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Activity After Shooting and Its Effect on the Retention of Primer Residue

One of the best known applications of neutron activation analysis (NAA) in the forensic laboratory is the determination of antimony (Sb) and barium (Ba) concentrations deposited on the hand when a firearm is discharged.

Sb and Ba are present in the primer mixture of many cartridges and these elements are deposited on the thumb, forefinger, and connecting web area of the hand holding the weapon when the weapon is discharged. Using a lifting medium such as moistened cotton swabs or paraffin, these elements are lifted from the pertinent area of the hand. NAA is the analytical method of choice in the FBI Laboratory for detecting and quantifying Sb and Ba found in microgram concentrations on the lifting medium.

The most extensive research in the field of primer residue analysis was conducted at Gulf General Atomic [*1,2*]. Their compilation of test firings and hand blank values is the most extensive one available. The compilation of test firings lists the Sb and Ba concentrations on the hand but does not list concurrent Sb and Ba concentrations on the nonshooting hand.

An in-house project was conducted in the FBI Laboratory during the late 1960's in order to evaluate the feasibility of conducting examinations for primer residue on the hands of a suspected shooter on a routine basis. Handguns used were from the firearms collection maintained in the FBI Laboratory. Our results showed that when a gun is discharged in a bullet recovery room, most of the handguns deposit significant amounts of Sb and Ba on the hand holding the weapon when compared to the nonshooting hand. Based on our findings, the Sb and Ba test appeared to have merit and was instituted as an examination offered to our contributors.

Sb and Ba determinations conducted on paraffin lifts and cotton swabs which have been submitted by law enforcement agencies in actual cases have only rarely exhibited significant concentrations of antimony and barium on one or both of the hands of a suspected shooter. Because the Sb and Ba are present on the surface of the hand, the possibility exists that the Sb and Ba that might have been deposited on the hand when the subject discharged the handgun are no longer there by the time the police officer apprehends, secures, and transports the subject to the police station where the lifting medium is applied. This "disappearance" of Sb and Ba (if, in fact, Sb and Ba were deposited) may be due to a variety of things such as washing the hands or physical removal by rubbing or wiping the hands. The purpose of this paper is to examine some of the parameters involved in this test, and to determine to some extent the reliability of the test.

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Experimental

The detailed procedure for the radiochemical separation of antimony and barium from a matrix of cotton or paraffin is beyond the scope of this paper and is available elsewhere [2]. Only the highlights of the procedure are included here.

In these tests, swabs, Sb and Ba standards, and neutron flux monitors were irradiated together for three minutes at a thermal neutron flux of approximately 5×10^{13} n/cm$^2 \cdot$s in the 10-MW National Bureau of Standards Reactor (NBSR), Gaithersburg, Md. The irradiated material was transported to the FBI Laboratory where the Ba was precipitated as $BaSO_4$ and the Sb was precipitated as Sb_2S_3. These precipitates were counted separately on a high resolution 50-cm^3 Ge(Li) gamma ray detector. The concentration of barium was determined using the 163-keV gamma ray of 83-min ^{139}Ba and the concentration of Sb was determined using the 564-keV gamma ray of 67.2-h ^{122}Sb. Chemical yields of the radiochemical separation were determined by the use of ^{133}Ba and ^{125}Sb radioactive tracers. These yields were typically on the order of 100% for Ba and 85 to 90% for Sb.

Background Preparation

Two cotton-type applicator swabs moistened with 5% nitric acid were used on all hands tested. A series of the moistened blank swabs was analyzed for Sb and Ba and the results are shown in Table 1. Because of the low concentration of Sb and Ba in the

TABLE 1—*Blank moistened swabs.*

Pairs of Swabs	Ba, μg	Sb, μg
1	0.05	0.002
2	0.04	0.001
3	0.09	0.001
4	0.07	0.001
5	0.05	0.002
6	0.06	0.001
7	0.06	0.001
8	0.06	0.001

moistened swabs, no blank corrections were necessary and therefore were not made in any of the results in the following tables.

