Journal of Forensic Sciences - October 1968
Vol. 13, #4.

· of such

the Docu-
ited States

·s of Ques-
ited States

University
. (1957).
o., Albany,

loser Com-

October 1968

Identification of Bullet Holes by Neutron Activation Analysis and Autoradiography *

*S. S. Krishnan, Ph.D.*** *and R. C. Nichol* **

The identification of bullet holes in materials such as clothing, wood, and tissue is one of the problems faced by the forensic firearms examiner. Up to the present time this examination has been performed primarily by use of microscopic examination and infrared photography—especially in cases where no powder or lead residues are present because of greater firing distances and the presence of intermediate targets. Rough handling of the target, weathering, wetting with blood or oil, or immersion in water and other such factors tend to obscure bullet holes. In certain cases, photographic methods using soft X rays or infrared radiation have been applied to detect the lead or powder residues respectively (1).

It is known from previous work (2) that metallic elements such as lead, antimony, and copper are deposited around bullet entries. This is especially true at the contact ring around the rim of the hole. This deposition at the contact ring has been found at muzzle-target distances of at least 75 feet (2) and, indeed, could be expected at any range. The deposition may often be invisible to the unaided eye on dark or bloodstained garments. While the amounts of metals in such deposits are not reproducible, their presence suggests an approach to the problem of identification of bullet holes at points of both entry and exit.

This paper describes a method of identification of bullet holes by neutron activation analysis (NAA) and autoradiography of

* Received for publication March 21, 1968. Accepted for publication June 14, 1968.

** The Centre of Forensic Sciences, Province of Ontario, Toronto, Canada.

24

the metallic deposits around the holes. The theory and experimental techniques generally used in NAA for applications to forensic science are described in detail elsewhere (3, 4). Because lead is not conveniently detected by NAA, bullet holes are identified in this work by the antimony (from unjacketed lead bullets) or copper (from jacketed bullets) deposition.

Experimental Procedure

Bullet hole samples were prepared by firing test shots with various weapons and ammunition against different target materials. Samples approximately 0.25 cm in diameter containing the contact ring were removed from each bullet hole for analysis. With materials such as wood where this was difficult, several samples containing most of the black deposit, with as little as possible of the adhering blank target material, were removed. The samples were then irradiated for 1 hour in a nuclear reactor at a thermal neutron flux of approximately 10^{13} neutrons/sec/cm^2. Copper and antimony reference preparations were also irradiated simultaneously with the samples.

No radiochemical separations were done in this work. When only copper or antimony was expected to be present, the analysis for the induced Cu^{64} and Sb^{122} radioactivities was done by gamma ray spectrometry using a sodium iodide crystal connected to a 400 channel pulse height analyzer. When both nuclides were present, the resolution of the 0.51 MeV and 0.56 MeV peaks from Cu^{64} and Sb^{122} respectively was not adequate using the sodium iodide detector. In such cases, a lithium drifted germanium detector, which is capable of much better resolution, was used.

The amounts of copper and antimony in the samples were calculated by comparison of the induced Cu^{64} and Sb^{122} radioactivities with similarly treated, weighed pure metal reference materials. Corrections were made for the target blank values, which were minor in all the experiments.

Results

The test shots in this work were, in most cases, fired from sufficiently great distances so that powder residues were not likely to be detected around the bullet holes. In the exceptions, where powder residues might be expected, the targets were screened by an intermediate target such as wet filter paper; hence, the deposits found at the bullet holes are essentially from the bullet and not from the other components of the ammunition.

Several test shots were fired using lead bullets. These lead bullets were all known to contain antimony from previous analysis by NAA, generally in the concentration range of 0.05% to 3%. The results of the measurements of the metal deposits at the bullet hole by NAA are given in Table I. It should be noted that in two instances the samples were from points of exit.

TABLE I

Deposition of Antimony at Bullet Holes by Lead-Antimony Alloy Bullets

Expt. No.	Target Material	Approx. Firing Dist. (ft.)	Weapon	Cartridge	Antimony Found (micrograms)	Copper Found (micrograms)	Remarks
1.	Skull	10	.22 cal. rifle, Cooey.	CIL .22 LR	0.427	Nil	Intermediate target: wet filter paper. Samples from entry.
2.	Skull	10	.22 cal. rifle, Cooey.	CIL .22 LR	0.133	Nil	Intermediate target: wet filter paper. Samples from entry.
3.	Skull	10	.22 cal. rifle, Cooey.	CIL .22 LR	0.042	Nil	Intermediate target: wet filter paper. Samples from exit.
4.	Skull	10	.22 cal. rifle, Cooey.	CIL .22 LR	0.036	Nil	Intermediate target: wet filter paper. Samples from exit.
5.	Wood	10	7.65 cal. pistol, Waffenfabrik	Dominion	9.68	Nil	
6.	Wood	10	7.65 cal. pistol, Waffenfabrik	Dominion	10.29	Nil	
7.	Wood	10	7.65 cal. pistol, Waffenfabrik	Dominion	35.21	Nil	
8.	Skin	5	.38 cal. revolver, S & W	Norma .38 Special	3.63	Nil	
9.	Skin	5	.38 cal. revolver, S & W	Norma .38 Special	3.39	Nil	
10.	Cotton cloth	5	.38 cal. revolver, S & W	Norma .38 Special	16.08	Nil	
11.	Cotton cloth	5	.38 cal. revolver, S & W	Norma .38 Special	41.71	Nil	

Test shots were also fired using copper-jacketed bullets. The samples from the bullet holes were analyzed to detect copper and, or antimony. The results are given in Table II.

