G. L. Loper,[1] Ph.D.; A. R. Calloway,[1] B.A.; M. A. Stamps;[1] G. M. Wolten,[2] Ph.D.; and P. F. Jones,[1] Ph.D.

Use of Photoluminescence to Investigate Apparent Suicides by Firearms

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ABSTRACT: A photoluminescence technique, which detects lead and antimony in gunshot residue, was evaluated for use in investigations of apparent gunshot suicides. The study was conducted in conjunction with forensic science laboratories in five U.S. cities. Samples were collected by the adhesive lift method from the backs of the hands of 67 gunshot suicide victims, 41 subjects who died of other causes, and 31 live subjects with high occupational exposure to lead and antimony. Tentative simultaneous threshold levels of 0.85 μg for lead and 0.01 μg for antimony were selected as criteria for presuming the presence of gunshot residue on samples from the hands of these suicide victims. Although blood decreases the detectability of lead and antimony in the samples, 48% of the suicide cases involving handguns other than .22 revolvers exceeded the threshold levels for both lead and antimony. Methods are suggested for eliminating the effects of blood, which should significantly increase the success rate for cases involving these guns. A much lower success rate was obtained for cases involving .22 revolvers and long guns, as expected from the sparse amounts of residue found in previous test firings of these guns.

KEYWORDS: criminalistics, luminescence, gunshot residue, suicide

Between January 1974 and February 1978, The Aerospace Corporation was under contract to the National Institute of Law Enforcement and Criminal Justice, the research branch of the Law Enforcement Assistance Administration, to develop improved methods for detecting gunshot residue on the hands of a person who has recently fired a gun. A survey and technical assessment [*1*] of the techniques used by criminalistics laboratories to detect gunshot residue were completed in 1974, and possible alternative approaches were identified.

As a result of recommendations made in the assessment, The Aerospace Corporation has investigated the feasibility of three potential [*2–5*] approaches to improved gunshot residue detection and identification. One approach involves the use of a photoluminescence technique described in Refs *2* and *3*. Quantitative elemental analyses are carried out to detect lead and antimony in residue removed from the hands of an individual suspected of having fired a handgun.

The present paper describes the results of a five-month effort in which medical examiners or criminalistics laboratories, or both, in Los Angeles, Phoenix, Dallas, Atlanta, and Baltimore participated with The Aerospace Corporation in a field study of the photoluminescence technique to detect gunshot residue. The objectives of the field study were

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[1]Members of the staff, Ivan A. Getting Laboratories, The Aerospace Corporation, El Segundo, Calif. 90009.

[2]Deceased.

to obtain data (1) to allow evaluations to be made of the use of the photoluminescence technique in particular and other elemental analysis procedures in general in the investigations of apparent gunshot suicides, (2) to obtain additional information concerning the levels of lead and antimony on hands resulting from environmental or occupational exposure, and (3) to determine how often fragments of powder are observed on the hands of apparent suicide victims.

The photoluminescence technique for the detection of gunshot residue is compared with other bulk elemental analysis gunshot residue detection methods, and the rationale for the field study is described. Descriptions of the technique, the procedures used in the study, and the data obtained are presented with a discussion of the results and the conclusions that have resulted from the investigation.

Background for Field Study

Valuable information concerning the levels of antimony, barium, and lead to be expected on the hands of persons who have and who have not fired a gun has been obtained through the use of the bulk elemental analysis procedures of neutron activation analysis [*6*], atomic absorption spectroscopy [*7*], and photoluminescence [*2,3*]. However, the detection of these elements on the hand of a person does not in itself provide conclusive identification of gunshot residue. Lead and barium are common in the environment and can be found in various amounts on the hands of most people. Antimony is less common in the general population but occurs on the hands of individuals employed as automobile mechanics, electronic assemblers, machinists, painters [*6*], and lead smelters [*4*].

To confirm the presence of gunshot residue, it is necessary to show that the amounts of these elements on the hands exceed the levels that could be expected to result from environmental exposure and are not of occupational origin. The problem is further compounded by the fact that gunshot residue on the hands of a normally active person declines rapidly with time and decreases generally by an order of magnitude from its initial value in 1 h after a gun is fired [*3,4*].

To account for environmental sources of barium and antimony, the Bureau of Alcohol, Tobacco, and Firearms (ATF) has suggested threshold values of 0.3 and 0.2 μg for these elements, respectively. Except for high levels resulting from occupational exposure, it was recommended that only amounts greater than these values should be taken as presumptive evidence for the presence of gunshot residue. However, a study conducted by Gulf General Atomic Corporation [*6*] has shown that even in samples taken from hands immediately after outdoor test firings, the recommended ATF threshold value of 0.3 μg for barium was exceeded in only about 55% of the firings of .38 and .22 caliber handguns, while the threshold value of 0.2 μg for antimony was exceeded in only about 50% of the .38 caliber firings and in 10% of the .22 caliber firings.

For an immobile subject such as a gunshot suicide victim, there is no rapid loss of residue from the hands with time if the victim's hands are not disturbed. The success rate of bulk elemental analysis techniques for gunshot suicide investigations should depend primarily on the quantity of residue deposited by the ammunition used rather than on the time that has elapsed between the firing and sampling. Because gunshot residue may be present on the hands of a victim of homicide, such a finding does not, in itself, constitute proof of a suicide. Instead, the presence of residue in cases of suspected suicide is taken as strengthening other, more circumstantial, evidence. In these cases, where the primary objective is to confirm a questioned suicide rather than to obtain evidence for a conviction, elemental analysis techniques may at least be adequate screening procedures for detecting gunshot residue.

Intact or partially burned flakes of smokeless powder can sometimes also be observed on the firing hand of a person who has discharged a handgun if the hand is examined promptly or if the person remains immobile. Confirmation of the nature of these flakes can be accomplished by thin-layer chromatography. By this method, residue can be shown readily and inexpensively to be of smokeless powder origin by the identification of the characteristic organic compounds, nitrocellulose or nitroglycerine. Smokeless powder flakes are lost so rapidly from the hands through normal activity that their identification on the hands of living subjects is seldom of practical criminalistic value; however, smokeless powder flakes may be helpful in investigations of apparent suicides. More information is needed to determine whether or not these flakes can be observed frequently enough in suicide cases to merit the time and effort spent in identifying them.

To determine how useful both photoluminescence analysis and the identification of organic flakes would be in investigations of gunshot suicides, laboratory personnel were requested to conduct the following tasks from mid-February 1977 to mid-June 1977:

(1) use photoluminescence to determine the quantity of lead and antimony on the hands of gunshot suicide victims and on the hands of a number of controls (people who had died of causes other than gunshot), and

(2) visually examine the hands of gunshot suicide victims for organic powder flakes and tabulate the frequency and quantity of their occurrence for statistical purposes.

Personnel were asked to record as complete a description as possible of the gun and cartridge used, along with other circumstances for each suicide. Participating laboratories and personnel are listed in the first six entries of Table 1. The Scientific Investigation Bureau of the Nassau County Police Department independently conducted a two-year program to examine the usefulness of the photoluminescence technique for the detection of gunshot residue on the hands of apparent gunshot suicide victims.