On separate days over a period of several weeks, blank concentrations of Sb and Ba were measured on the thumb, forefinger, and connecting web area of both hands of three subjects. Figure 1 shows the area of the hand that was swabbed. This area was meticulously swabbed by the same person for all tests to insure uniformity. From Table 2 it is seen that the hand blank concentrations of Ba are generally consistent from right to left hand for these subjects; however, there can be a significant difference in Ba concentration as a function of the day the swabs were obtained. On three separate days the Sb concentration on the hands of two of the subjects was much higher than on all other days. There was no apparent environmental explanation for the high amount of Sb on the hands of Subject B. Subject A used an air brush to paint models the night before the high amount of Sb was measured on his hands. Sb was not detected in a representative number of the paints that Subject A might have used.

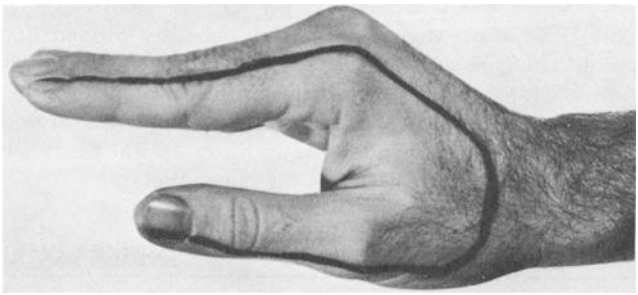

FIG. 1—*Area of hand sampled.*

TABLE 2—*Hand blanks.*

	Subject A		Subject B		Subject E	
Hand	Ba, μg	Sb, μg	Ba, μg	Sb, μg	Ba, μg	Sb, μg
R	0.21*	0.01	0.27	0.04*	0.43	0.03
L	0.42*	0.03	0.22	0.11*	0.40	0.01
R	0.41	0.01	0.18	0.01	0.41	0.01
L	0.50	0.01	0.18	0.01	0.33	0.01
R	0.32	0.01	0.32	0.01	0.32	0.01
L	0.32	0.01	0.25	0.01	0.35	0.01
R	0.23	0.01	0.47	0.04*	0.23	0.02
L	0.19	0.01	0.50	0.05*	0.22	0.01
R	0.28	0.01	0.41	0.01	0.25	0.02
L	0.31	0.02	0.27	0.01	0.30	0.02
R	0.49	0.11*			0.28	0.03
L	0.45	0.13*			0.24	0.01
R					0.35	0.01
L					0.36	0.01

Average of hand blanks: 0.32 ± 0.10 μg and 0.01 μg Sb (excluding starred Sb values).
* Unusual cases.

Inasmuch as the hand blank values for Sb and Ba vary and are (as will be shown) a relatively small contributor to the total Sb and Ba detected after firing the test weapon, no hand blank correction has been made in any of the following tables. For graphical purposes, average Sb and Ba concentrations were employed. Sb concentrations in the range from 0.001 to 0.01 μg, which were encountered in this study and are encountered in actual casework, have been assigned the value 0.01 μg. In our experience, 0.01 μg of Sb is an insignificant amount.

Gun Tests

A .45 caliber U.S. pistol, Model 1911, which deposited Sb and Ba in concentrations higher than most handguns generally deposit, was employed for all tests. Ammunition of Remington manufacture was used for all test firings. Table 3 shows the concentrations of Sb and Ba on the hand holding the weapon for a single discharge of the weapon on twelve separate days. Also shown is the Ba to Sb ratio, which is reasonably consistent, indicating that Sb and Ba are deposited in the same proportion.

TABLE 3—*Test firings of .45 caliber U.S. pistol Model 1911.*

	Ba, μg	Sb, μg	Ba to Sb Ratio
	10.13	0.98	10.3
	16.25	1.70	9.6
	4.32	0.38	11.4
	12.30	1.65	7.5
	7.44	0.92	8.1
	3.43	0.43	8.0
	16.49	2.47	6.7
	9.65	0.99	9.7
	12.46	1.62	7.7
	3.81	0.38	10.0
	11.29	2.54	4.5
	8.53	1.53	5.6
Avg	9.68 ± 4.43	1.30 ± 0.75	8.3 ± 2.0

It is recognized that this type of weapon is seldom used in actual cases which come to the attention of the FBI Laboratory. However, because of the high concentrations of Sb and Ba deposited, the weapon was very useful in conducting the following experiments.

Controlled Experiments

Several activities were chosen which could be monitored carefully and which approximated types of activity that are encountered by a suspected shooter. These activities are washing hands, rinsing hands, wiping hands on towels and clothing, placing hands in pockets, and handcuffing the hands behind the back.

