced x-ray emission) analysis was performed on samples taken from pieces of pig bone cut with three different hacksaw blades. The analysis was used to determine if the blades left any elemental residue on the bone. When the results of the PIXE analysis were completed, lead was identified as a residue left from the paint on the blades. It was also found that the ceramic blade, which was used to collect a portion of the samples, left elemental residue. There were also some interesting changes in other elements such as copper in various samples.

Introduction

Forensic anthropologists are used in cases involving skeletal trauma in order to identify any evidence of trauma or to further study already identified trauma [1]. In some of the cases a forensic anthropologist will be examining a dismembered body. When a saw has been used as the instrument of dismemberment, the saw marks on the bones are of interest to the forensic anthropologists. By using a variety of saws on other bones such as deer or cow, the cut can be reproduced in order to determine the type of saw used. The saw commonly used for dismemberment is the hacksaw. Hacksaws are made for cutting through metal and thus are good saws for cutting bone. Also, the hacksaw, a common household tool, is inexpensive (~\$5.00 at a hardware store) and small. Thus it is easily accessible [2].

Many forensic scientists have done studies on saw marks and their characteristics, which include “blade and tooth size, set, shape, power, and direction of cut” (p. 394). These characteristics are used to identify the class of saw, thus narrowing the range of possible tools used [3]. Hacksaw blades, for example, have a wavy set of teeth, which produce a certain kerf (cut mark) different from carpentry saws, most of which have an alternating set of teeth. Also, all hacksaw blades are painted, and the paint scheme varies with the manufacturer. If a hacksaw has been the tool used and there is paint residue on the bones, then the paint could be analyzed to help determine the manufacturer of the hacksaw [1,4].

For my project I used Particle Induced X-ray Emission (PIXE) to see if hacksaw blades leave any traces of elements on bones. I looked for traces from both the paint and metal from the saw blade. I did this because the paint on the hacksaw blade is rubbed off

during use, exposing the metal. Thus, the research, if successful, could possibly be used to determine if the dismembered body was cut using either a new blade or a worn blade.

PIXE is a technique used for analyzing elements through the detection of x-rays. It has the ability to simultaneously detect a large number of elements. PIXE's high sensitivity allows it to detect concentrations down to parts per million (ppm) for trace elements ranging from aluminum to uranium. Its highest sensitivity is for elements with "atomic numbers $20 < Z < 40$ and $Z > 75$ " (p. 37) [5]. PIXE is also fairly quick and non-destructive to samples. These characteristics of PIXE make it useful in a number of research fields including biology, archaeology, art, environmental science, etc. [6-9].

The process for PIXE analysis uses a high-energy ion beam of protons to bombard a target. This interaction causes the inner-shell electrons of the target atoms to be ejected creating vacancies. Then the outer-shell electrons fall to fill those vacancies, and energy is given off in the form of x-rays. The energy of the x-rays is uniquely characteristic to the element from which the x-ray was emitted and thus is like a fingerprint of that element.

Even with its useful characteristics, PIXE has been used very little for forensic applications. At the University of Florida, F.E. Dunnam, H.A. Van Rinsvelt (Physics department faculty), and I.I. Kravchenko (Sr. Engineer Tech), have used PIXE to help with forensic cases. For one of the cases they were asked to determine if some disputed cremated remains were human cremated remains or not, and in the two other cases they were asked to determine if trauma on bone samples was from a gunshot [5]. Also, Fishbeck et al. successfully used PIXE to identify lead residue from a gunshot wound that was obscured [10].