TABLE 1—*Participants in field study.*

Laboratory	Participating Personnel
Georgia State Crime Laboratory Atlanta, Ga. Director: Larry B. Howard, Ph.D.	Warren Tillman Kenneth Czyscinski, Ph.D.
Medical Examiner's Office Fulton County, Ga. Director: Robert R. Steivers, M.D.	Robert R. Steivers, M.D. Sgt. J. T. Cameron
Office of the Chief Medical Examiner State of Maryland Department of Post-mortem Baltimore, Md. Director: Russell S. Fisher, M.D.	Bert Morton, M.D., deputy chief Yale Caplan, Ph.D.
Southwestern Institute of Forensic Sciences Dallas, Tex. Director: Charles Petty, Ph.D.	Irving C. Stone, Ph.D. Larry Fletcher
Department of the Chief Medical Examiner/ Coroner Los Angeles, Calif. Director: Thomas T. Noguchi, M.D.	Marc Taylor Tuan Nguyen
Maricopa County Medical Examainer's Office Phoenix, Ariz. Director: Ramon A. Morano	Ramon A. Morano Marilyn Elsmore
Scientific Investigation Bureau Nassau County Police Department Mineola, N.Y. Laboratory Director: Capt. Henry Hack	Det. Thomas A. Kubic Det. Henry T. Galgan

Field Study Procedures

Detection of Lead and Antimony by Photoluminescence

The photoluminescence technique for the quantitative detection of lead and antimony in gunshot residue [*2,3*] is based on the strong luminescence observed at low temperatures for halogen ion complexes of certain metals [*8,9*] having the electronic shell configuration $1\,s^2 \ldots np^6\,nd^{10}\,(n+1)\,s^2$. The transition responsible for this luminescence is believed to be analogous to the intense $^3P_1 \rightarrow {}^1S_0$ emission observed for mercury atoms at 253.7 nm. Strong luminescence is thus observed at low temperatures for submicrogram amounts of the chloride and bromide ion complexes of the mercury-like ions, germanium(II), arsenic(III), selenium(IV), tin(II), antimony(III), tellurium(IV), thallium(I), lead(II), and bismuth(III). No luminescence can be observed from halogen ion complexes of 45 other inorganic ions under the same experimental conditions [*9*]. Concentrated hydrochloric acid solutions (~6 to 8*M*) form transparent glasses at 77 K. Low-temperature complexing of lead(II) and antimony(III) by the chloride ion in concentrated hydrochloric acid solutions provides the most sensitive, convenient, and rapid method for luminescence analysis known for these metal ions. Both ions can be sought sequentially in the same sample.

Lead styphnate and antimony sulfide are both major constituents of most cartridge primers and their residues form luminescent lead(II) and antimony(III) chloride ion complexes when dissolved in concentrated hydrochloric acid [*2*]. The lead(II) and antimonyIII) chloride ion complexes may also be formed by dissolution of metallic lead and antimony from bullet residues by concentrated hydrochloric acid. Barium ion, from the primer constituents barium nitrate or barium peroxide, does not luminesce in frozen hydrochloric acid solutions. At 77 K, the emission spectrum (the plot of the variation in luminescence intensity at a fixed excitation wavelength as a function of emission wavelength) for the chloride ion complex of lead(II) exhibits a maximum at 390 nm, while the emission maximum for the chloride ion complex or complexes of antimony(III) occurs at 620 nm [*2,3*]. The excitation spectrum (the plot of the luminescence intensity at a fixed emission wavelength as a function of excitation wavelength) peaks near 276 nm for the chloride complex of lead(II), and at 250 nm and 300 nm for the chloride complex or complexes of antimony(III) [*2,3*].

Equipment

The photoluminescence instrumentation included spectrofluorometers equipped with xenon lamp excitation sources and both scanning excitation and emission monochromators. Complete spectrofluorometers are available commercially from several manufacturers [*1*], or they can be easily assembled from modular components purchased separately. These instruments can determine both the excitation and emission spectra of a sample. The shapes of the excitation and emission spectral profiles often provide a high degree of specificity to photoluminescence analysis.

Either Perkin-Elmer Model MPF2A or Aminco-Bowman Model 4-8202 commercial spectrofluorometers were used. The photomultiplier tubes (S-5 spectral response), provided as standard equipment with each of these instruments, lacked sufficient red-sensitivity to adequately carry out the analysis of antimony in gunshot residue. Therefore, a Hamamatsu R-777 photomultiplier tube (S-20 spectral response) was provided to each laboratory. This tube fit directly into the Perkin-Elmer spectrofluorometers, but the Aminco-Bowman instrument needed a J10-219 adapter.

Additional equipment included Suprasil quartz sample Dewar flasks and sample tubes, outer Dewar collars, inner Dewar sample tube fittings, and optical cutoff emission filters (Schott FG-10).

As originally equipped, none of the spectrofluorometers had the manufacturer-supplied sample compartment accessories necessary to directly accept the sample Dewar flask needed to conduct the low temperature luminescence measurements. The sample compartment of each Perkin-Elmer spectrofluorometer was modified by removing both the solution cell cuvette holder and the disk-shaped metal cover plate to the sample compartment. Each cover plate was replaced by a disk-shaped cover of the same diameter from which a circular section had been removed that was just large enough to accept the outer collar designed to hold a sample Dewar flask. For each Aminco-Bowman spectrofluorometer, the cuvette and slit holder assembly were removed along with the sample compartment cover plate. These were replaced by comparable parts fabricated from balsa wood and designed to permit the sample compartment to accommodate a sample Dewar flask.

Sampling and Procedures

Each laboratory that collected "handsamples" was provided with sampling disks and instructions for using them in The Aerospace Corporation version of an "adhesive lift" technique [*3,4*]. The sampling disks coated with adhesive transfer tape were identical to those used to collect handsamples for scanning electron microscope particle analysis [*4*]. Generally, the backs of both hands of a subject were sampled separately. This involved sampling the web area between the thumb and forefinger, the backs of the fingers, and the back of the hand.

Before the photoluminescence analyses, each laboratory, using its own spectrofluorometer, constructed calibration plots [*2*] for detecting the chloride ion complexes of lead (II) and antimony(III). The procedures used for detecting lead and antimony in handsamples are presented in Ref *3*. Thin-layer chromatographic procedures [*10*] for confirming the presence and identity of unburned or partially burned smokeless powder flakes on the hands of apparent gunshot suicide victims were also provided to each field study participant for use in selected cases as desired.

Data from Control Subjects

Control Cases—During the study, 65 "handblank" samples were collected by the participating laboratories from the backs of the hands of 41 subjects who had died from causes other than gunshot wounds (Tables 2 through 5). Samples from all but three control subjects were analyzed at The Aerospace Corp. None of the handblank samples from these 38 subjects had measured antimony levels equal to or above 0.01 μg. The three cases LC-6 through LC-8 (Table 5) were reported to have antimony levels above 0.01 μg. These values (as well as the antimony values obtained for the suicide cases L-1 through L-15, discussed below), can be considered upper limit values only, since instrumental problems with the spectrofluorometer recorder during these analyses prevented the accurate measurement of excitation spectra baseline values.

When the back of the hand with the largest amount of lead from each subject is considered, the average amount of lead from the 41 control subjects is 0.26 ± 0.36 μg.[3] The subject with the largest amount of lead, 1.68 μg, had paint on his hands. If this person is not

[3]The standard deviations associated with the average amounts of lead and antimony reported throughout this paper are expressed, for simplicity, by the conventional relationship used for data with normal (Gaussian) distributions:

$$\sigma = \sqrt{\sum_i [(x_i - \bar{x})^2]/(n-1)}$$

However, results obtained during the Gulf General Atomic Study [*6*] and during gunshot residue characterization studies by scanning electron microscope particle analyses [*8*] at The Aerospace Corporation suggest that the amount of gunshot residue found on the hands of people who have fired a gun may more closely obey a log-normal than a normal distribution. If log-normal statistics are obeyed, it would be more correct to use a logarithmic standard deviation than the conventional standard deviation used here. The observation that the standard deviations calculated in the conventional manner here are often larger than their corresponding means may indicate that log-normal statistics are being obeyed.

