CASE REPORT

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Bullet Identification: A Case of a Fatal Hunting Accident Resolved by Comparison of Lead Shot Using Instrumental Neutron Activation Analysis

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ABSTRACT: Bullet identification by chemical analysis often provides a powerful clue in forensic science. A case is reported in which a hunting accident was resolved by using instrumental neutron activation analysis (INAA) for direct comparison of the trace element content in lead shot.

Different preparation batches of lead shot appear to have a high within-group composition homogeneity, and good differentiation is achieved between different batches.

Determination of the nickel and antimony content on a bush branch demonstrated that the branch had been perforated by one of the shot pellets, and this helped the detectives in reconstruction of the crime scene.

KEYWORDS: criminalistics, ballistics, instrumental neutron activation analysis, lead, bullet identification, chemical analysis

Investigation of criminal cases involving the use of firearms often requires analysis and comparison of bullets and bullet fragments to ascertain their brand, type, and homogeneity.

Bullet examination can be a powerful tool in investigative work and its results can be used as evidence in court, especially if a multielemental, rapid, and possibly nondestructive analytical technique is employed [*1*]. The information obtained can also be used to establish the trajectory of a bullet, if the projectile has perforated an object in its path [2].

Instrumental neutron activation analysis (INAA) has proven its feasibility as a powerful analytical technique even with very small bullet fragments [*3–10*]. With judicious choice of experimental conditions, a typical INAA analysis can determine 7 to 8 trace elements in a common bullet lead, and if the nature and complexity of the case makes it necessary, the number of instrumentally determinable elements can be increased to 12 to 13. More

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refined gamma counting apparatus (an anti-Compton shielded detector) and longer experimental procedures can be used, even for lead with a low trace element content [*11*].

Case Report

A 47-year-old white male was found dead in a wood, crouched behind a bush. A small basket containing some mushrooms was beside the body.

The autopsy revealed two fatal wounds, caused by two lead shot pellets which penetrated the anterior chest and stopped at the left glenoid cavity and the clavicle, respectively, perforating the left lung and the heart. A third shot pellet stopped against a gold crucifix hanging on a gold chain round the neck of the man and was only slightly buckled in the impact.

The shot used was of the nickel-jacketed type, with a diameter of 8.5 mm and a weight of about 3.7 g. Two twigs and a branch of the large bush in front of the victim appeared to have been recently chopped off, while, not far away, a shotgun cartridge case was found. The incident was presumed to be a hunting accident while the victim was collecting mushrooms, probably during a boar shoot, considering the large caliber of the shot.

No eyewitness information could be obtained about the presence of hunters in the woods at the time of the individual's death.

Investigation

The investigating magistrate decided to order a testing of all the shotguns in the district. After this testing, a limited number of shotguns remained in consideration, based on close similarity between the percussion pin and extractor marks on the cartridge case, presumably because all the shotguns were of the same type and model. A few days later, in the house of one of the owners of a suspected shotgun, some shot of the same type and caliber as that extracted from the body of the victim were found.

Nevertheless, the man resolutely refused to admit that the shotgun was used by anyone on the day of the murder. The shot and lead fragments from the victim were sent to the Analytical Chemistry Laboratory of ENEA Casaccia, Rome, Italy, together with the known shot, for comparison. From the investigation it was learned that only one factory in Italy produces nickel-jacketed shot for hunting uses. Two representative samples of shot of the same brand and type as the ones under investigation, but belonging to different production batches, were obtained from the factory.

The broken twigs and branches of the bush in front of the victim were also collected and sent to the laboratory for analytical determination.

Experimental Procedure

All the samples (the shot and lead fragments extracted from the victim, the known shot, and the shot obtained from the manufacturer) were placed in plastic vials and irradiated for about 3 h in a rotating rack (lazy Susan) of the 1-MW Triga reactor of the Institute of Casaccia, Rome, Italy. The thermal neutron flux was 2.6×10^{12} neutrons/cm^2/s, and the flux homogeneity was greater than 99.85%. Primary and secondary analytical standards (lead BCR CRM 288) were simultaneously irradiated and used for gamma spectra calibration and conversion to concentration units. After irradiation, the samples were allowed to decay some weeks from the very high activity of antimony-122 (^{122}Sb) produced during the irradiation and then treated with a mixture of dilute hydrochloric and sulfuric acid.