Washing Hands

Intuition dictates that if a subject washes his hands with soap and water and then wipes them with paper towels, any Sb and Ba present as a deposition from a handgun will be removed. Table 4 shows that the Sb and Ba measured after such washing is less than many of the hand blank values for Sb and Ba measured on Subject B. This test was not repeated.

TABLE 4—*Effect of washing hands on Sb and Ba concentrations on Subject B.*

Hand	Ba, μg	Sb, μg
R	0.19	0.02
L	0.22	0.01

Rinsing Hands

After discharging the test weapon, the hands were rinsed with low pressure aerated water for three seconds. The hands were swabbed while they were wet. Table 5 lists the concentrations of Sb and Ba and the Ba to Sb ratio for this controlled activity. This activity removed a substantial amount of Sb and Ba from the hand; however, the Ba to Sb ratio of the material remaining on the hand is generally the same as observed in the test firings in Table 3.

TABLE 5—*Effect of three-second rinse with low pressure aerated water on Sb and Ba concentrations.*

Subject	Hand	Ba, μg	Sb, μg	Ba to Sb Ratio
A	R	0.80	0.09	8.9
	L	0.21	0.01	
	R	2.81	0.35	8.0
	L	0.38	0.01	
B	R	1.51	0.18	8.4
	L	0.27	0.01	
	R	0.77	0.08	9.6
	L	0.31	0.01	
E	R	1.77	0.16	11.1
	L	0.20	0.01	
	R	2.14	0.16	13.4
	L	0.35	0.01	
Avg	R	1.63 ± 0.79	0.17 ± 0.10	9.9 ± 2.0
	L	0.29 ± 0.07	0.01	

Wiping Hands With Towel

After discharging the test weapon, the hands were wiped with a cloth laboratory towel. Table 6 lists the concentrations of Sb and Ba and the Ba to Sb ratio of the material remaining on the hand for this controlled activity. These data show that this activity appears to transfer some Sb and Ba from the right hand to the left hand and that the Ba to Sb ratio of the remaining material has essentially no significance. On four of the tests there is very little difference in the Sb and Ba concentrations between the right and left hands.

Fifteen Seconds to Remove Residue

In a fourth test the three subjects were given 15 s to use any means available on their person to remove Sb and Ba. Subjects A and B wiped their hands on their clothing while Subject E wiped both hands together. The data in Table 7 show that Subject E transferred some of the Sb and Ba from the right hand to the left hand. Subjects A and B removed substantial amounts of Sb and Ba from their hands.

TABLE 6—*Effect of wiping hands with cloth towel on Sb and Ba concentrations.*

Subject	Hand	Ba, μg	Sb, μg	Ba to Sb Ratio
A	R	2.91	0.20	14.6
	L	0.40	0.08	
	R	1.11	0.08	13.9
	L	0.70	0.04	
B	R	0.26	0.02	13.0
	L	0.27	0.03	
	R	0.86	0.11	7.8
	L	0.77	0.07	
E	R	0.33	0.04	8.3
	L	0.25	0.02	
	R	0.27	0.01	27
	L	0.33	0.02	
Avg	R	0.96 ± 1.02	0.08 ± 0.07	
	L	0.45 ± 0.23	0.04 ± 0.03	

TABLE 7—*Effect of using 15 s to remove Sb and Ba.*

Subject	Hand	Ba, μg	Sb, μg	Ba to Sb Ratio
A	R	0.60	0.05	12
	L	0.29	0.03	
B	R	0.29	0.02	14.5
	L	0.22	0.02	
E	R	1.66	0.19	8.7
	L	0.51	0.01	
L		0.06		
Avg	R	0.64 ± 0.37	0.05 ± 0.03	
	L	0.34 ± 0.16	0.04 ± 0.02	

Placing Hands in Pockets

In a controlled test to determine Sb and Ba removal by placing the hands in the pockets, it is seen that while substantial amounts of Sb and Ba are removed when the hand is placed in a pocket three times, a significant portion still remains (Table 8). It appeared that the position of the pocket on the trousers affected the removal of Sb and Ba. More of the thumb, forefinger, and connecting web area came in contact with the fabric on Subject B's trousers, which had a vertical pocket opening. Subject A's trousers had a horizontal pocket opening and less of the thumb, forefinger, and web area contacted the fabric.