TABLE 2—*Field study data (control samples),*[a] *Maricopa County Medical Examiner's Office, Phoenix, Ariz.*

Case	Victim's Sex and Occupation	Hand Area Sampled	Lead Found, μg	Antimony Found,[b] μg	Comments
PC-1	f/housewife	right back	0.01	ND	cause of death: heart disease
		left back	0.06	ND	
PC-2	m/retired	right back	0.08	ND	cause of death: heart disease
		left back	0.05	ND	
PC-3	f/housewife	right back	0.05	ND	cause of death: inhalation of auto exhaust
		left back	0.04	ND	
PC-4	m/retired	right back	0.08	ND	cause of death: internal bleeding
		left back	0.10	<0.01	
PC-5	m/tire changer	right back	0.09	ND	...
		left back	0.05	ND	
PC-6	m/consulting engineer	right back	0.06	ND	...
		left back	0.04	ND	
PC-7	m/postal employee	right back	0.05	ND	cause of death: diabetes
		left back	0.05	ND	
PC-8	f/realtor	right back	0.01	ND	died in hospital under sterile conditions
		left back	0.01	ND	
PC-9	f/retired	right back	0.03	ND	history of hypertension
		left back	0.01	ND	
PC-10	m/warehouse worker	right back	0.55	ND	cause of death: heart attack; dirt present on samples
		left back	0.28	ND	
PC-11	f/housewife	right back	0.06	ND	cause of death: strangulation
		left back	0.04	ND	
PC-12	f/housewife	right back	0.03	ND	cause of death: ectopic pregnancy
		left back	0.07	<0.01	
PC-13	f/housewife	right back	0.48	ND	cause of death: victim was run over by an automobile; moderate amount of dirt present on samples
		left back	0.92	ND	
PC-14	m/student	right back	0.05	ND	heart attack; slight amount of dirt present on samples
		left back	0.05	ND	
PC-15	m/bartender	right back	0.04	ND	cause of death: victim was struck by an automobile
		left back	0.03	ND	
PC-16	m/retired	right back	0.15	ND	heart attack; dirt present on samples
		left back	0.05	ND	

[a] Analyses of the samples were done at The Aerospace Corporation.
[b] ND = not detectable.

TABLE 3—*Field study data (control samples),*[a] *Georgia State Crime Laboratory, Atlanta, Ga.*

Case	Victim's Sex and Occupation	Area Sampled	Lead Found, μg	Antimony Found,[b] μg
AC-1	f/housewife	left hand	0.10	ND
AC-2	f/housewife	...	0.06	ND
AC-3	.../secretary	...	0.07	<0.01
AC-4	.../nurse	...	0.35	<0.01
AC-5	.../photographer	...	0.13	ND

[a] Analyses of the samples were done by The Aerospace Corp.
[b] ND = not detectable.

TABLE 4—*Field study data (control samples),*[a] *Office of the Chief Medical Examiner, Baltimore, Md.*

Case	Victim's Sex and Occupation	Area Sampled	Lead Found, μg	Antimony Found,[b] μg	Comments
BC-1	f/housewife	right hand	0.13	ND	cause of death: cardiovascular disease
BC-2	m/garbage collector	right hand	0.15	ND	cause of death: stab wounds; slight amount of blood present on samples
BC-3	m/unknown	right hand	0.25	ND	cause of death: cardiovascular disease; slight amount of dirt present on samples
BC-4	m/retired laborer	right hand	0.18	ND	cause of death: cardiovascular disease
BC-5	m/unknown	right hand	0.15	ND	cause of death: trauma; slight amount of dirt present on samples
BC-6	m/accountant	right hand	0.28	ND	cause of death: cardiovascular disease; slight amount of dirt present on samples
BC-7	m/heavy equipment operator	right hand	0.35	ND	cause of death: trauma; slight amount of dirt present on samples
BC-8	f/housewife	right hand	0.09	ND	cause of death: overdose; slight amount of dirt present on samples
BC-9	m/student	right hand	0.03	ND	cause of death: trauma; slight amount of dirt present on samples
BC-10	m/photographer	...	0.05	ND	...
BC-11	m/maintenance man	...	0.05	ND	...
BC-12	m/morgue attendant	...	0.11	ND	...

[a]The samples were analyzed by The Aerospace Corp.
[b]ND = not detectable.

TABLE 5—*Field study data (control samples),*[a] *Department of the Chief Medical Examiner/Coroner, Los Angeles, Calif.*

Case	Victim's Sex and Occupation	Hand Area Sampled	Lead Found, μg	Antimony Found,[b] μg	Comments
LC-1	m/unemployed	right back	0.46	ND	...
		left back	0.52	ND	
LC-2	m/...	right back	1.68	ND	cause of death: overdose; dirt and paint present on samples
		left back	1.04		
LC-3	m/warehouse foreman	right back	0.54	ND	cause of death: heart attack
		left back	0.70	ND	
LC-4	f/unknown	right back	0.81	ND	cause of death: fatal jump from hotel
		left back	0.72	ND	
LC-5	m/unknown	right back	0.22	ND	cause of death: stab wounds; blood present on samples
		left back	0.36	ND	
LC-6	f/unknown	right back	0.334	≤0.052	...
		left back	0.336	≤0.021	
LC-7	m/helicopter pilot	right back	0.105	≤0.013	cause of death: helicopter collision; blood and dirt present on samples
		left back	0.160	≤0.096	
LC-8	m/unknown	right back	0.44	≤0.119	cause of death: fatal jump from hotel; slight amount of blood present on samples; some ash-like material
		left back	1.30	≤0.04	

[a] Samples LC-1 through LC-5 were analyzed by The Aerospace Corp.
[b] ND = not detectable.

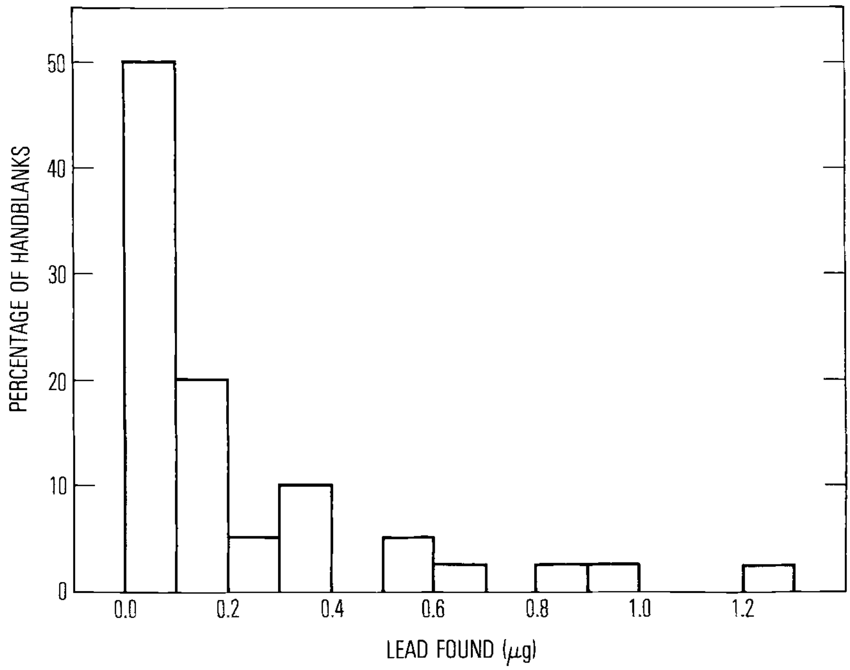

FIG. 1—*Percentage distribution of the number of control cases from coroners' offices versus the largest amount of lead from each case.*

considered, the average amount of lead found on these control subjects is 0.23 ± 0.28 μg. The percentage distribution of the number of control cases (excluding the subject with paint on his hands) versus the largest amount of lead from each case is shown in Fig. 1. Ninety-five percent of the handblanks have quantities of lead equal to or less than 0.85 μg, and 90% have quantities of lead equal to or less than 0.60 μg. None of the handblanks from the 41 control subjects had levels of lead greater than 0.85 μg together with antimony levels equal to or greater than 0.01 μg.

Occupational Handblanks—Handsamples from the backs of the hands of live subjects in the Los Angeles area who were members of various occupations with potential exposure to lead or antimony were collected and analyzed. These data (Table 6) extend the information obtained in previous studies and represent the results of analyses of handsamples collected from 31 subjects immediately after each person engaged in his or her work for 15 min or longer. These subjects were not allowed to wash their hands prior to the sampling.

Based on the handsample with the largest amount of lead from each subject, the average amount of lead on the backs of the hands of these 31 "occupational handblank" subjects was 0.85 ± 0.99 μg. Handsamples from 81% of the subjects in Table 6 had lead levels equal to or less than 0.85 μg, and antimony levels below 0.01 μg were obtained for 84%. In the previous study [7], 90% of the 45 subjects selected because of potentially high occupational exposure to lead or antimony gave lead levels less than 0.85 μg, while all but one subject gave antimony levels less than 0.01 μg. Handsamples from slightly more than 90% of the 31 subjects in Table 6 simultaneously had lead and antimony levels less than 0.85 and 0.01 μg, respectively.