TABLE II

Deposition of Copper at Bullet Holes by Copper-Jacketed Bullets

Expt. No.	Target Material	Approx. Firing Distance (ft.)	Weapon	Cartridge	Antimony Found (micrograms)	Copper Found (micrograms)
1.	Wood	10	7.65 cal. pistol, Waffenfabrik	Dominion	Nil	8.82
2.	Wood	10	7.65 cal. pistol, Waffenfabrik	Dominion	Nil	8.30
3.	Wood	10	7.65 cal. pistol, Waffenfabrik	Dominion	Nil	6.92
4.	Painted wooden door	10	.303 cal. rifle, Lee Enfield	British Dominion KKSP	Nil	9.50
5.	Painted wooden door	10	.303 cal. rifle, Lee Enfield	British Dominion KKSP	Nil	20.62
6.	Plastic sheet	0.5	.30 cal. rifle, Winchester	KKSP Dominion Winchester .30–30 cal.	Nil	12.10
7.	Plastic sheet	1	.30 cal. rifle, Winchester	KKSP Dominion Winchester .30–30 cal.	Nil	9.71
8.	Plastic sheet	5	.30 cal. rifle, Winchester	KKSP Dominion Winchester .30–30 cal.	Nil	10.42

Another series of test shots was fired using lead bullets with thin outer copper plating to determine whether both antimony and copper would be deposited at the bullet holes. The results obtained are given in Table III.

The effects of varying firing distances and target materials on the deposition of antimony at the bullet holes were tested. The firing distances were varied over a range of 5 to 70 feet using a filter paper and cloth targets. The results are given in Table IV.

TABLE III

Deposition of Antimony and Copper at Bullet Holes by Lead Bullets with Thin Outer Copper Plating

Weapon: Rohm RG .38 caliber revolver
Cartridge: Western Special
Target Material: Wood
Detector: Lithium drifted germanium
Intermediate Target: None

Expt. No.	Approx. Firing Dist. (ft.)	Antimony Found (micrograms)	Copper Found (micrograms)
1.	4	70.6	4.15
2.	4	188.5	4.48
3.	8	298.0	8.04
4.	8	143.6	20.40
5.	12	414.0	25.62
6.	12	75.5	5.36

TABLE IV

Variation of Antimony Deposition at Bullet Holes with Firing Distance and Target Material

Weapon: 22 cal. rifle, Cooey
Cartridge: CIL, .22 LR

Firing Distance (ft.)	Quantity of Antimony at the Bullet Entry (micrograms): Filter paper target	Cotton cloth target
5	0.025	0.231
10	0.018	0.214
15	0.019	0.177
20	0.014	0.211
30	0.019	0.196
50	0.016	0.22
70	0.017	0.185

Neutron Activation Autoradiography

Bullet holes can be identified in clothing and similar material and an estimate of the firing distance can be made by a simple and elegant method using autoradiography. The target material in these cases should be capable of being contained in the irradition capsule which, in this work, was a small aluminum container 1 inch in diameter and 2 inches in depth.

Approximately 2 inches × 2 inches of the target material is cut out around the bullet hole. It is irradiated in the reactor for approximately 30 minutes. The now radioactive target material is placed in close contact with an X-ray film or other suitable photosensitive film for an appropriate time and is then developed. The decay time between the end of irradiation and the exposure of the film as well as the film's exposure time can be varied to obtain the best autoradiograph. The autoradiograph demonstrates the metallic deposits at and around the bullet hole. Typical autoradiographs obtained after one day's decay of the short-lived background radioactivities followed by overnight exposure are shown in Fig. 1. The dark spots can be subsequently identified as antimony or copper radioactivity either by counting the entire material or the excised spots alone.

Discussion

It can be seen from Table I that when lead alloy bullets containing antimony are used, antimony is detected at the bullet holes. Negligible amounts of copper are detected. If the bullets involved have copper jackets, the metal deposited at the holes is copper, and no antimony is detected as seen from Table II. However if the bullet contains only a thin outer metal plating of copper, both the copper from the plating and the antimony from the inner lead are deposited. This results from the fact that as the bullet passes through the barrel some of the plating metal is removed to expose the inner core of the bullet. The copper and the antimony deposits at the holes are thus characteristics of bullet holes, and the metal or metals detected give an indication of whether the bullet is lead, copper-jacketed, or copper-plated.