TABLE 8—*Effect of placing hand in pocket three times on Sb and Ba concentrations.*

Subject	Hand	Ba, μg	Sb, μg	Ba to Sb Ratio
A	R	2.01	0.24	8.4
	L	0.21	0.01	
	R	3.42	0.27	12.7
	L	0.35	0.02	
	R	1.66	0.19	8.7
	L	0.51	0.01	
B	R	0.50	0.07	7.1
	L	0.20	0.01	
Avg	R	1.90 ± 1.20	0.19 ± 0.09	9.2 ± 2.4
	L	0.32 ± 0.15	0.01	

Handcuffing and Transporting

When a person's hands are handcuffed behind his back and he is then placed in an automobile for 15 minutes, some of the Sb and Ba on the right hand is transferred to the left hand. The limited test results in Table 9 show that the Sb and Ba concentrations on the left hand are much higher than the average hand blank values. A suspected shooter should therefore be swabbed before he is handcuffed and transported.

TABLE 9—*Effect of handcuffing and transporting subject on Sb and Ba concentrations.*

Subject	Hand	Ba, μg	Sb, μg	Ba to Sb Ratio
A	R	1.18	0.13	9.1
	L	0.98	0.15	
	R	1.16	0.14	8.3
	L	0.49	0.11	
B	R	3.75	0.41	9.2
	L	0.89	0.11	
Avg	R	2.03 ± 1.49	0.23 ± 0.16	8.6 ± 0.5
	L	0.79 ± 0.26	0.11 ± 0.04	

Summary of Controlled Experiments

Figures 2 and 3 are graphs of the average amounts of Sb and Ba remaining on the right hand after engaging in the controlled activities.

Unrestricted Activity (Except Washing)

In order to test the effect of the passage of time accompanied by unrestricted activity (except washing) on the concentration of Sb and Ba, the hands of Subjects A and E were