The subjects in Table 6 that yielded lead levels greater than 0.85 μg on at least one handsample included a painter, a lead foil manufacturer, a gas station attendant, a printer, and

TABLE 6—*Occupational handblanks.*

Sample Number	Occupation	Hand	Lead Found, μg	Antimony Found,[a] μg
OHB-1	secretary	right	0.10	ND
OHB-2		left	0.15	ND
OHB-3	secretary	right	0.18	ND
OHB-4		left	<0.01	ND
OHB-5	secretary	right	0.10	ND
OHB-6		left	0.13	ND
OHB-7	electrician[b]	left	0.22	0.001
OHB-8	painter[b]	right	0.17	0.040
OHB-9		left	0.20	ND
OHB-10	carpenter[b]	right	0.33	0.012
OHB-11		left	0.35	0.009
OHB-12	carpenter[b]	right	0.40	ND
OHB-13		left	0.25	ND
OHB-14	electrician[b]	right	0.50	ND
OHB-15	photo technician	right	0.20	ND
OHB-16		left	0.25	ND
OHB-17	machinist	right	0.85	ND
OHB-18		left	0.85	ND
OHB-19	machinist[b]	right	0.15	ND
OHB-20		left	0.13	ND
OHB-21	composites technician	left	0.53	ND
OHB-22	machinist	right	0.55	ND
OHB-23	machinist	right	0.85	ND
OHB-24	machinist	left	0.45	ND
OHB-25	painter[b]	left	0.70	ND
OHB-26	air conditioning mechanic	right	0.33	0.001
OHB-27		left	0.50	0.001
OHB-28	plumber[b]	right	0.33	ND
OHB-29		left	0.35	0.003
OHB-30	lead foil manufacturer[b]	right	4.05	ND
OHB-31		left	3.73	ND
OHB-32	brake mechanic	right	0.08	ND
OHB-33		left	0.23	ND
OHB-34	brake mechanic	right	0.10	ND
OHB-35		left	0.18	ND
OHB-36	gas station attendant[b]	right	2.15	0.083
OHB-37		left	2.53	ND
OHB-38	painter	right	2.53	0.002
OHB-39		left	2.83	ND
OHB-40	painter	right	2.60	ND
OHB-41		left	2.35	ND
OHB-42	printer	right	2.55	0.150
OHB-43		left	2.60	0.199
OHB-44	welder[b]	right	0.85	ND
OHB-45		left	0.65	ND
OHB-46	assembler/wire stripper[b]	right	0.33	ND
OHB-47		left	0.18	ND
OHB-48	assembler/solderer	right	1.30	0.052
OHB-49		left	1.30	0.063
OHB-50	die caster[b]	right	0.30	ND
OHB-51		left	0.38	ND
OHB-52	die caster[b]	right	0.30	ND
OHB-53		left	0.48	ND
OHB-54	gardener[b]	right	0.60	0.003
OHB-55		left	0.33	ND

[a] ND = not detectable.
[b] Smoker.

an assembler/solderer. Antimony levels equal to or greater than 0.01 μg were obtained for a different painter, a carpenter, the same gas station attendant, the same printer, and the same assembler/solderer. Forty-eight percent of the subjects included in Table 6 were smokers. No correlation could be observed from the data to suggest that smoking increases the levels of lead or antimony on the hand.

Considerably less antimony was detected in this study using photoluminescence in conjunction with the adhesive tape lift sampling technique than was found earlier for a similar class of subjects in a study using neutron activation analysis and the paraffin lift sampling technique [6]. Similar results were observed in the previous photoluminescence study [3]. Levels of elements characteristic of gunshot residue collected by various sampling techniques can be expected to differ quantitatively because different areas of the hand are sampled and the efficiency of retrieval of various components of the residue may vary with the sampling method. The recovery of lesser amounts of antimony from handblanks with the photoluminescence and adhesive lift technique should lead to the use of antimony photoluminescence thresholds substantially lower than the 0.2 μg level suggested by ATF for gunshot residue detection by neutron activation analysis and atomic absorption spectroscopy. In tests using the latter two procedures, samples were obtained by swabbing the backs of the hands.

Comparison of Data

Where the information is available, the results from the gunshot suicide cases of Tables 7 to 11 are categorized in Table 12 according to weapon type, caliber, bullet type, and whether blood was reported to be present on the hand sampled, on the disk after sampling, or in the hydrochloric acid solution following its removal from the sampling disk. To calculate the averages in Table 12, values from Tables 7 to 11 were chosen in each case for the back of whichever hand had the larger amount of lead and antimony.

Previous photoluminescence work [3] showed that larger average amounts of lead and antimony are deposited on the hand during test firings with .38-caliber revolvers than with .22-caliber revolvers. A similar trend is seen in the limited data of Table 12 for gunshot suicide cases both when blood is present and when it is not present on the hand. Comparison of the data in Table 12 with results from the previous study [3] reveals that generally lower lead and antimony levels are found on handsamples from gunshot suicide cases involving .38 and .22 revolvers than are found on the corresponding handsamples collected immediately after one-round test firings of .38 and .22 revolvers.

The average amounts of lead and antimony found on handsamples collected in suicide cases involving .22 revolvers, rifles, and shotguns are close to those of control subjects.

Effect of Blood

The average amount of lead and antimony from .38 revolver firings in which bare lead bullets were used was lower when blood was present on the hand sampled than when blood was absent. However, the numbers of cases in each category were too small to allow a statistically firm conclusion to be drawn that the amounts of lead and antimony found on handsamples by photoluminescence are decreased by the presence of blood on the hand. The data, however, suggest such an effect.

For this reason, controlled laboratory experiments were conducted to examine the effect of blood on lead and antimony analyses by photoluminescence. The data in Table 13 represent the results of analyses of samples taken from the back of the firing hand immediately after one-round test firings of a .380 Browning automatic pistol with Remington fully jacketed ammunition, which typically gives less residue than other types of ammunition. Handsamples 1 through 4 in Table 13 were analyzed directly. Various quantities of

TABLE 7—*Field study luminescence data, Maricopa Medical Examiner's Office, Phoenix, Ariz.*

Case	Weapon; Barrel Length; and Ammunition	Victim's Sex and Occupation	Time Between Firing and Sampling	Hand Area Sampled	Lead Found, μg	Antimony Found,[a] μg	Comments
P-1	revolver, .38, Smith & Wesson; 102 mm (4 in.); Reload, bare lead	m/laborer	12–14 h	right back left back	0.6 1.3	ND	outdoors, gun near right hand
P-2	automatic, .380, Firearms International; 102 mm (4 in.); Remington-Peters jacketed	f/housewife	3 h	right back left back	2.4 0.4	0.28 0.09	indoors, gun near right hand
P-3	rifle, .22, Remington; 508 mm (20 in.); Remington short plated	m/unemployed	10 h	right back left back	0.63 0.07	ND ND	outdoors; wound, right neck
P-4	revolver, .22, Ruger, single action; 140 mm (5½ in.); Winchester Western Super X Magnum, semi-jacketed hollow point	m/truckdriver	4 h	right back left back	0.24 0.28	ND ND	indoors; wound behind right ear
P-5	rifle, .308, 660; 610 mm (24 in.); Western, Super	m/unemployed	5 h	right back[b] left back	0.2[c] 0.4	ND ND	indoors; victim was right-handed
P-6	Derringer, .22, #913 Frontier; 51 mm (2 in.); Remington-Peters short round nose lead	f/retired	unknown	right back left back	0.5 0.4	ND ND	indoors, gun near right hand
P-7	revolver, .22, Rohm Gesellschaft, 14; 51 mm (2 in.); long rifle Winchester Western, Super X, bare lead	m/student	12–18 h	right back left back	0.6 0.37	ND ND	outdoors; wound, left temple
P-8	rifle, .22, Ranger, single shot; 660 mm (26 in.); long rifle, Federal, plated	m/carpenter	16–18 h	right back left back	0.7 0.42	ND ND	inside pickup cab; wound, hard palate
P-9	revolver, .22, Rohm Gesellschaft, 51 mm (2 in.); unjacketed	f/housewife	18–20 h	right back left back	1.3 1.6	ND ND	indoors; victim was left-handed
P-10	automatic, .25, Tanfoglio, GT 27; 51 mm (2 in.); Remington, 50 grain, fully jacketed	m/warehouse worker	3 h	right back left back	0.42 0.26	ND ND	indoors, murder/suicide; two shots each into wife and self