Calibration

Before I could begin my project, the beam energies needed to be calibrated, and the resolution of the Kevex Si(Li) x-ray detector needed to be found. To calibrate the beam energy, first two different gamma radiation sources (^{60}Co , ^{137}Cs) with known decay energies were attached to a gamma radiation detector to calibrate the Accuspec program on the MCA (multi channel analyzer). The program uses signals from a detector to produce spectra. Next, we (John Shreck and myself) put an aluminum target into a vacuum chamber with the gamma radiation detector next to it. The target was bombarded with a proton beam from the 1.7 MV NEC Peletron tandem accelerator. This caused the following nuclear reaction: $^{27}\text{Al} + \text{p} \rightarrow ^{28}\text{Si}^*$, where the ^{28}Si nucleus, excited by the protons, emits gamma rays. The resonance (point at which the ^{28}Si atom is excited) of this nuclear reaction has been studied and verified as the incident proton energy of ~ 992 keV [11-13]. We changed the magnetic field strength, through which the beam passes on its way to the various beam lines, thus changing the beam energy, until we got the resonance energy of 992 keV. The Kevex Si(Li) detector was calibrated next. We placed a ^{55}Fe x-ray source in the PIXE target chamber, and left the detector, which is in the chamber, on overnight to gather a good spectrum. Accuspec automatically calibrated itself to the ^{55}Fe x-ray energies. Next, we changed the pulse processor to determine which pulse-shaping time (2 μsec , 4 μsec , 6 μsec , or 8 μsec) gave the best resolution for the detector. The resonance was determined by taking the difference between the K_{α} and K_{β} energies of Fe (6.400 keV and 7.056 keV respectfully), dividing by the difference in the K_{α} and K_{β} peaks (25 channels). This gave us the energy per channel, which we found to be 26.36 eV/channel. We then multiplied that by the FWHM

(full width at half maximum) of the K_{α} peak to get the resolution. We found that 4 μ sec gave us the best resolution. Then, we made samples from three standards: bovine liver, orchard leaves, and bowen. Four targets were made from each and analyzed. These standards were used to check the calibration of the detector.

Experimental

For my project, I obtained three small pieces of pig bone to use to make my samples. Before sawing I cut slivers off the bones to use as a basis of comparison for the rest of the samples. I used a zirconium ceramic knife in order to minimize any contamination. To cut the bones, I used a new hacksaw with a bright yellow blade and two used blades, one having black paint and the other a dull yellow paint. I wiped down the blades with alcohol to make sure they were clean before making the cuts. I made one cut with each saw blade, the bright yellow and black on one piece of bone and the dull yellow on a second piece of bone. I collected the sawdust from the first 0.5 cm of each cut. After making the cuts in the bones, I used the ceramic knife to cut slivers from the cuts. Next I took the blades and sandblasted them to remove the paint. Because hacksaw blades are all made of similar alloys of steel and limitation of time, I used only two of the blades and repeated the above procedure on the second bone. The slivers and sawdust samples were put in vials and then put in an oven for 18 hours at 80°C to remove any moisture.

I then used a mortar and pestle to crush the slivers to a sand-like powder. This was done to increase the uniformity of those samples, the sawdust already being uniform and in powder form. I put the samples on aluminized Mylar, which was attached to nylon

rings about the size of a quarter, to make targets for PIXE analysis. I did this by putting a drop of polystyrene solution with a 50- μ L pipette onto the Mylar rings, then using a spatula I put approximately one milligram of sample on the solution. The polystyrene acts as like glue to keep the sample on the Mylar during PIXE analysis. The aluminized Mylar was used as a backing to minimize charge buildup on the target. I made three targets from each sample. I also made two targets for each of the paints. Normally four or more targets are made from each sample to acquire a good average of the sample, but I made only three due to time constraints. The Mylar film backing, Mylar with polystyrene, and a piece of the ceramic knife were also analyzed using PIXE to see if they contained any contamination that would show up on the bone samples.

Each target was put into the PIXE vacuum chamber and bombarded with a 2.5 MeV proton beam. The total charge was kept between 20-30 micro-Coulombs, and the beam intensity was kept between 20-40 nA. The x-rays given off were detected by the Si(Li) detector. Accuspec used the information from the detector to produce the PIXE spectra of beam energy versus count number.

I took the data from each spectrum and saved them to a floppy disk as .dat files. Then on separate computer I used a dat2asc program to change all of the files to .asc so that I could open them in Microsoft Excel to graph. Each graph was plotted in logarithmic form to best show the data. For each graph the channel numbers were multiplied by the energy/channel found during the calibrations: 26.36 eV/channel. Next, I combined the three spectral graphs for each sample to make one graph per sample. The Robwin program was used to check the trace elements in the samples.

Results

The analysis of the Mylar revealed traces of iron, zinc, and gallium. Analysis of Mylar with polystyrene revealed traces of zinc. After comparing the graphs of the samples taken from each bone to the graphs of the bone before sawing, I could see that there were some differences. The graph of the sawdust sample in which the black saw blade was used oddly showed fewer elements present than the bone itself. The graph of the sample from around the cut, however, showed slight traces of lead and an increase in the amount of iron present. The sawdust from the bright yellow saw blade showed much more titanium and a slight increase in iron. The sample from around this cut showed more titanium also, as well as zirconium and yttrium.