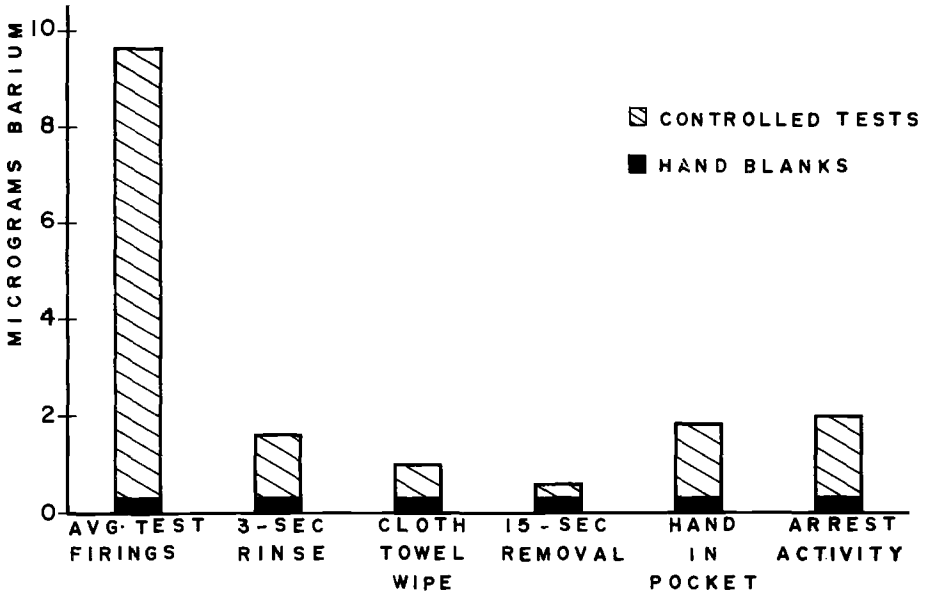

FIG. 2—*Effect of controlled variables on Ba concentration.*

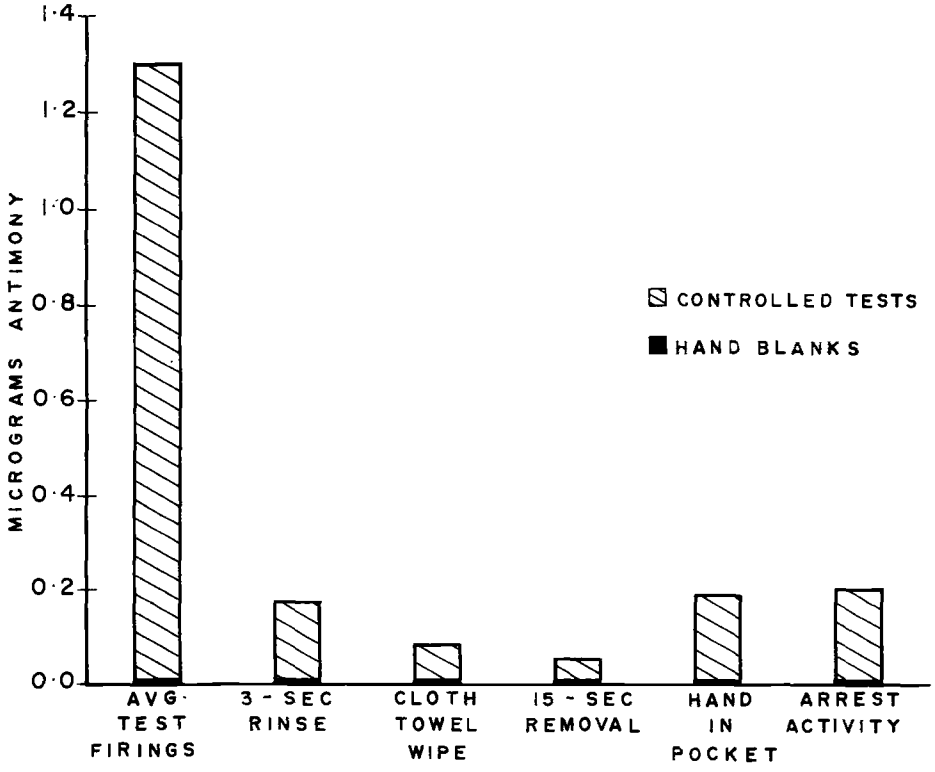

FIG. 3—*Effect of controlled variables on Sb concentration.*

swabbed at various time intervals after discharging the test weapon. Several tests were conducted in which each subject discharged the weapon and both hands were immediately swabbed. The average concentrations of Sb and Ba for these test firings are listed in the first row of Table 10. The subjects then fired the weapon and were instructed to

TABLE 10—*Effect of unrestricted activity (except washing) and passage of time on concentrations of Sb and Ba.*

		Subject A		Subject E	
Time, h	Hand	Ba, μg	Sb, μg	Ba, μg	Sb, μg
0	R	10.86	1.44	7.36	1.12
	L	0.33	0.01	0.30	0.01
0.5	R	4.30	0.43	1.31	0.32
	L	0.40	0.02	0.32	0.01
0.75	R	0.74	0.10	3.67	0.38
	L	0.32	0.02	0.30	0.01
1.5	R	2.01	0.22	0.78	0.04
	L	0.42	0.04	0.59	0.03
2.25	R	0.80	0.12	0.90	0.06
	L	0.70	0.08	0.73	0.05
3.0	R	0.75	0.11	0.58	0.05
	L	0.65	0.11	0.40	0.03
4.25	R	0.57	0.04	0.41	0.01
	L	0.50	0.02	0.37	0.02
5.75	R	0.66	0.08		
	L	0.50	0.05		

go about their normal daily activity. The only restriction was that they were not permitted to wash their hands. The hands were swabbed after each test firing. The time between each test firing and the swabbing depended on the availability of the subject. The time interval ranged from approximately 0.5 to over 5.5 h. These tests were conducted over several days and the subjects were involved in activities such as driving a vehicle, putting on and removing a coat, typing, working in a mail room, and reading.

Table 10 lists the Sb and Ba concentrations on the hands of Subjects A and E over the several-hour period. After two hours there appears to be little difference in Sb and Ba concentrations between the right and left hands. As the time interval increases, the amounts of Sb and Ba are generally decreasing on the right hand. Concurrently, the amounts of Sb and Ba are increasing on the left hand. Figures 4-7 show these data graphically. It appears that after approximately two hours have passed, substantial amounts of Sb and Ba have been removed and it becomes very difficult to conclude that the remaining Sb and Ba are consistent with a deposition of primer residue from the firing of the test weapon.