A preliminary analysis of several bullet alloys showed that bullets contain many trace elements such as tin, zinc, chromium, bismuth, aluminum and silver. It could be expected that these elements are also deposited at the bullet holes along with lead, antimony and/or copper. While it is simpler to identify bullet holes by antimony and copper deposits, it is conceivable that the other trace metals could also be used for the same purpose should circumstances such as background contamination demand it.

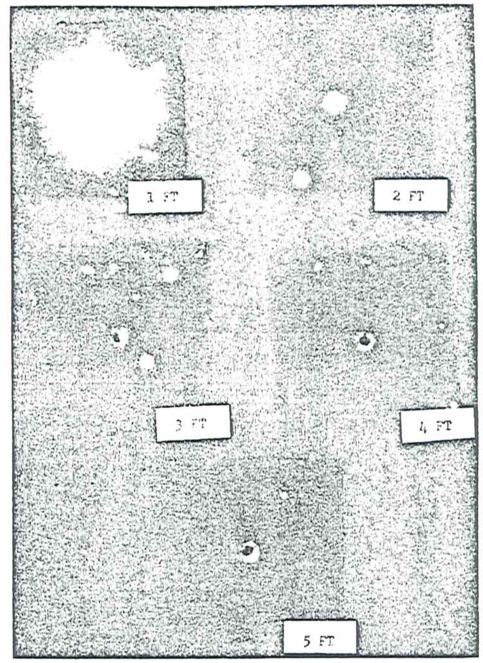

Fig. 1—Neutron activation autoradiographs of bullet holes (entries) using a Cooey .22 rifle and filter paper targets. (Muzzle-Target distances are given at the bottom right hand corners.)

In a target material such as a painted wooden door, the paint might be a source of contamination; however, samples without paint contamination can easily be obtained from below the surface along the bullet track.

The data indicate that the copper and antimony deposits are not quantitatively reproducible. It was found that, in general, the denser the target the larger is the deposit, which is not surprising since the denser targets would scrape off more of the bullet material. While the metal deposits at the bullet holes have been found up to at least 70 feet with a .22 caliber rifle in this work, they are expected to be present at any range.

The data show that in most cases, microgram amounts of antimony and copper are found at the bullet holes. These amounts are also detectable by other instrumental methods such as spectrography or atomic absorption. These methods would also detect the accompanying lead which can be expected to be present in far larger amounts than antimony. However, in these techniques, the sample has to be either destroyed or chemically treated to remove the metals in solution. In some cases, such as exit holes in the skull, the deposits are in submicrogram levels and hence would be very close to the lowest limits of detection of these techniques.

The results of the autoradiographs show that neutron activation autoradiography is an effective method of identifying bullet holes. An estimate of the firing distance can also be made using this method. It is effective even when the normal photographic methods using soft X rays or infrared radiations fail because of lack of sufficient lead or powder deposits respectively.

The neutron activation technique for the identification of bullet holes is, therefore, simple, fast, and effective. The method is nondestructive apart from the fact that the bullet hole site, or part of it, must be removed for the analysis. Several samples can be analyzed simultaneously thus minimizing the expense.

Summary

A simple and fast method of identifying bullet holes using neutron activation analysis technique has been described. The method is nondestructive apart from the fact that samples have to be removed from the bullet holes for analysis. The method utilizes the antimony and/or copper deposits at the bullet holes for the identification. The bullet involved can be identified as to whether or not it is copper-jacketed.

Another simple method for identifying bullet holes using neutron activation autoradiography is described in which targets such as clothing are involved. By this technique, an estimation of firing distances can also be made from comparisons with exemplar tests.

Acknowledgment: The authors take pleasure in expressing their sincere appreciation to Mr. E. J. Anderson and Mr. G. Deporter of this laboratory for their cooperation; to Dr. A. K. Perkons of this laboratory for conducting the experiments with the skull targets; to Drs. R. E. Jervis and G. V. R. Rayudu of the University of Toronto for the loan of their solid state detector and other accessory equipment.

REFERENCES

1. Nichol, R. C. and U. von Bremen. Unpublished work. The Centre of Forensic Sciences, Toronto, Canada.
2. Krishnan, S. S. Firing Distance Determination by Neutron Activation Analysis. J. Forensic Sci. 4, 471–483 (1967).
3. Krishnan, S. S. Determination of Gunshot Firing Distances and Identification of Bullet Holes by Neutron Activation Analysis. J. Forensic Sci. 1, 112–122 (1967).
4. Guinn, V. P. Non-Biological Applications of Neutron Activation Analysis in Forensic Studies. Methods of Forensic Science, A. S. Curry (ed). Vol. 3, pp. 47–68. Interscience Publishers, London (1964).

8 Jarvis Street
Toronto 2, Ontario, Canada