P-11	revolver, .38, Colt; 51 mm (2 in.); Western, 158 grain, round nose lead	f/housewife	6 h	right back	1.8	0.05	outdoors; gun found in right hand
				left back	4.8	0.28	
P-12	revolver, .22, Firearms International; 51 mm (2 in.); long rifle, Winchester Western, round nose lead	m/unknown	3 h	right back	0.75	ND	outdoors; right-handed firing; heavy powder smudging left palm
				left back	5.4	ND	
P-13	revolver, .44, Blackhawk; 140 mm (5½ in.); high velocity	m/car salesman	4-5 h	right back[d]	0.29	0.21	indoors
				left back[e]	4.25	0.095	
P-14	revolver, .22, Schmidt-Ostheim-Rohm; 102 mm (4 in.); Remington-Peters long rifle round nose lead	m/unknown	2 h	right back[e]	0.50	ND	right-handed firing indoors
P-15	revolver, .38, Special, Smith & Wesson; 152 mm (6 in.); Federal .38 Special round nose lead	m/janitor	10 days	right back	0.15	ND	indoors
				left back	4.45	0.50	
P-16	automatic, .22, Ruger; 102 mm (4 in.); long rifle plated	m/butcher	4½ h	right back[d]	0.23	ND	right-handed firing indoors
				left back[d]	0.11	ND	
P-17	shotgun, 12-gauge Ithaca; 660 mm (26 in.); Winchester Western XL 900 automatic #8 shot	m/laborer	8-10 h	right back[e]	0.14	ND	indoors
				left back	0.65	ND	
P-18	shotgun, 12-gauge Remington; 711 mm (28 in.); Remington #6 shot	m/unemployed	unknown	right back	0.45	0.02	indoors
				left back[e]	0.88	0.07	

[a] ND = not detectable.
[b] Heavy amount of blood on disk.
[c] Heavy amount of blood in solution.
[d] Moderate amount of blood on disk.
[e] Slight amount of blood on disk.

TABLE 8—*Field study luminescence data, Southwestern Institute of Forensic Sciences, Dallas, Tex.*[a]

Case	Weapon; Barrel Length; and Ammunition	Victim's Sex	Hand Area Sampled	Lead Found, μg	Antimony Found,[b] μg	Comments
D-31	revolver, .38, Smith & Wesson Special; Remington-Peters hollow point	f	right back	2.08	0.14	indoors; wound on right side of head
			right palm	0.24	0.01	
			left back	0.15	0.002	
			left palm	0.25	ND	
D-32	automatic, .32	f	right back	0.20[c]	0.02	indoors; wound on right side of head
			right palm	0.05[c]	0.006	
			left back[d]	0.04[c]	ND	
			left palm[d]	0.03[c]	ND	
D-33	rifle, .22, Winchester M-67; Remington-Peters	m	right back[d]	0.42[e]	ND	indoors
			right palm[d]	0.10[e]	ND	
			left back[d]	0.19[e]	0.006	
			left palm[d]	0.83[e]	0.005	
D-34	shotgun, 16-gauge, Revelation; Winchester-Western	m	right back[d]	0.12[e]	ND	indoors
			right palm[d]	0.10[e]	ND	
			left back[d]	0.13[e]	ND	
			left palm[d]	0.12[e]	ND	
D-35	revolver, .38, Smith & Wesson Special M-10; Winchester Western round nose lead	f	right back[f]	0.49[e]	0.11	indoors
			right palm	0.15[c]	ND	
			left back[g]	0.90[c]	0.034	
			left palm[g]	1.22[c]	0.006	
D-36	rifle, .22; Remington-Peters round nose lead	m	right back[d]	0.23[c]	ND	...
			right palm	0.08	ND	
			left back	0.05	ND	
			left palm	0.05	ND	
D-37	revolver, .38, Smith & Wesson Special; SV round nose lead	f	right back[g]	1.21[c]	0.10	indoors
			right palm[g]	0.13[c]	ND	
			left back[g]	0.50[c]	0.006	
			left palm[g]	0.08[c]	ND	
D-38	revolver, .22, Remington-Peters round nose lead	f	right back	0.20	ND	outdoors
			right palm[d]	0.13[c]	ND	
			left back	0.19	ND	
			left palm	0.23	ND	
D-39	rifle	m	right back[d]	0.20[c]	ND	outdoors; identified as a homicide
			right palm[d]	0.14[c]	ND	
			left back[g]	0.10[e]	ND	
			left palm[f]	0.01[e]	ND	
D-40	revolver, .32, ACP; Remington-Peters fully jacketed	m	right back[g]	0.09[e]	ND	outdoors; identified as a homicide
			right palm[g]	0.13[e]	ND	
			left back[f]	0.05[h]	ND	
			left palm[g]	0.08[e]	0.018	

[a] Data from Cases D-1 through D-30 could not be used because of problems with the instrument during analyses.
[b] ND = not detectable.
[c] No blood in solution.
[d] Slight amount of blood on disk.
[e] Slight amount of blood in solution.
[f] Heavy amount of blood on disk.
[g] Moderate amount of blood on disk.
[h] Heavy amount of blood in solution.

TABLE 9—*Field study luminescence data, Georgia State Crime Laboratory, Atlanta, Ga.*

Case	Weapon; Barrel Length; and Ammunition	Victim's Sex and Occupation	Time Between Firing and Sampling	Hand Area Sampled	Lead Found, μg	Antimony Found,[a] μg	Comments
A-1	revolver, .38, Colt; (2 in.); Peters, round nose lead	m/unknown	1 h	right back	1.85	ND	indoors
A-2	revolver, .38, Charter Arms Speer	unknown	unknown	unknown	4.55	0.2	...
A-3	revolver, .22, Rohm Gesellschaft; Remington	unknown	unknown	right back	0.3	ND	...
				right wrist	0.20	ND	
				left back	0.05	ND	
				left wrist	0.28	0.002	
A-4	unknown	unknown	unknown	unknown	1.65	ND	...
A-5	revolver, .38, Smith & Wesson	unknown	unknown	unknown	0.35	ND	...
A-6	revolver, .32, Smith & Wesson; 4 in.; Remington-Peters	m/unemployed	5 h	right back	1.55	ND	indoors
A-7	revolver, .38, Taurus; 4 in.; Winchester Western jacketed	m/unknown	1½ h	right back	0.25	ND	indoors
A-8	revolver, .357, Smith & Wesson; 2 in.; semijacketed hollow point	m/police lieutenant	3 h	right back	3.2	ND	indoors
A-9	revolver, .38, INA; 1½ in.; Remington round nose lead	m/paint salesman	4 h	right back	0.65	ND	indoors
A-10	shotgun, .410, Sears; 26 in.; #5 shot	m/unknown	3-4 h	right back	0.8	ND	outdoors
				left back	0.35	ND	
A-11	revolver, .45, Colt United States Army; 4 in.; Peters automatic colt pistol,	f/unknown	1 h	right back	0.15	ND	indoors
				right wrist	0.15	ND	

[a] ND = not detectable.