The dull yellow saw blade samples, both the sawdust and around the cut, had very obvious amounts of lead, which was not present in the bone itself. There were also increased amounts of iron and chromium in the samples. I noticed lead was present in all four samples from the sandblasted blades, but in decreased amounts. The samples from around those two cuts also showed zirconium and yttrium. Varying amounts of copper showed up in a number of the samples in no particular pattern. Interestingly, the spectral graph of the second bone compared to the graph of the first bone showed differences in the elements present. The second bone had fewer elements. See Fig. 1 and 2. Because of this difference and the lead found in the samples from the dull yellow blade, the sample targets from the second bone were run again. The results were the same. These data were added to previous data for a final spectral graph for the second bone.

Discussion

The spectrum of the ceramic knife piece clearly shows that the zirconium and yttrium came from the ceramic knife used to collect the samples from around the cuts in the bones. The lead present in the samples is from the paint as is evident when from the spectrum of the paint samples in comparison to the spectra of the bone samples. This is supported by the still present but decreased amounts of lead in the samples from the sandblasted blades. Upon comparison of the spectra, both the increased iron and titanium appear to be due to the saw blade paint as well. See Fig. 3-6 as compared to Fig. 1 and 2.

I do not know why the copper increased in some of the samples; there is a possibility that the increase was caused by saw blade. More tests would need to be performed to find an answer to this. I cannot say why the two bones had different amounts of certain elements. Part of this mystery might be answered by researching the background of the bones (i.e. what happened to them before I received them). More tests would need to be conducted to see if the difference in the bones originates from the outside or the inside of the bone. Also, samples could be taken from the third bone, which I did not use, to test if it resembles either of the two bones used, or if it differs from both. Studies could be made of other paints as well. I can say that the hacksaw blades did leave elemental traces on bones (i.e. lead, iron, and maybe copper). However, this research was done over a limited amount of time, thus limiting the amount of time to collect and run samples. Therefore, to further establish these results and the degree to which they could be used for forensic applications, more studies must be performed.

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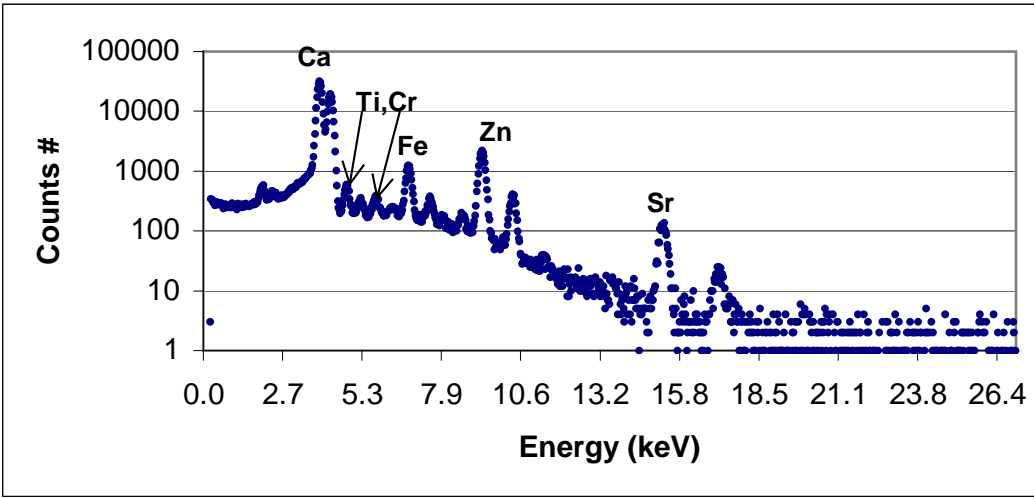


