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Examination of Gunshot Residues

The examination of gunshot residues in a forensic science laboratory should be a series of integrated procedures. The Southwestern Institute of Forensic Sciences includes both the Office of the Medical Examiner and the Criminal Investigation Laboratory. Accordingly, a unique opportunity for comprehensive and coordinated examination of gunshot residues presents itself. This paper deals with those aspects involving items of clothing and deposits which may be present on the hand; the pathological evidence is not covered.

A number of papers have dealt with the detection of firearm discharge residues by chemical, atomic absorption spectrophotometry (AAS) and neutron activation analysis techniques [*1-3*]. In this paper we will deal with gunshot residues utilizing soft X-ray radiography, emission spectroscopy (ES), and AAS.

Examination of Clothing

A series of experiments was devised to determine the applicability of various instrumental techniques for analysis of gunshot residues in our facility. Two weapons, a .22 caliber Colt Offical Police revolver and a .38 caliber Special Smith and Wesson Model 15 revolver, were discharged at measured distances from white muslin cloth. Each person discharging the weapon washed his hands before firing; immediately after firing, each hand was washed with 15 ml of 1 *N* HNO_3 with 5 volume percent HCl. Also, one empty cartridge case was swabbed with the same acid, and the swab allowed to soak in 15 ml of the acid before being filtered and analyzed. The distances used and cloth designations are shown in Table 1.

An X-ray radiograph of each cloth was made after experimenting with exposure times, distance, and tube current using a portable X-ray unit. The conditions were as follows:

X-Ray tube target-to-cloth distance	35 cm
Tube voltage	10 kV
Tube current	2 mA
Exposure time	20 s
Film	Kodak RP/M Mammographic Sheet Film, 8½ by 10 in.

Microscopical examination of the holes showed partially burned powder particles scattered around the bullet hole at all distances fired (up to 30 in.). These powder particles are opaque to the X-rays under the conditions used. Also, blackened areas

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TABLE 1—*Description of conditions for test firing.*

Cloth No.	Distance from Barrel End to Cloth, in.	Weapon	Cloth No.	Distance from Barrel End to Cloth, in.	Weapon
22-C	contact	.22 caliber Colt[a]	38-C	contact	.38 caliber Smith and Wesson[b]
22-6	6	a	38-6	6	b
22-12	12	a	38-12	12	b
22-18	18	a	38-18	18	b
22-24	24	a	38-24	24	b
22-24	30	a	38-30	30	b

[a] .22 caliber Remington Long Rifle, High-Speed, gilded bullets.
[b] .38 caliber Special Winchester 158 grain, round-nosed, lead bullets.

TABE 2—*Analysis of test cloth by AAS (a barium lamp was not available for this experiment).*

Sample	Pb, ppm	Sb, ppm	Cu, ppm	Sample	Pb, ppm	Sb, ppm	Cu, ppm
Cloth blank	ND[a]	ND	ND	Right hand, .38 caliber	1.8	<0.5	<0.5
Right hand, .22 caliber	2.1	ND	0.5	Left hand, .38 caliber	1.1	ND	<0.5
Left hand, .22 caliber	0.9	ND	0.6	38 cartridge case	12.8	7.4	1.6
22 cartridge case	100[b]	ND	1.7	38-C	175[b]	4.7	10.3
22-C	75[b]	ND	0.9	38-6	75[b]	1.9	5.3
22-6	85[b]	ND	5.8	38-12	7.2	<0.5	1.2
22-12	10.2	ND	1.1	38-18	2.6	ND	<0.5
22-18	6.7	ND	0.5	38-24	3.0	ND	<0.5
22-24	3.6	ND	<0.5	38-30	2.1	ND	<0.5
22-30	3.0	ND	<0.5				

[a] ND means not detected.
[b] High lead values beyond linear range of standard curve but estimated from high lead standards.

around the entrance holes are opaque up to about 12 in.; the blackened areas are caused by carbon fouling and primer residues. ES analysis of a small portion of the .38 contact cloth at the entrance showed the following: less than 0.1 percent of barium, lead, and copper and trace amounts of magnesium, antimony, silicon, aluminum, and calcium. The silicon, aluminum, and calcium were contaminants from the cloth. The 1 by 1-in. portion of cloth around the bullet hole was removed and placed in 15 ml of the HNO_3 solution. After filtering the solution, AAS analysis yielded the data shown in Table 2.

Using the foregoing as background, we developed a general scheme for the examination of clothing. After drying, soft X-ray radiographs are obtained from clothing with suspected bullet holes. ES analysis is then performed on a few fibers at the periphery of the apparent bullet hole, using an undamaged portion of the same clothing as the control. The Walker nitrite test is also employed at this point [4]. From the pattern of discharge residues on the radiograph and the elemental analysis, we are able to determine inshoot versus outshoot and obtain some indication of range in most cases.