TABLE 10—*Field study luminescence data, Office of the Chief Medical Examiner, Baltimore, Md.*

Case	Weapon; Barrel Length; and Ammunition	Victim's Sex and Occupation	Time Between Firing and Sampling, h	Hand Area Sampled	Lead Found,[a] μg	Antimony Found,[a] μg	Comments
B-1	revolver, .22; 2 in.; short, plated	m/student	19	right back and wrist[b]	0.4	ND	indoors
B-2	revolver, .38, Smith & Wesson; 2 in.; lead	m/accountant	27	right back and wrist[c]	0.75	ND	outdoors, shot wife four times, self once
B-3	shotgun, 12 gauge, Remington; 36 in.; Remington, #7 lead shot	m/unemployed	13½	right back and wrist[c]	ND	ND	indoors
B-4	automatic, .25; 2 in.; semijacketed	m/retired	23+	right back and wrist[d]	ND	ND	indoors
				left back[e]	0.9	0.01	
B-5	revolver, .22; semijacketed	f/housewife	24	right back[c]	0.3	0.003	indoors
				left back[e]	0.6	0.006	
B-6	revolver, .38, Harrington & Richardson; 2½ in.; lead	f/housewife	21	right back and wrist[c]	1.2	0.014	indoors, 2 shots
				left back[e]	0.9	0.008	
B-7	shotgun, 12 gauge, Winchester; 36 in.; Remington, #7 lead shot	m/unknown	12–14	right back[c]	0.35	0.005	indoors
				left back[c]	0.25	0.007	
B-8	revolver, .38, Smith & Wesson; 4 in.; unjacketed	m/farmer	20	right back[e]	0.2	0.003	indoors
B-9	revolver, .22; 2 in.; long lead	m/factory worker	11	right back[e]	0.25	0.003	indoors
B-10	revolver, .38, Smith & Wesson; 2 in.; lead	m/restaurant owner	24	right back[d]	ND	ND	indoors
B-11	rifle, .22, Remington; single shot, plated	m/unknown	5½	right back[e]	ND	ND	indoors
B-12	automatic, .25; 2 in.; standard, fully jacketed	m/government employee	14-15	right back and wrist[e]	0.07	ND	indoors
B-13	revolver, .38, Colt; 2 in.; standard, lead	m/unknown	12	right back and wrist[e]	0.63	ND	indoors
B-14	shotgun, 16 gauge, Remington; 36 in.; standard	m/student	13-14	right back and wrist[e]	0.14	0.005	indoors
B-15	rifle, .30, Marlin; blunt nose lead	m/gas station attendant	14	right back and wrist[c]	0.05[c]	0.006	outdoors

[a] ND = not detectable.
[b] Moderate amount of blood on disk.
[c] Slight amount of blood on disk.
[d] Heavy amount of blood on disk.
[e] No blood present.

TABLE 11—*Field study luminescence data, Department of the Chief Medical Examiner, Coroner, Los Angeles, Calif.*

Case	Weapon; Barrel Length; and Ammunition	Victim's Sex and Occupation	Time Between Firing and Sampling	Hand Area Sampled	Lead Found, μg	Antimony Found, μg	Comments
L-1	revolver, .22, Ruger 4 in.; 40 grain	m/unemployed	unknown	right back[a]	0.1	0.034	indoors
				left back[a]	0.46	0.056	
L-2	revolver, .22, high standard; 6 in.; Winchester Western, Super X, lead	m/unemployed	2 h	right back[a]	0.7	0.032	outdoors
				left back[a]	0.5	0.026	
L-3	revolver, .22, Ruger, Single Six; 4 in.; long rifle, Remington, lead	m/unknown	6 h	right back[a]	0.32	0.026	indoors
				left back	0.45	0.014	
L-4	revolver, .38, Colt; 2 in.; Remington-Peters, 158 grain, semijacketed	m/unknown	unknown	right back	2.84	0.158	indoors, weapon found in right hand
				left back	0.84	0.046	
L-5	revolver, .38, Smith & Wesson; 6 in.; Remington 158 grain, semijacketed	m/plumber	2 h	right back[a]	0.47	0.10	indoors
				left back[a]	0.2	0.38	
L-6	automatic, .25; Eibar unjacketed	m/unknown	unknown	right back[b]	0.76	0.048	indoors
				left back[a]	0.77	0.021	
L-7	revolver, .22; 6 in.; lead	m/unknown	3½ h	right back	0.52	0.014	indoors
				left back	0.57	0.034	
L-8	shotgun, .410, savage, 220A; 36 in.; unjacketed	m/diesel mechanic	3 h	right back[a]	0.24	0.012	indoors
				left back[a]	0.24	0.012	
L-9	shotgun, 16 gauge, Stevens; 30 in.; Western, Super X, 7½ shot	m/retired colonel	7 h	right back[a]	0.96	0.032	indoors
				left back[a]	0.97	0.046	
L-10	rifle, .22, Marlin, 989 M-2; 18 in.; Cascade Cartridge Industry, semi-jacketed	m/oil field maintenance	unknown	right back	0.52	.018	indoors, dirty hands
				left back	0.34	.01	
L-11	revolver, .22, Harrington & Richardson, 949; 6 in.; Western, Super X, long, semijacketed	m/tree trimmer	5 h	right back	0.76	0.039	indoors
				left back	0.42	0.014	
L-12	revolver, .22, Harrington & Richardson, 949; 6 in.; Western, Super X, semijacketed	f/housewife	5 h	right back	0.63	0.021	indoors
				left back[a]	0.42	0.013	
L-13	automatic, .45, Ruger, Blackhawk; 6 in.; lead	m/writer	unknown	right back[a]	1.79	0.038	indoors
				left back	0.53	0.027	
L-14	revolver, .357 magnum, Ruger, Blackhawk; 4½ in.; Winchester, Super, lead hollow point	m/unknown	2 h	right back	0.12	0.48	outdoors, dirty hands
				left back[b]	0.18	0.050	
L-15	.22; 2 in.; short, plated	m/clerk foreman	2 h	right back[a]	0.74	0.032	indoors, 2 shots
				left back[a]	0.16	0.026	

[a] Moderate amount of blood present.
[b] Slight amount of blood present.

TABLE 12—*Effect of blood on the average amounts of lead and antimony in the handsamples from gunshot suicide victims. Values in brackets are the ranges.*

Gun Type	No Blood Present: Average Lead, μg	No Blood Present: Average Antimony, μg	No Blood Present: Number of Samples and Bullet Type	Blood Present: Average Lead, μg	Blood Present: Average Antimony, μg	Blood Present: Number of Samples and Bullet Type
Revolvers						
.45	0.15	not detectable (ND)	1; fully jacketed	...	...	...
.44	...	...	...	4.25	0.10	1; unknown
.38	2.68 [0.6-4.45]	0.24 [ND-0.5][a]	6; bare lead	1.02 [ND-2.4]	0.02 [ND-0.10]	7; bare lead
.38	2.92 [0.85-5.00]	0.10 [ND-0.2]	2; unknown	0.44 [0.2-0.65]	<0.01[b]	3; 1 semijacketed, 1 fully jacketed
.357	3.2	ND	1; semijacketed	0.18	...[c]	1; bare lead
.32	2.2	0.17	1; unknown	...	...	...
.22	1.03 [0.2-5.4]	<0.01[d]	8; 7 bare lead, 1 plated	0.56 [0.4-0.74]	ND[e]	5; 3 bare lead, 1 plated, 1 unknown
.22	0.77 [0.28-1.6]	<0.01[f]	5; 4 semijacketed, 1 unknown	...	...	...
Pistols						
.45	...	...	...	1.79	...[g]	1; bare lead
.380	2.40	0.28	1; fully jacketed	...	...	...
.32	0.20	0.02	1; unknown	...	...	...
.25	0.46 [0.07-0.9]	ND	3; 1 semijacketed, 2 fully jacketed	0.77	...[h]	1; unknown
Rifles						
.308	...	...	...	0.4	ND	1; unknown
.30	...	...	...	0.05	<0.01	1; bare lead
.22	0.44 [ND-0.7]	ND	3; plated	0.42	ND	1; unknown
.22	0.52	...[i]	1; semijacketed	...	...	...
Shotguns						
12 gauge	0.65	ND	1	0.41 [ND-0.88]	0.03 [ND-0.07]	3
16 gauge	0.14	<0.01	1	0.55 [0.13-0.97]	ND[j]	2
.410	0.8	ND	1	0.24	...[k]	1

[a] Excludes Case L-4.
[b] Excludes Case L-5.
[c] Excludes Case L-14.
[d] Excludes Cases L-3 and L-7.
[e] Excludes Cases L-1, L-2, and L-15.
[f] Excludes Cases L-11 and L-12.
[g] Excludes Case L-13.
[h] Excludes Case L-6.
[i] Excludes Case L-10.
[j] Excludes Case L-9.
[k] Excludes Case L-8.

