J Forensic Sci, Apr. 1974, Vol. 19, No. 2

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Firing Distance Determination by Atomic Absorption Spectrophotometry

A determination of muzzle-to-target distance is often required in criminal cases involving shooting. The conventional method using Walker's test [*1*] or visual examination of test firings may not be sufficiently accurate under certain circumstances. In other circumstances the maximum distance to which such tests are effective may not be adequate. In such cases the neutron activation analysis (NAA) method [*2*], which is effective to greater distances, can be used. However, the drawbacks of this method could be the expense and the possible long analysis time. The NAA method of firing distance determination is based on the concentration pattern of antimony around bullet holes. This method is not effective in analyzing for lead, which is present around bullet holes.

This paper reports an alternative method of determining firing distances by using the concentration pattern of lead around bullet holes determined by atomic absorption spectrophotometry. The concentration patterns of lead have been studied with respect to variations of weapon, ammunition, and target. A practical method is recommended and results from simulated cases are reported.

Apparatus

The atomic absorption instrument used was a Perkin Elmer Model 303 unit. The burner was of 3-slot Boling type. The source was a Perkin Elmer hollow cathode lamp. A Perkin Elmer recorder readout connected to a Sargent recorder was used to obtain the absorption measurements. Increased sensitivity with lower noise was obtained by using a dry-ice trap to remove the acetone from the acetylene fuel.

Materials and Reagent

Stock solutions were prepared from "Fisher Certified" or "Analar" grade chemicals. The acid used was BDH "Aristar" quality and all dilutions were made with water which was double-distilled and deionized.

Experimental Procedure

The experimental procedure used was as follows:

(1) Test shots were fired from different distances using the weapon-ammunition-target combination of interest.

Received for publication 11 June 1973; revised manuscript received 7 Aug. 1973; accepted for publication 13 Sept. 1973.

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(2) Concentric circular samples around the bullet hole of 0.25-cm width were cut out of the target material. Generally three or four such sections were adequate. This was done with both the test shots and the case sample. (The sample containing the black ring produced by the bullet was discarded since the lead concentration is not reproducible in these samples.)

(3) One ml of 4 *M* nitric acid was added to each sample in a centrifuge tube and allowed to stand for a few hours, or overnight if possible.

(4) The amount of lead in the supernatant liquid in each sample was then determined using the optimum instrumental settings listed in Table 1.

(5) The muzzle target distance was then determined by a comparison of the data from the case sample with those from test shots. The error was estimated from the variations in the values obtained for the different excised sections from the case and test samples, and also from the results of duplicate test shots.

TABLE 1—*Optimum conditions for atomic absorption analysis of lead.*

Fuel:	air—22.7, l/min at 40 psig acetylene—4.4, l/min at 8 psig
Slit width:	0.3 mm, 0.2 nm band pass
Wavelength:	283.3 nm
Source Current:	30 ma
Burner Height:	Light path at 3 mm above the burner top

Results and Discussion

Variation in Lead Concentration with Firing Distance

Most of the experimental data in this study have been obtained using a Remington Model 66, .22 semiautomatic rifle, Canadian Industries Ltd. (CIL) ammunition, and filter paper targets. The amount of lead deposited around a bullet hole rapidly decreases with increasing muzzle-to-target distance, as shown in Fig. 1. This result is similar to the NAA results with antimony. The accuracy and precision of the atomic absorption method is ±10 percent and the reproducibility of the lead concentration at a fixed firing distance was generally less than ±25 percent. Accurate determinations of firing distance are therefore possible on the basis of the lead concentration pattern around bullet holes. It is seen (Fig. 1) that the lead can be detected at firing distances of 36 in. in these experiments. The radii of the samples mentioned in Fig. 1 are the outer radii. The corresponding inner radius is 0.25 cm lower in all the cases. In contrast the powder residue around the bullet hole is not detectable, in this instance, beyond 18 to 20 in. by conventional techniques. As in an earlier NAA work, the targets were generally shaken prior to atomic absorption analysis in order to eliminate loose surface particles. This somewhat simulates case situations, where the targets generally are handled during their collection and transportation to the laboratory.