Handwashings

Numerous papers discuss the deposition of metallic components from primer and cartridge components on the hand of a person firing a weapon [*3,5*]. At the Institute each hand is washed separately as per Green and Sauve [*6*]; depending on circumstances, palms may be washed separately. Five-millilitre portions of 1 *N* nitric acid, 5 volume percent in hydrochloric acid and 1 percent in potassium content, are used. The potassium is added to suppress the ionization of barium in the flame [*7*]. Gauze pads, 2 by 2 in., are used instead of swabs and each solution is filtered before aspiration. Lead, antimony, and copper are determined on a Perkin-Elmer Model 303 atomic absorption spectrophotometer using air-acetylene; barium is determined with nitrous oxide-acetylene.

The suicide weapon routinely accompanies the body brought in for autopsy. In 18 months of analysis, gunshot residues on hands were determined in 285 cases; of these, 235 were suicides, 44 involved murder, and six were accidental shootings. In most of these cases, hands of the victims were covered at the scene with plastic bags by an investigator from the Office of the Medical Examiner.

During 1973 60 weapons were test-fired in conjunction with suicides. In 27 of the 60 cases, significant contrast in lead content of the firing versus nonfiring hand was determined; usually this was supported by one or more of the other elements determined—antimony, copper, and barium. The 33 instances where no significant contrast was detected were due to a combination of tight weapon, ammunition, and circumstance.

It was reported in 237 of the 285 cases that it was indeterminate from the analytical data that the deceased had discharged a firearm recently. In 48 cases, we reported that the metallic contents showed significant contrast between left and right hand, and were consistent with the weapon being discharged in a particular hand.

One of the 48 cases showing contrast involved the following data (ND means not determined).

Location of Residue	Pb, ppm	Sb, ppm	Cu, ppm	Ba, ppm
Right hand, deceased	7.6	ND	4.3	1.0
Left hand, deceased	3.4	ND	2.4	ND
Cartridge case	11.8	2.8	3.0	>20
Right hand, police cadet	3.7	ND	1.2	1.0
Left hand, police cadet	1.9	ND	0.6	0.5

It is with some reluctance that we report actual analyses in parts per million of the metal. We realize that the sampling of the hands is not quantitative, nor is the deposition of the gunshot residues reproducible. Interpretation of data needs all available input, including the presence of partially burned powder noted on gauze pads, sodium rhodizonate spot tests for suspected lead particles, noticeable fouling on the hands, and other observations by the medical examiner at autopsy.

Another innovation we have used is to test-fire the weapon under conditions similar to the incident. If a contact wound is involved, the weapon is held in contact with a gelatin block which simulates the consistency of the human body [*8*]. This affords a basis for determining whether the weapon and ammunition in question are likely to leave detectable gunshot residues. We have observed that more residues are deposited on the firing hand using weapons in contact with the gelatin blocks than if the same weapon is discharged several inches from any obstruction.

Observations

Our experience is that each weapon differs in the amount of gunshot residues deposited on a firing hand or on clothing. An estimate of range is considered valid only for the actual weapon being discharged with the ammunition remaining in the gun. If ammunition from the same lot is unavailable, we test-fire the weapon with ammunition from the same manufacturer. During this test firing, handwashings are obtained which yield a basis for determining the expected elemental levels. As expected, we experience different residue depositions for revolvers depending on the individual chambering of the round. Seldom do we detect gunshot residues in cases involving autoloading pistols, unless in contact wounds or for calibers smaller than .32 caliber.

We perform the radiography, ES, AAS, and range estimation as an adjunct to the findings at autopsy. This information is passed on to the police officer to assist in his investigation. It is important to emphasize that we are dealing with available evidence; residues are lost from clothing and hands. The sampling is seldom quantitative although we strive for efficiency and uniformity. From each of the examinations and analyses comes a segment of information of value as an investigative aid.

The major improvement to be made is in the AAS technique for hand residues. The procedures using flame atomic absorption lack sensitivity for barium and antimony. This has been pointed out by recent workers [*9,10*]. Nonflame atomic absorption techniques are being instituted in our laboratory, and show promise for lowering the detection limits.

Summary

Examination of gunshot residues is a coordinated sequence involving soft X-ray radiography, emission spectroscopy, and atomic absorption spectrophotometry. Clothing is examined for gunshot residues by soft X-rays and emission spectroscopy. Gunshot residues on the hands of a person suspected of discharging a weapon are analyzed by atomic absorption spectrophotometry and compared with handwashings under test-firing conditions. In 285 cases, 48 were reported as having metallic residues consistent with firearm discharge. Atomic absorption spectrophotometry sensitivity for barium and antimony in flame atomic absorption spectrophotometry is poor; flameless methods hold forth promise.

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