FIGURE 1: PIXE analysis of samples of Bone 1

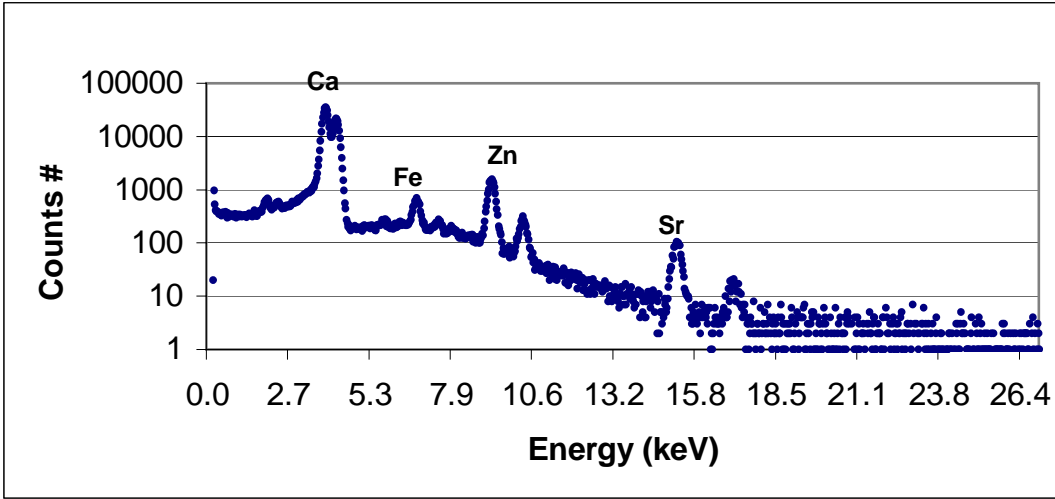


FIGURE 2: PIXE analysis of samples of Bone 2

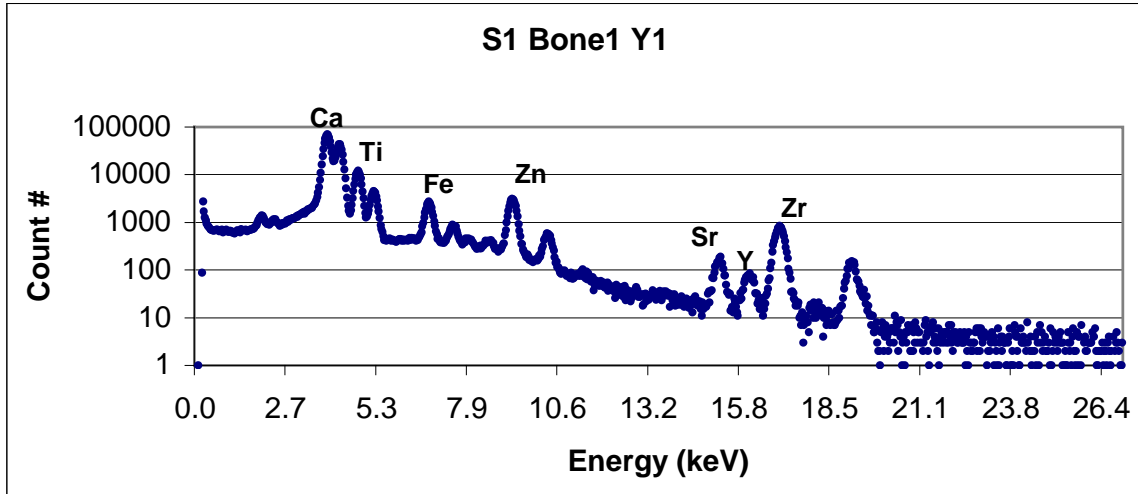


FIGURE 3: PIXE analysis of bone from around a bone cut.