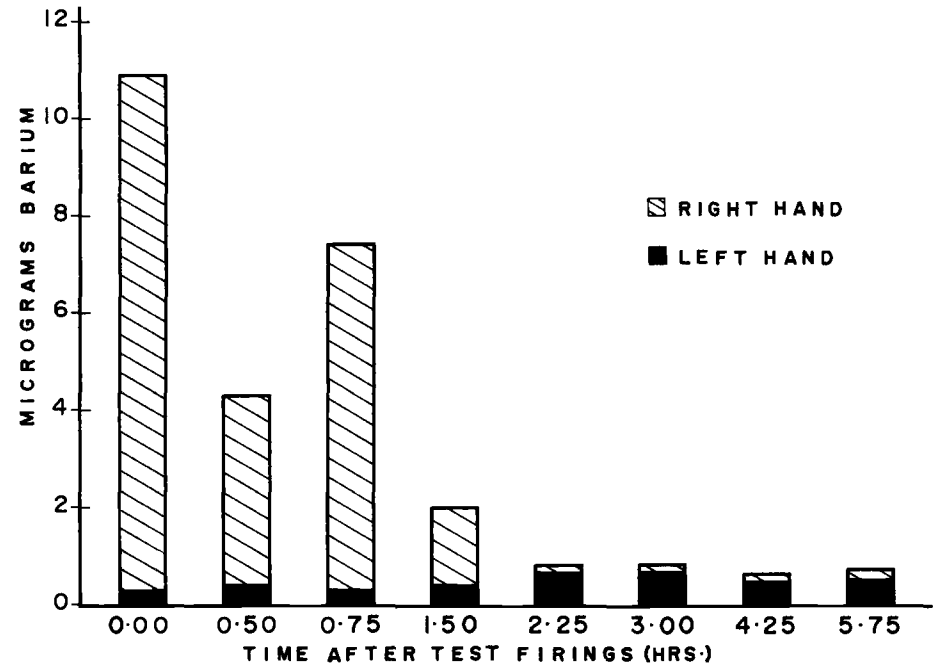

FIG. 4—*Effect of unrestricted activity (except washing) and passage of time on Ba concentration on Subject A.*

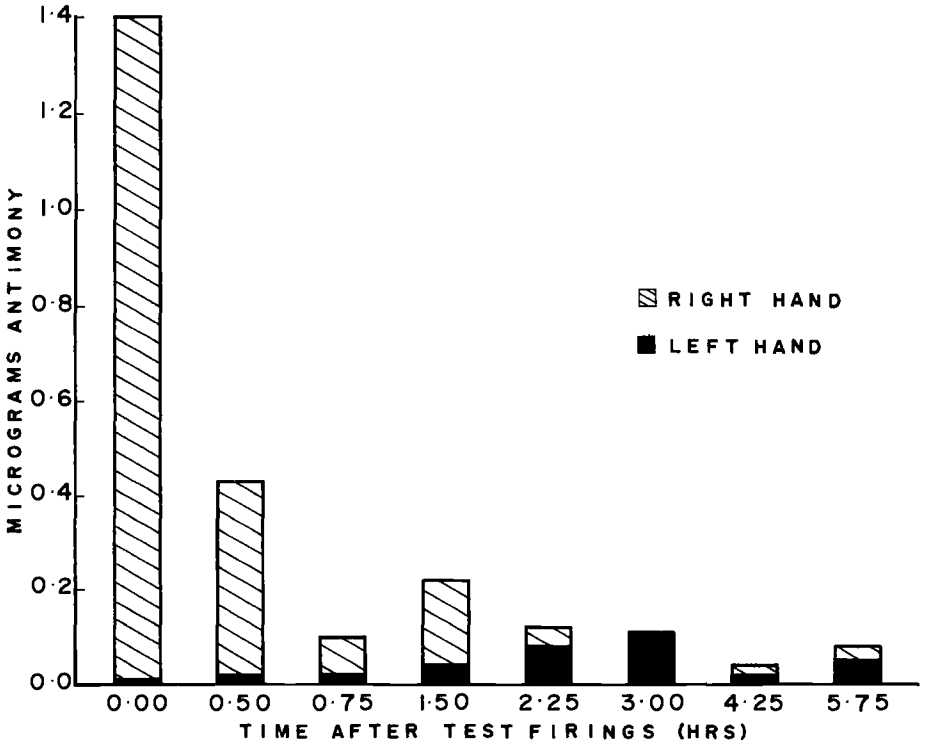

FIG. 5—*Effect of unrestricted activity (except washing) and passage of time on Sb concentration on Subject A.*