TABLE 13—*Effect of blood on lead and antimony levels from .380 automatic pistol firings.*[a]

Sample	Amount of Blood Present on Disk	Lead Found, μg	Antimony μg	Ratio of Lead Found to Average Lead from Samples Samples 1-4	Ratio of Antimony Found to Average Antimony from Samples 1-4
1	0	0.65	0.09	...	...
2	0	0.85	0.19	...	...
3	0	1.80	1.16	...	...
4	0	0.73	0.11	...	...
Average, Samples 1-4	...	1.01 ± 0.54	0.39 ± 0.52	...	...
5	0.001 mL[b]	0.48	0.09	0.48	0.23
6	0.004 mL[b]	0.50	0.32	0.50	0.82
7	0.008 mL[b]	0.15	0.07	0.15	0.18
8	0.015 mL[b]	0.18	0.08	0.18	0.21
9	1 drop[c]	0.08	ND[d]	0.08	ND
10	2 drops[c]	0.15	0.01	0.15	0.03
11	3 drops[c]	0.05	0.02	0.05	0.05
12	4 drops[c]	0.08	0.02	0.08	0.05

[a] Remington 95-grain, round-nose, fully jacketed cartridges.
[b] Whole blood was diluted into solution, then pipetted onto the sampling disk. These values represent the amount of blood present on the disk prior to allowing the solution to dry.
[c] Whole blood added directly to the disk.
[d] ND = not detectable.

blood were added to the eight remaining sampling disks after collection. For Samples 5 through 8 in Table 13, various quantities of a 10% solution by volume (for ease of quantitative application) of whole blood in distilled water were applied to the sampling disks, spread uniformly across the disks, and allowed to dry. A similar procedure was used for Handsamples 9 through 12, except that various amounts of whole blood were applied directly. Comparisons of results indicate that decreasing amounts of lead and antimony are generally found by photoluminescence as a function of increasing amounts of blood on the sampling disks.

Small amounts of blood that may not always be detected visually on handsamples can decrease the amounts of lead and antimony found by photoluminescence. However, some indication of blood on a sampling disk may be obtained by examining the excitation spectrum recorded to determine the presence of antimony. Figures 2a and 2b compare the excitation spectra recorded to determine the levels of antimony on Samples 2 and 5 in Table 13. Figure 2c shows the excitation spectrum obtained for approximately the same quantity of blood as was present on Sample 5 shown in Fig. 2b but with antimony absent. Besides decreasing the excitation spectral intensity observed for the chloride ion complex or complexes of antimony, blood also distorts the baseline for the excitation spectrum.

Possible Effect of Delay

The results shown in Tables 7 to 11 were examined to determine whether the length of time between a suicide and the sampling of a victim's hands can affect the amount of gunshot residue found. The data for blood-free handsamples from cases involving any handgun/cartridge combination giving lead or antimony levels well above background levels suggest an overall trend of decreasing amounts of lead with increasing time between firing and sampling. Nearly all of the handgun cases with more than 2.0 μg of lead in at least

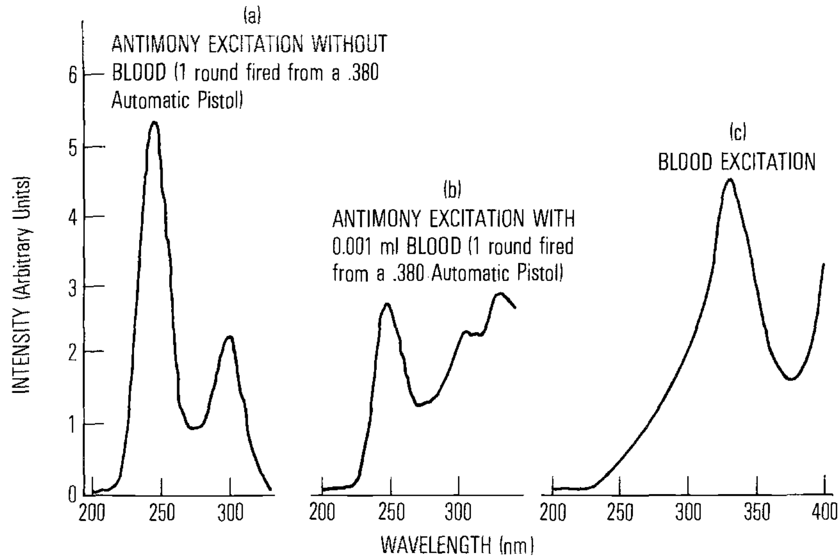

FIG. 2—*Effect of blood on antimony excitation spectra (660 nm emission).*

one handsample were collected within 5 h of firing. Most of the samples from handgun cases collected within 5 h of firing that gave less than 1.0 μg of lead involved jacketed bullets or the handsamples contained blood, or both. The smaller amounts of lead found on the latter samples might thus be expected.

If the apparent loss of gunshot residue with time from the hands of suicide victims is real, it is still substantially slower than the order of magnitude loss observed from the hands of normally active live subjects in the first hour after firing. It is not known why this slow loss might occur from the hands of immobile subjects such as suicide victims. The decreasing amounts of lead observed with time may reflect the greater opportunity for the victims' hands to be disturbed. Another possibility is that increasing amounts of decomposition products from the skin may form and either quench the luminescence of the lead(II) and antimony(III) chloride complexes or react with lead(II) or antimony(III) ions in some manner to inhibit their quantitative recovery from the hand. That a decrease in the amounts of lead and antimony found on the hands of a gunshot suicide victim does not always occur with time, however, is indicated by the large amounts of lead and antimony (4.45 and 0.50 μg, respectively) found on the back of one of the hands of a subject sampled more than ten days after the firing (Case P-15, Table 7). Much more data from suicide cases involving particular handgun/cartridge combinations giving copious lead and antimony levels are needed before an effect of delay between firing and sampling on the amounts of these elements detected on victims' hands can be confirmed and a mechanism for this apparent loss established.

Data from Gunshot Suicide Victims

The averages of the largest lead and antimony values from each gunshot suicide case are listed in Table 14 according to various weapon categories. These averages were calculated without distinction between cases in which blood was observed on handsamples after collection and cases in which blood was absent.

Also listed in Table 14 are the percentage of cases reported with (1) lead levels above

0.85 μg, (2) antimony levels equal to or above 0.01 μg, and (3) lead levels above 0.85 μg with antimony levels equal to or greater than 0.01 μg.

In approximately 50% of the gunshot suicide cases blood was present on at least one handsample after collection. The average lead and antimony values and the percentage of cases exceeding various thresholds might be expected to increase significantly if the deleterious effects of blood on the photoluminescence analyses could be overcome. For this reason, the results in Table 14 (where blood effects are ignored) represent lower limits to the results that would be obtained in the absence of blood effects.

Lead Levels—The data in Table 14 indicate that the lead values greater than 0.85 μg were found on handsamples from the back of at least one hand of each victim in 53% of the cases (16 of 30) involving all handguns other than .22 revolvers. Levels of lead greater than 0.85 μg were observed for 12% of the cases (2 of 17) involving long guns and only 11% of the cases (2 of 19) involving .22 revolvers. When all cases are considered, 30% (20 of 66) exceeded 0.85 μg of lead. By comparison, 95% of the control subjects had lead values equal to or less than 0.85 μg.

Antimony Levels—Excluding from consideration the upper limit antimony values obtained in cases L-1 through L-15, antimony levels equal to or greater than 0.01 μg were found on handsamples from the back of at least one hand of each suicide victim in approximately 50% of the cases involving handguns other than .22 revolvers. None of twelve .22 revolver cases and only 1 of 14 cases involving long guns gave antimony levels equal to or greater than 0.01 μg. Antimony values equal to or greater than 0.01 μg were obtained in 27% of all the cases (14 of 51). None of the control cases had antimony values equal to or greater than 0.01 μg, excluding the upper limit values obtained in cases LC-6 through LC-8.