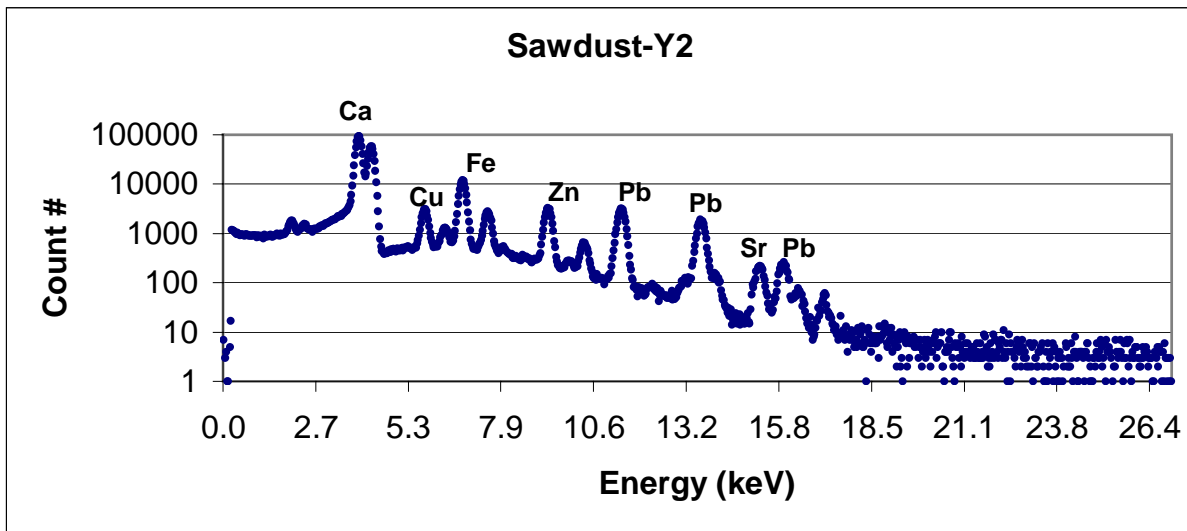


FIGURE 4: PIXE analysis of sawdust from bone cut with dull yellow blade.