Effect of Different Target Materials

A series of test shots was fired from a fixed distance using cloth, filter paper, and human skin as targets in order to determine the variation of lead concentration in these targets. The data will be useful in casework, where the same target involved in the case may not always be available for test purposes, particularly human tissue material. The results are

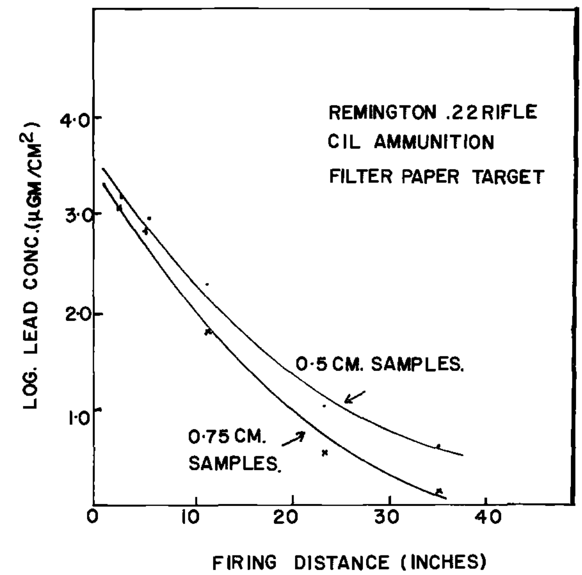

FIG. 1—*Variation of lead concentration with firing distance.*

shown in Fig. 2. The lead concentration patterns on these targets are generally similar and the error in firing distance estimate resulting from the use of a different target is not significant. The filter paper target and human skin give very similar results, while the cloth used in this work gives slightly higher lead concentrations. This indicates that test firings can be made conveniently on filter paper targets without a significant loss of accuracy in the firing distance estimate.

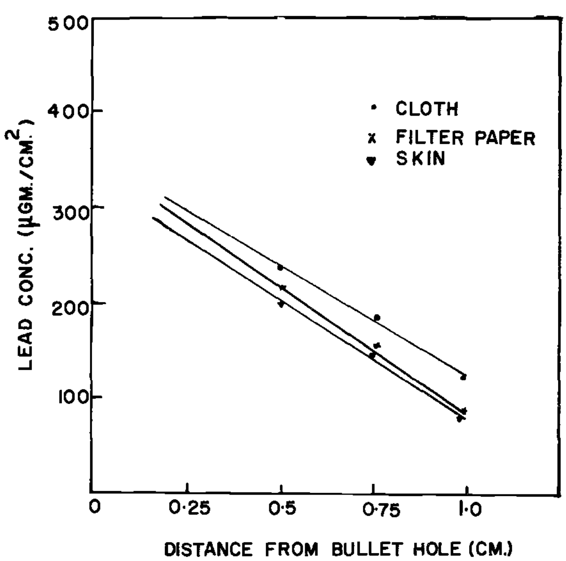

FIG. 2—*Variation of lead concentration with different targets.*

Effect of Different Weapons

The data obtained from a series of test shots fired from a fixed distance using different weapons are illustrated in Fig. 3. This information is necessary and helpful in drawing conclusions regarding firing distance estimates in criminal cases where the actual weapon used may not be available. It is seen here that the different weapons produce somewhat different lead concentration patterns around the bullet hole, although the general concentration range is similar. Hence, the error introduced in casework as a result of using a different weapon for the test firings is not significant.

Effect of Different Ammunition

The effect of using different ammunition on the lead concentration pattern is shown in Fig. 4. Here again it is seen that, although different ammunitions produce somewhat different lead concentration patterns, the lead values are generally in the same range. The error introduced from this source in the firing distance estimate is also not significant.

Simulated Cases

In order to determine whether or not the atomic absorption method will work in actual cases, seven test shots were fired by a member of the Firearms Section in the absence of the atomic absorption analyst. The targets were turned over to the atomic absorption group, who conducted the lead determinations and arrived at a firing distance estimate. The results are tabulated in Table 2. The actual firing distances were revealed after the experimental determinations had been made. The excellent agreement between the estimated and actual values shows that the atomic absorption method is an effective one for firing distance determination.

