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A New Field Kit for Bullet Hole Identification

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ABSTRACT: The identification of bullet marks and holes is very often essential in criminal cases. The common methods for the determination of trace metals around bullet holes are used in the laboratory and not at the scene of the crime. The application of atomic absorption spectrophotometry and the spot test technique for the determination of lead and copper is reported. Data obtained by test firing a variety of weapons, indicated that the spot test technique can be adapted successfully for the identification of bullet holes. Subsequently, a new kit was developed that facilitates a simple, reliable, and sensitive method for identifying these holes and other suspected marks at the scene of a crime by nonscientific field personnel.

KEYWORDS: criminalistics, field kits, chemical analysis, gunshot residues, bullet holes, spot tests, atomic absorption spectrophotometry

In criminal investigations it is often necessary to determine whether or not a given hole or mark in a car, wall, door, or cloth is a bullet hole. Morphology of the hole alone can often lead to erroneous results; hence it seems that a chemical method should be applied for the detection of metals deposited by the bullet.

The typical laboratory methods used for the detection of trace metals around bullet hole periphery (BHP) are atomic absorption spectrophotometry (AA) [*1*] and neutron activation analysis [*2,3*]. For the same purpose, scanning electron microscopy (SEM) with energy dispersive X-ray analysis (EDA), was successfully adapted in the authors' laboratory.

The published methods for the identification of lead residues with sodium rhodizonate in BHP are scanty [*4,5*]. Moreover, they have their drawbacks because they also can be applied only in the laboratory and are of low sensitivity levels.

The identification of copper residues around bullet holes by spot test analysis has not been reported previously.

The most common reagents for the determination of lead and copper (which are the main components of bullet cores and jackets), are sodium rhodizonate [*6*, p. 284] and rubeanic acid (dithiooxamide) [*6*, pp. 213-215], respectively.

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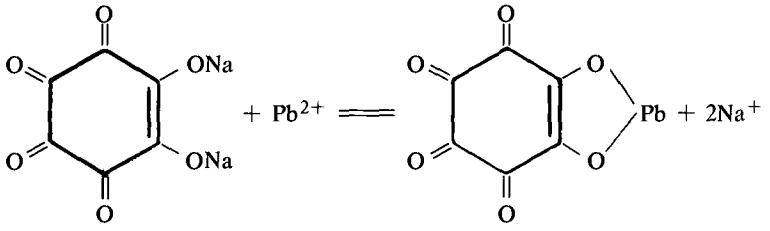
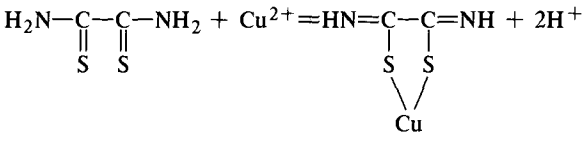
The reaction of lead with sodium rhodizonate is as follows:



red-violet

The reagent is not specific and reacts with other metal ions. However, the test for lead is the most sensitive of the reactions.

The reaction of copper with rubeanic acid is as follows:



green-black

Cobalt and nickel also precipitate with rubeanic acid, but these colors are different being brown and blue, respectively. The copper test is more sensitive than the test for cobalt and nickel.

To the best of the authors' knowledge there are no reports in the literature on specific chemical methods to determine bullet holes at the scene of crime.

A method providing the ability to reach a clear conclusion at the scene of a crime may save both crucial time and effort, since the exhibit does not have to be first transferred to the laboratory. It is also desirable that such a method be nondestructive to enable further complementary laboratory examinations.

A variety of weapons and ammunitions were test-fired on commonly encountered types of targets to produce bullet hole samples. This was followed by quantitative and qualitative study of lead and copper traces on the periphery of the bullet holes using atomic absorption spectrophotometry and spot test analysis.

Consequently, a field test kit has been developed. It facilitates a quick, reliable, and sensitive determination of bullet holes at the crime scene followed, if necessary, by other sensitive laboratory methods, for example, AA or SEM-EDA. The latter procedure is routinely practiced in the authors' laboratory.