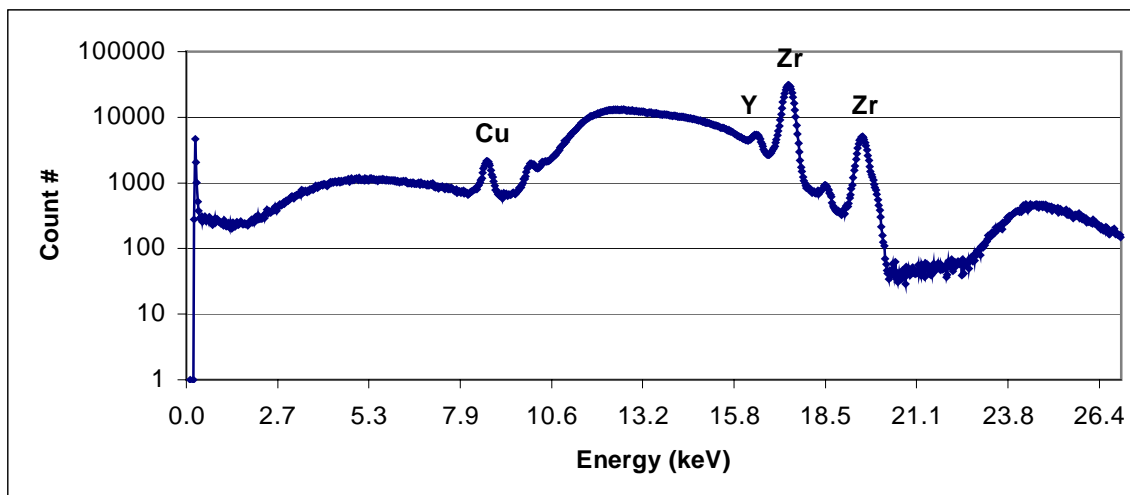


FIGURE 5: PIXE spectrum of ceramic knife

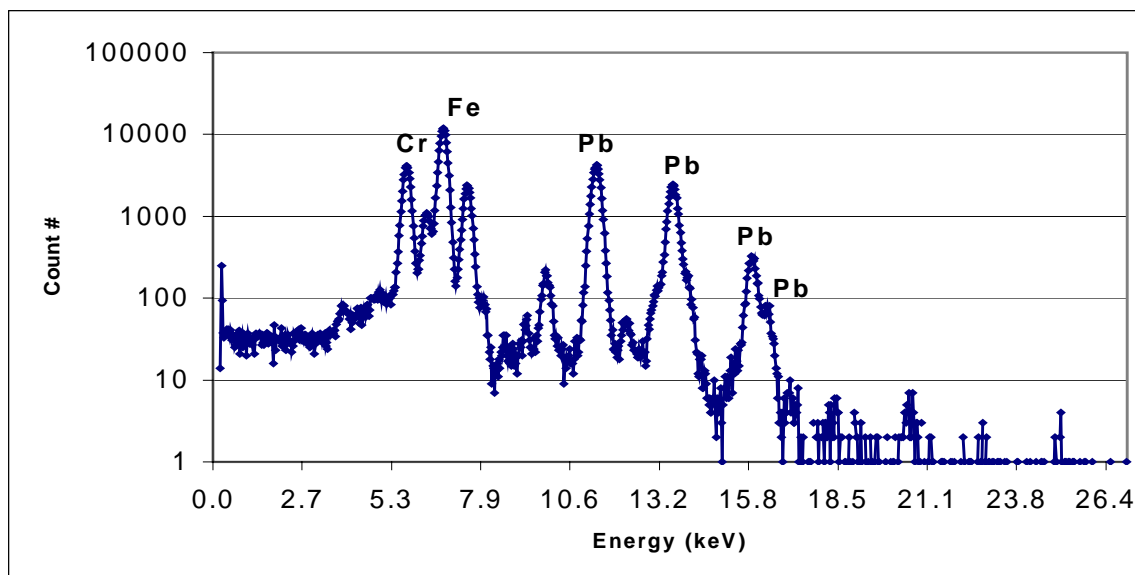


FIGURE 6: PIXE spectrum of dull yellow paint

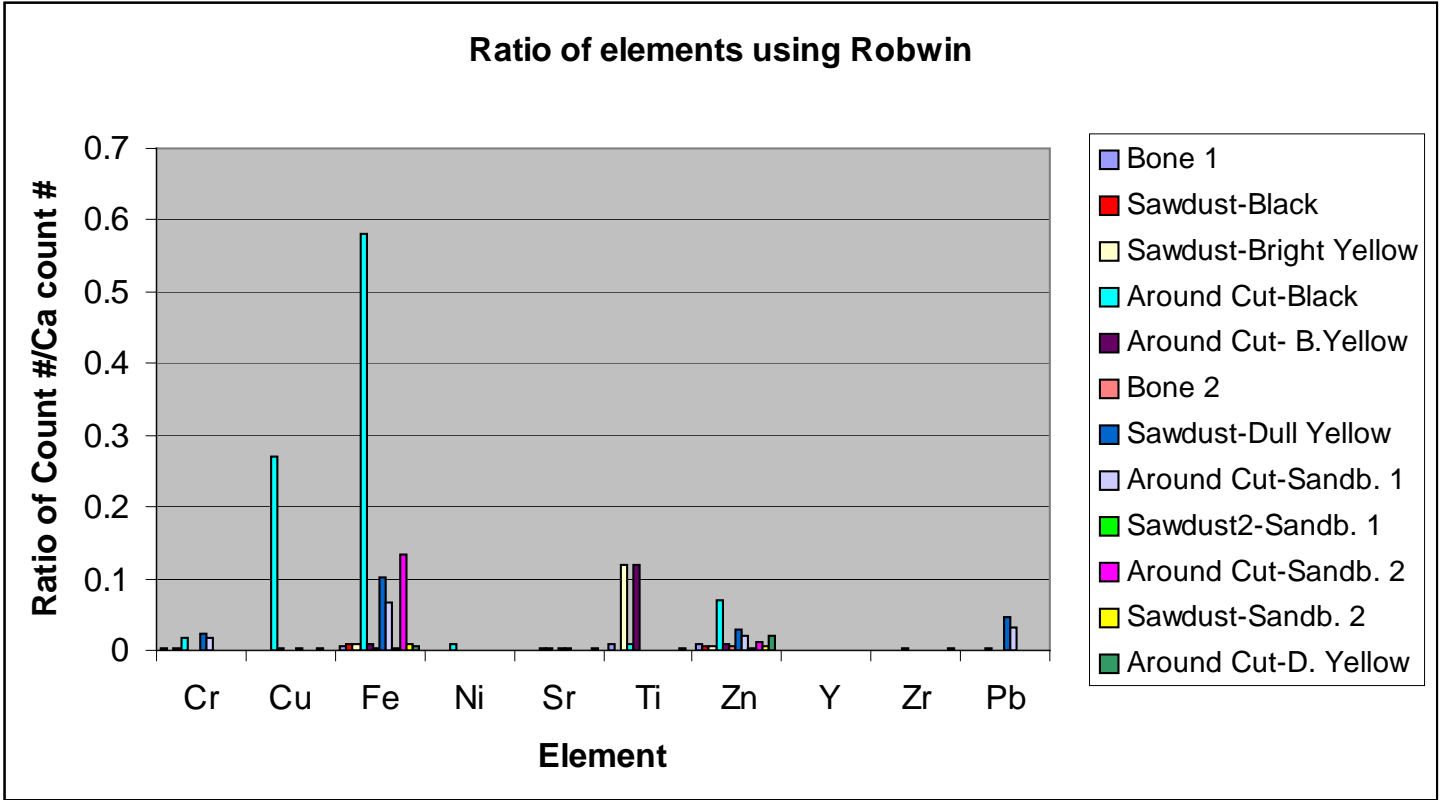


FIGURE 7: Ratio of Element count #/ Ca count #