This procedure allowed separation of the soluble nickel jacket without appreciable contamination from the lead in the nickel solution. The lead spheres and the solutions were transferred to the counting system, and an automatic sample changer was used in positioning the samples on the detector, to ensure reproducibility in the measurement geometry.

Data collection was performed using an Ortec high-purity germanium detector with a full width at half maximum (FWHM) of 1.68 keV and an efficiency of 29% at 1332 keV, coupled with a Livius (Silena) 8-K-channel pulse height analysis/multichannel analyzer (MCA) system for measurement of the net area of gamma peaks.

After correction of the spectra for low-energy gamma-ray attenuation due to self-absorption by the samples, they were evaluated by direct comparison with the irradiated primary and secondary analytical standards. The silver and antimony content in the lead spheres and the nickel, cobalt, and silver content in the nickel jackets of each of the samples was determined. Successively, each lead shot sphere, without its jacket, was irradiated for 60 s in an in-core irradiation site of the Triga reactor, furnished with a fast-transfer pneumatic system (rabbit), using a flux of 1.1×10^{13} neutrons/cm^2/s. Short-lived radionuclides were produced, and their activity was evaluated as described above.

This second series of measurements allowed determination of the copper, manganese, and arsenic concentrations in the lead. The broken branches were cut into slabs and then irradiated for 30 h in the Triga reactor rotating rack. The resulting activity was measured and their metallic element concentrations were determined as previously described.

Results and Discussion

In Fig. 1, a comparison between the trace element content of the shot from the body of the victim and the suspected shot is shown. The trace element content of two different production batches of shot obtained from the factory, which were of the same type as the shot obtained from the body of the victim and the known shot, is reported in Table 1. The production batches show a difference in mean values between the batches and a

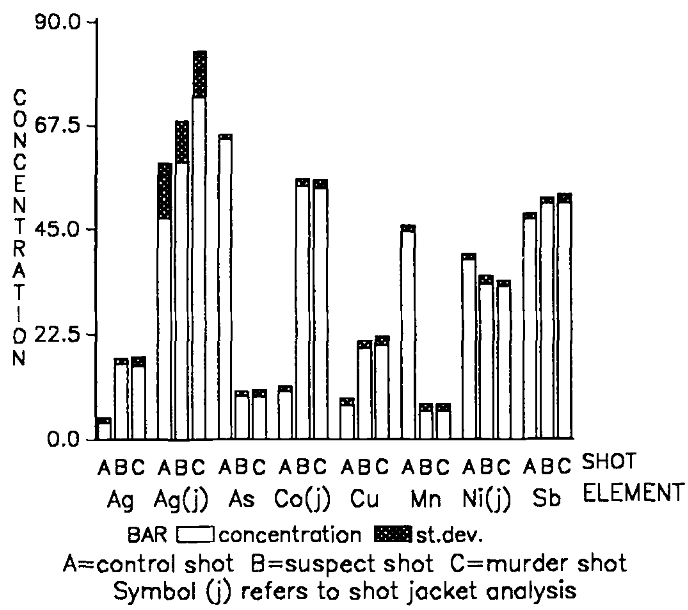

FIG. 1—*Comparison of the trace element concentrations in the lead shot. The concentration values are reported in arbitrary units to accommodate all the elements on the same bar diagram.*

TABLE 1—*Trace element concentrations, in parts per million, in two different production batches of shot of the same type and brand (Batches A1 and A2), in the suspect's shot (B), and in the shot from the body of the victim (C).*

Element	A1 (N = 25)	A2 (N = 25)	B (N = 18)	C (N = 4)
Ag(j)[a]	35.4 ± 12	39.0 ± 9	47.6 ± 8.5	66.7 ± 10
Co(j)	8.9 ± 1.2	13.0 ± 2	54.9 ± 2.5	52.1 ± 1.8
Ni(j)	37.3 ± 1.4	35.1 ± 2	31.4 ± 1.8	31.4 ± 1.2
Ag	2.3 ± 0.9	5.2 ± 0.8	15.4 ± 0.9	13.7 ± 2
Sb	45.9 ± 1.5	44.5 ± 1	49.3 ± 1.1	48.5 ± 2
Cu	5.6 ± 1.3	8.5 ± 2	17.5 ± 1.5	18.0 ± 2.1
As	63.6 ± 1	68.1 ± 1.2	8.2 ± 0.9	7.5 ± 1.5
Mn	42.9 ± 1.6	36.4 ± 1.1	4.5 ± 1.3	4.5 ± 1.5

[a]The symbol j refers to the shot jacket analysis.

high degree of homogeneity within the batches, as the low standard deviation indicates, except for the silver content of the nickel jacket, which may be due to the chemical separation procedure used.