Experimental Methods

Specimen Collection and Preparation

Test shots were fired on various types of targets, for example, floor tiles, metal sheets, cloths, and cardboards. The test shots were fired from accurately measured distances using various types of weapons and ammunition. Two types of the most common bullets were mainly used; ordinary lead bullets and brass (usually, copper alloyed with 5 to 10% zinc) jacketed lead bullets (see Table 1). The possible interference of contamination from previously fired bullets was examined by multiple firing of different types of ammunition on the same targets.

For quantitative determination by atomic absorption spectrophotometry of lead and copper, the traces were extracted from the targets by 17% (v/v) nitric acid in one of the two ways:

1. Circular sections having a radius of 10 mm were cut around the holes of the soft targets (clothes and cardboards) and were stored in corked polypropylen test tubes.
2. Specimens from bullet holes in hard substances were sampled for 30 s using cotton swabs moistened with 17% nitric acid. The swabs were then stored in corked test tubes.

The metals were quantitatively extracted by the immersion of the swabs in the nitric acid solution (2 mL) for 2 h. Blanks were similarly taken from the samples at a distance of at least 10 cm.

The qualitative identification by spot tests of lead and copper was performed directly on the bullet hole area of the targets.

Quantitative Determination of Lead and Copper

The sample and blank solutions were analyzed for lead and copper with a Perkin-Elmer Model 403 atomic absorption spectrophotometer. Standard solutions of lead and copper were prepared by diluting stock solutions (1000 ppm). Usually all the samples were analyzed twice with a maximum relative error of 3%.

Qualitative Identification of Lead and Copper

To determine the optimal conditions and procedures for the spot test reactions of lead and copper many exploratory experiments were carried out on a variety of calibrated standards of the elements and of BHPs and bullet marks.

It was shown recently that lead and copper in gunshot residues appear generally in the elemental metallic form [*7*], hence it was necessary to dissolve these residues before the determination or identification. Lead and copper were therefore dissolved in solutions of 5% acetic acid and 12% ammonium hydroxide, respectively. This mixture of solvents was found to be the most appropriate. These reagents also served as buffers in the reactions with sodium rhodizonate and rubeanic acid, thus simplifying the reactions' procedure. It should be noted that the methods used were different than those reported by Feigl [pp. 284, 213–215] and Harrison and Gilroy [*9*]. The authors' method therefore allowed for the combination of the dissolution and the buffer steps into one step.

It has been realized that in spot test analysis the substrate employed affects the sensitivity of a given reaction [*6*, pp. 7–11, *8*]. To find the most suitable substrate for the reactions, dozens of types of filter paper and other media (for example, spot test plates, adhesive tapes, and cotton swabs) were surveyed. The Benchkote® Whatman filter paper appeared to be the most appropriate substrate for the two reactions. This type of paper has a higher sensitivity (0.1 μg of lead and copper in the above reactions) compared to other papers. Moreover, the polyethylene layer under the paper prevents the dispersion of the reaction product and lessens the contamination of the paper during handling, allowing for easier and tidier operation of the test on bullet holes.

The identification of lead and copper around bullet holes is carried out with Benchkote 5- by 7-cm filter paper, moistened with the aforementioned solvent. The paper is then pressed against the BHP for a short time. After removing the paper, a few drops of the reagent (sodium rhodizonate or rubeanic acid) are applied to produce the colored mark. The appearance of a colored mark similar to the shape of the hole, indicates the presence of lead or copper. An advantage of this method, stemming from the fact that areas located further away from the hole do not react, is that those areas can be considered as blanks.

Results

Quantitative Analysis by AA Spectrophotometry

Data for lead and copper residues on various targets are listed in Table 1. The data indicate that lead bullets deposited large amounts of lead (dozens of micrograms) on BHPs while jacketed bullets deposited significant amounts of lead and copper in most of the tests. These

TABLE 1—*Quantitative determination of lead and copper at the periphery of bullet holes by atomic absorption spectrophotometer (results corrected for background).*[a]