The rifles used in the examples quoted above each had a barrel length of approximately 20 in. Hence, if the firing distance (that is, muzzle-to-target distance) is more than approximately 16 in., then the possibility of a struggle or suicide, in which the victim released the

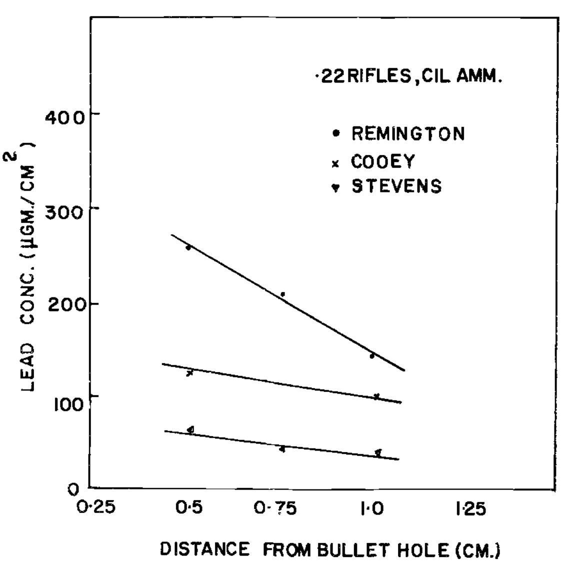

FIG 3—*Variation of lead concentration with different weapons.*

TABLE 2—*Determination of firing distances in simulated cases (weapon: Remington Model 66 .22 semiautomatic rifle; ammunition CIL).*

Case No.	Estimated Firing Distance, in.	Actual Distance Revealed Later, in.	Error, in.
1	7.5 ± 1.5	8	0.5
2	1 ± 1	2	1
3	11.8 ± 1	10	1.8
4	17.4 ± 1	18	0.6
5	12.9 ± 1	12	0.9
6	14.3 ± 0.7	14	0.3
7	17 ± 0.3	16	1

trigger, is eliminated. This is because the victim at whom the muzzle is pointed could not reach the trigger in such instances. The firing distance estimate is of maximum value in this situation. The atomic absorption method as described in this work is effective up to 36 in. as mentioned earlier. The sensitivity of the method, of course, decides the maximum range to which the technique is applicable. The limit of detection for lead in this work is approximately 0.5 μg/ml. Thus, if non-flame atomization equipment (such as the graphite furnace) were available, the lead sensitivity would be greatly increased and the range of effectiveness of the method would be much higher. The method described above is inexpensive and the analysis time is only a few minutes per sample. The method is therefore rapid, practical, and can be used routinely by most forensic science laboratories for firing distance determination. Bullet holes can also be identified by the same method through the lead concentration pattern around the hole.

Summary

An inexpensive and rapid method for the determination of firing distances has been reported. The method uses atomic absorption spectrophotometry for the determination

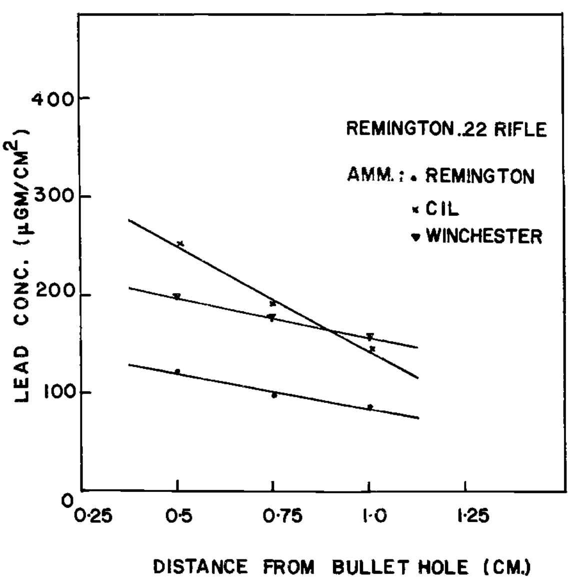

FIG. 4—*Variation of lead concentration with different ammunition.*

of the lead concentration patterns around bullet holes. The sections around the bullet holes are removed and soaked in 4 *M* nitric acid and the amount of lead in the supernatant solution is determined. The firing distance estimates are made by comparison with data obtained from test firings.

Acknowledgments

The author wishes to thank the members of the Firearms Section of The Centre of Forensic Sciences, particularly Mr. R. Monument, for their help and cooperation in firing test shots. The criticism and comments from Mr. D. M. Lucas, director, and Mr. E. G. Clair, head of the Chemistry Section, are acknowledged.

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