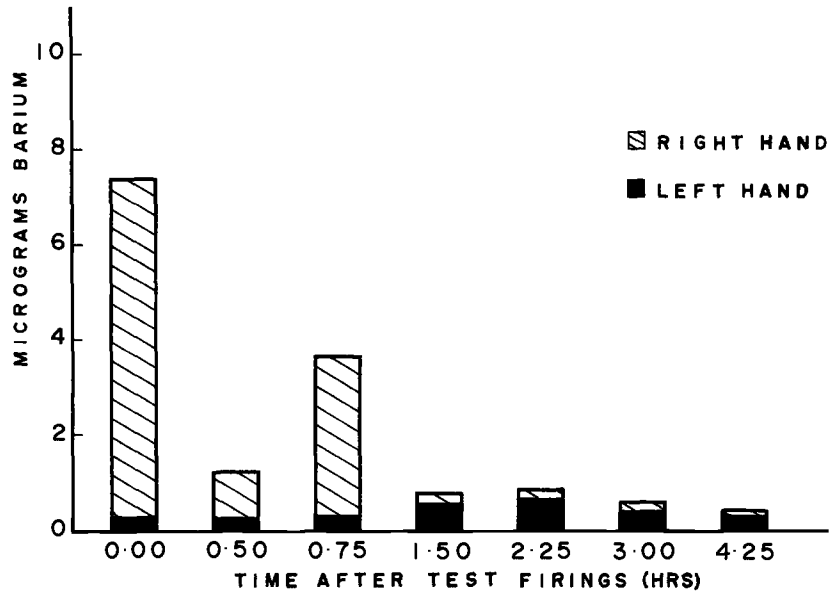

FIG. 6—*Effect of unrestricted activity (except washing) and passage of time on Ba concentration on Subject E.*

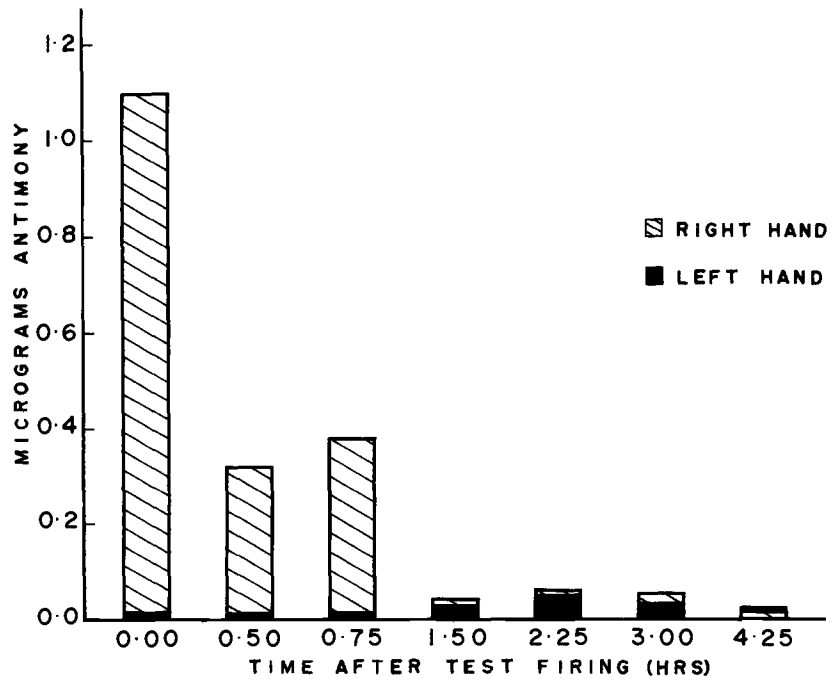

FIG. 7—*Effect of unrestricted activity (except washing) and passage of time on Sb concentration on Subject E.*

Conclusions

The controlled tests and the tests involving the passage of time show that activity removed Sb and Ba from the hands. The lifting medium must be applied to the hands of a suspected shooter before he is permitted to engage in any activity. As the time after the shooting passes, the possibility decreases that significant amounts of Sb and Ba will be detected. This is an especially important point to note, inasmuch as most of the handguns used in the commission of crimes deposit substantially less Sb and Ba than the test weapon used in this study.

A substantial number of primer residue cases are submitted to our laboratory when an evaluation of the suspect's activities or the time interval between the shooting and the swabbing or both would suggest that no meaningful information could be obtained from the analysis.

Acknowledgments

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