Target	Type of Weapon	Bullet Type	Firing Distance, m	Results, μg	
				Lead	Copper
White cloth	9-mm Israeli submachine gun	lead with brass jacket	2	6.85	8.79
	9-mm Israeli submachine gun	lead with brass jacket	50	5.86	6.70
	5.56-mm M16 rifle	lead with brass jacket	1.5	3.71	2.54
	7.65-mm semiautomatic pistol	lead with brass jacket	1.5	15.20	9.25
	.38 revolver	lead	20	44.22	0.45
Red cloth	9-mm Israeli submachine gun	lead with brass jacket	50	4.71	5.64
Cardboard	9-mm Israeli submachine gun	lead with brass jacket	50	5.85	14.85
	.22 revolver	lead	20	34.30	0.25
Plastic container	9-mm Israeli submachine gun	lead with brass jacket	10	0.83	1.25
	5.56-mm M16 rifle	lead with brass jacket	10	0.09	0.66
	.22 semiautomatic pistol	lead	10	13.53	0.04
Wooden board	9-mm Israeli submachine gun	lead with brass jacket	30	0.60	2.85
	.22 semiautomatic pistol	lead with copper plate	5	89.10	35.30
	7.65-mm semiautomatic pistol	lead with brass jacket	10	3.15	0.32
Metal sheet	9-mm Israeli submachine gun	lead with brass jacket	20	0.45	4.65
	9-mm Israeli submachine gun	lead with brass jacket	10	1.80	1.77
	.22 semiautomatic pistol	lead	10	69.00	0.20
	.38 revolver	lead	10	77.50	0.20
	7.65-mm semiautomatic pistol	lead with copper and nickel jacket	10	5.00	1.23
Floor tile	7.65-mm semiautomatic pistol	lead with brass jacket	10	5.59	7.92
	.22 semiautomatic pistol	lead	2	99.22	0.06

[a] For each weapon several types of ammunition were used.

results, though not very unexpected, supported in the first place the approach of devising a field kit for the identification of bullet holes.

Qualitative Identification of Bullet Holes by Spot Test

Data for 250 test shots are listed in Table 2. A (+) mark denotes a red-violet or green-black positive result similar to the shape of the hole. These results indicate that around bullet holes and marks there is a sufficient amount of lead and copper residues to be detected using spot test techniques. The procedure was found to be a quick, sensitive, and reliable for the identification of metals around bullet holes under field conditions. Another important outcome is the possibility to determine also the type of bullet that penetrated the hole; lead bullets produce positive results only with the reagent for lead, while brass or copper jacketed lead bullets produce positive results with both reagents. (Note that the experience accumulated in the authors' laboratory shows that when a lead bullet is shot, the contribution of copper residues from previously shot copper/brass jacketed bullets is practically negligible.)

The Field Kit

The new field kit developed in this laboratory applied the results obtained in the quantitative and qualitative analyses of bullet holes to the identification of lead and copper at the scene of crime.

The kit is designed as follows (see Fig. 1):

(a) Two different colored polyethylene tubes marked 1 and 2 (a different color for each of the reagent). The reagents in solution form have a short shelf life, therefore the reagents crystals are kept apart from the solvent by storing the solvent in a glass ampule. The ampule is then inserted into the tube which contains the solid reagent. Tube 1 contains 10 mg of sodium rhodizonate powder and in its ampule 5 mL of deionized water. Tube 2 contains 50 mg of rubeanic acid and in its ampule 5 mL of ethanol. After breaking the ampules and shaking the

TABLE 2—*Qualitative identification of lead and copper at the periphery of bullet holes using the spot test method.*[a]

Target	Bullet Type	Number of Test Shots	Results	
			Lead	Copper
Cloth	lead with brass jacket	20	+	+
	lead	20	+	−
Cardboard	lead with brass jacket	15	+	+
	lead	15	+	−
Wooden board	lead with brass jacket	20	+	+
	lead with copper and nickel jacket	10	+	+
	lead	20	+	−
Metal sheet	lead with brass jacket	30	+	+
	lead with copper and nickel jacket	20	+	+
	lead	30	+	−
Floor tile	lead with brass jacket	10	+	+
	lead with copper and nickel jacket	10	+	+
	lead	10	+	−
Wall plaster	lead with brass jacket	10	+	+
	lead	10	+	−

[a] Mixed types of weapons and ammunition were used.