In Table 2, the results of a monovariate *t*-test are reported for each of the elements determined. As can be seen, a consistent probability is, in general, obtained for the hypothesis that the suspect's shot and the murder shot belong to the same production batch. The analysis of the twigs found near the victim showed no significant difference between the broken and unbroken sections. The bigger and harder bush branch shows, on the contrary, clear differences in the nickel and antimony content. Figure 2 shows the difference between the unbroken section (blank, A) of the bush branch and two sections, one scratched on the surface (B) and the other perforated with a deep hole (C), of the same branch.

Before it hit the victim, the shot evidently perforated the hard branch, and some metallic debris remained on the wood. From these results, the following conclusions could be drawn and were presented to the magistrate:

1. The preparation batches appear to have a high homogeneity of composition, and good differentiation is achievable among different batches by chemical analysis. In particular, the shot seized in the suspect's house and the shot extracted from the body of the victim appear to be consistent with the same production batch.

2. A broken branch from the bush in front of the victim shows a deep hole and a superficial scratch. The nickle and antimony concentrations in the perforated sections of

TABLE 2—*Probabilities, by* t-*test, of connecting shot among the different groups.*[a]

Element	A = B	A = C	B = C
Ag(j)[b]	0.34	0.0033	0.36
Co(j)	0.0001	0.0001	0.94
Ni(j)	0.013	0.003	0.97
Ag	0.0002	0.002	0.89
Sb	0.031	0.08	0.997
Cu	0.0008	0.001	0.88
As	0.0001	0.0001	0.93
Mn	0.0001	0.0001	0.9999

[a]A is the control shot, B is the suspect's shot, and C is the murder shot group. The columns marked A = B, A = C, and B = C report the probabilities of connecting A shot to the B group, A shot to the C group, and B shot to the C group, respectively.

[b]The symbol j refers to the analysis performed on the nickel jackets.

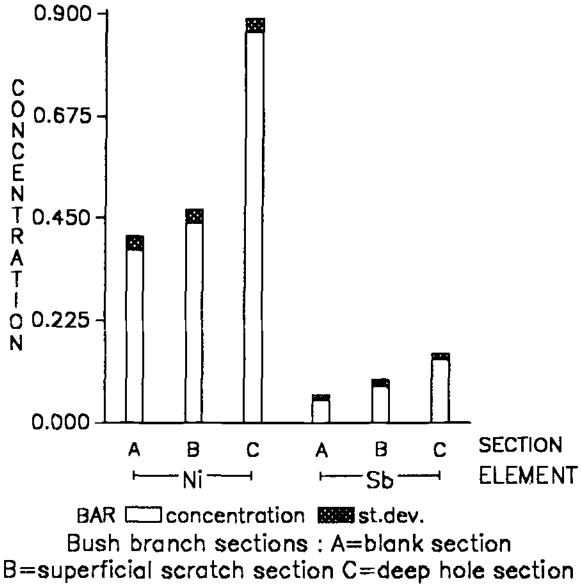

FIG. 2—*Analysis of different sections of the broken bush branch found in front of the victim. The element concentrations are expressed in micrograms.*

the branch appears to be significantly higher than those in an unbroken branch, which suggests that the branch had been perforated by the lead shot.

These results, in addition to the study of the murder site and of the pattern of the seized shotgun, demonstrated that, from the position from which the cartridge was fired, the victim was not visible because of the bush, which entirely hid from view the body of a crouched man. After the presentation of this evidence in court, the suspect admitted that he had heard a sound coming from the bush and believing that a wild boar was hiding behind it, fired a shot from a distance of about 15 m. Witnesses were found who reported that the victim suffered from fits of asthmatic coughing, a sound which effectively resembled the cry of a wild boar. The court deemed entirely valid the conclusion drawn from the analytical determinations, and the suspect was therefore found guilty and sentenced for manslaughter.

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