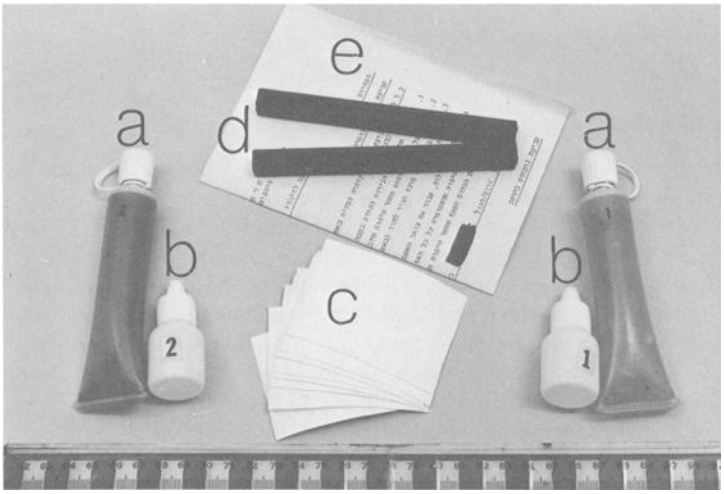


FIG. 1—*The kit components:* (a) *the reagents in polyethylene tubes,* (b) *the solvents in polyethylene bottles,* (c) *filter papers,* (d) *breaking pliers, and* (e) *instructions and form.*

tubes a 0.2% aqueous solution of sodium rhodizonate and 1% alcoholic solution of rubeanic acid are obtained.

(b) Two solvents in small polyethylene bottles. Bottle 1 contains 5 mL of 5% acetic acid solution and Bottle 2 contains 5 mL of 12% ammonium hydroxide solution.

(c) Ten Benchkote 5 by 7-cm filter papers.

(d) Five empty polyethylene bags (to store the papers after sampling).

(e) Pliers for breaking ampules.

(f) A printed form, with brief sampling instructions on one side and a form for filling in details of the case on the other side.

All these components are sealed in an outer bag made of polyethylene.

Operational Instructions

Identifying the Presence of Lead

1. Take one sheet of paper and hold near the rim.
2. Drip a few drops from Bottle 1 onto the paper until most of the paper is moistened.
3. Press the wet part of the paper onto the periphery of the hole for 60 s, being careful not to slide it.
4. With the enclosed pliers, break the ampule inside Tube 1 and shake it for a few seconds.
5. Place several drops from Tube 1 onto the moistened part of the paper.
6. To remove the orange background, apply several drops from Bottle 1 onto the paper.

A red-violet color similar to the shape of the hole or mark implies the presence of lead.

Identifying the Presence of Copper

Follow Steps 1 to 5 with Bottle 2 and Tube 2 on the same hole or mark. A green-black color similar to the shape of the hole or mark implies the presence of copper.

Note: One kit is sufficient for testing five holes or marks.

Conclusions

The newly developed field kit has many pronounced advantages:

1. The kit has been designed for simplicity of operation, and it can be used at the scene of the crime by any technician or nonscientific police officer with a minimum of training.
2. The color development is fast, simple, and reliable. Overall time for testing one hole is about 3 min.
3. The color produced reflects the shape of the hole while the area further away remains uncolored. It is not necessary therefore to sample blanks.
4. The color reactions produce distinct and unmistakable colors on the white background of the filter paper.
5. It is often possible to classify the type of the bullet that penetrated the target namely, lead or brass/copper jacketed.
6. If the colored imaging of the hole is circular or parabolic, it is often possible to assess the direction from which the bullet was fired.
7. It is possible to identify bullet holes on many types of targets and the identification is not biased by personal judgment.
8. The reagents in the kit form are stable for a fairly long period (at least 18 months).
9. The above method enables a nondestructive test of the target to be examined, thus preserving the evidence for further laboratory analysis, for example, by sampling the bullet hole for scanning electron microscopy. The target is also preserved as evidence for court.
10. The price of the kit is low (approximate cost is in the range of $10 to 20).

The kit has two disadvantages:

1. In the rare cases when the type of the bullets involved are lead with both a copper and nickel jacket, the color produced is a combination of the reactions with both metals of the jacket. It is therefore impossible to discern between the reactions.
2. The colored image of lead with sodium rhodizanate often fades after a short time (about 30 min). It is therefore recommended to take photograph(s) of the image.

Note: In cases involving bullet holes in glass, it is impossible to identify lead and copper traces around the hole because of the fact that the area surrounding the hole is scattered away on impact of the bullet.

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