Lead and Antimony Levels—The occupational and control handblank data obtained during the field test are too limited to allow selection of the optimum threshold values for distinguishing firing handsamples from nonfiring handsamples by the photoluminescence technique. However, slightly greater than 90% of the occupational handblanks had simultaneous levels of lead and antimony below 0.85 μg and 0.01 μg, respectively. It would be expected that much closer to 100% of the handsamples of subjects chosen at random from the general population would have simultaneous levels of lead and antimony below 0.85 μg and 0.01 μg, respectively; the lead and antimony levels on handsamples from 100% of the control cases were simultaneously below these limits.

The data in Table 14 show that if lead levels greater than 0.85 μg in conjunction with antimony levels equal to or greater than 0.01 μg are taken as being suggestive of the presence of gunshot residue on handsamples, correct identification of gunshot residue is obtained for 48% of the cases (12 of 25) involving all handguns other than .22 revolvers for which lead and antimony analyses are available. Using the same criteria, correct identification of gunshot residue was obtained for only one of seven of the cases involving shotguns and for none of the cases involving either .22 revolvers or rifles of various caliber.

The low success rate obtained by the photoluminescence technique for cases involving shotguns and especially rifles (Table 14) is expected on the basis of the sparse amounts of gunshot residue found by scanning electron microscope particle analysis [*4*] on handsamples from persons who had recently fired those weapons. On the basis of analysis results of handsamples taken during .22 revolver test firings [*3*], a higher success rate than is observed in Table 14 might be expected for cases involving .22 revolvers. The reason for this discrepancy is not known. The low success rate for cases involving .22 revolvers in this study, however, is consistent with the fact that the Bureau of Alcohol, Tobacco and Firearms will not accept cases involving .22 revolvers (unless the cartridge is known to have been a Federal brand) for barium and antimony analysis by atomic absorption spectroscopy because of a similar low success rate for these cases.

The lower limit (48%) success rate (12 of 25 cases) obtained for all handguns other than

TABLE 14—*Percentage of gunshot suicide cases simultaneously having*

	.38 Revolvers	.22 Revolvers	Other Revolvers	Automatic Pistols
Average lead, μg	1.69 ± 1.59	0.82 ± 1.15	2.00 ± 1.82	0.94 ± 0.86
Average antimony,[d] μg	0.18 ± 0.16	<0.01	0.14 ± 0.05	0.10 ± 0.15
Not detected, %	43.8	50.0	50.0	40.0
Cases having >0.85 μg lead, %	55.6 (n = 18)	10.5 (n = 19)	60 (n = 5)	42.9 (n = 7)
Cases having ≥0.01 μg antimony,[d] %	50 (n = 16)	0 (n = 12)	50 (n = 4)	60 (n = 5)
Cases having >0.85 μg lead and ≥0.01 μg antimony,[d] %	50 (n = 16)	0 (n = 12)	50 (n = 4)	40 (n = 5)

[a]These data (where blood effects have been ignored) represent lower limits to the results that would be obtained in the absence of blood effects.

[b]Subjects died of causes other than gunshot-related causes.

.22 revolvers should increase significantly if the adverse effects of blood on the photoluminescence analyses can be eliminated. For example, 8 of the 16 cases involving .38 revolvers gave lead and antimony values below their respective 0.85 μg and 0.01 μg threshold levels. Of these eight .38 revolver cases, six had blood present on at least one handsample after collection. Of the eight .38 revolver cases where both limits were exceeded, only two had a significant amount of blood, and one had a slight amount of blood. For the .38 revolver cases without blood, the suggested thresholds were exceeded by five out of seven cases (71%), and for those with blood, three out of nine cases (33%) exceeded the limit.

The lower limit results (Table 14) for handguns other than .22 revolvers thus suggest that the photoluminescence technique should be suitable as a method that can be used to strengthen other, more circumstantial, evidence in gunshot suicide investigations if the adverse effects of blood on the photoluminescence analyses can be overcome. The previous photoluminescence study [*3*] showed that under optimum conditions (samples collected from the firing hands of live subjects immediately after one-round indoor test firings) lead and antimony levels above threshold levels were obtained for 95% (41 of 43) of firings of handguns other than .22 revolvers and for 88% (15 of 17) of .22 revolver firings.

Of the nine cases involving handguns other than .38 or .22 revolvers, five gave lead and antimony levels each below threshold levels. None of the handsamples from these five cases had blood on them. The below-threshold levels in these cases may be the result of the type of bullet used. Four of these cases involved jacketed bullets, while the fifth was of an unknown bullet type.

Minimizing Blood Effects

In the analysis of handsamples for barium and antimony by atomic absorption spectroscopy, severe problems are also encountered in the contamination of the sample collection surface (usually a cotton swab) with blood. Contamination by blood may make the swab impervious to the penetration of the dilute nitric acid used to leach gunshot residue from the swab for analysis. The measured levels of barium and antimony will thus be lower than those actually present on the sample. Blood on handsamples must also be removed prior to sample atomization, by plasma ashing or some other technique, to avoid high background absorption resulting from light scattering by particulate matter from the blood.

Because of the problems encountered with the effects of blood on the detection of gunshot *greater than 0.85 μg of lead and at least 0.01 μg of antimony.*[a]

Rifles	Shotguns	All Guns	Handblanks from Deceased Subjects[b]	Handblanks from Live Subjects[c]
0.37 ± 0.26	0.46 ± 0.37	1.06 ± 1.28	0.26 ± 0.36	0.85 ± 0.99
<0.01	0.03 ± 0.04	0.11 ± 0.14	<0.01	0.04 ± 0.06
71.4	57.1	58.8	89.5	67.7
0 (n = 8)	22.2 (n = 9)	30.3 (n = 66)	5.0 (n = 40)	19.4 (n = 31)
0 (n = 7)	14.3 (n = 7)	27.5 (n = 51)	0 (n = 38)	16.1 (n = 31)
0 (n = 7)	14.3 (n = 7)	25.5 (n = 51)	0 (n = 40)	9.7 (n = 31)

[c] Subjects had expected occupational exposure to lead and antimony.
[d] The average value given for antimony was calculated only with values for which antimony was detectable.

residue by both atomic absorption spectroscopy and the photoluminescence technique, it is expected that both methods would be roughly equivalent in their usefulness to detect gunshot residue on the hands of gunshot suicide victims.

A recent paper [*11*] describes a low pressure oxygen plasma technique that can be used before atomic absorption spectroscopy to pre-ash gunshot residue samples contaminated with blood, dirt, or grease. Because this plasma ashing technique can be used on other types of collection materials, including tape, it might be a useful technique for eliminating blood from handsamples before photoluminescence analysis. Since the plasma ashing technique is an oxidative procedure, there is some concern that it may raise Pb^{+2} and Sb^{+3} to Pb^{+4} and Sb^{+5}, respectively. Only the chloride ion complexes of the lower-valent ions luminesce.

Cold concentrated hydrochloric acid converts lead dioxide to lead tetrachloride, but at room temperature lead dioxide will oxidize hydrochloric acid with evolution of chlorine and lead reverts to the divalent state. One should therefore add the 7*M* hydrochloric acid specified in the procedure at room temperature and wait a few minutes before freezing the solution. When we prepared a standard lead solution by dissolving lead dioxide in dilute hydrochloric acid, subsequent photoluminescence analysis gave the correct lead concentration.

Pentavalent antimony is relatively unstable, but in acid solution its oxidation potential is only half that of tetravalent lead. It may be that it reverts to the trivalent state just on addition of hydrochloric acid, but, if not, a drop of almost any moderately good reducing agent should be effective.

Organic Smokeless Powder Flakes

During the field study, each of the participating laboratories examined the hands of gunshot suicide victims for the presence of smokeless powder flakes and tabulated the frequency and quantity of their occurrence for statistical purposes. These laboratories reported that at least one organic flake could be observed on the hands of 10 to 15% of the gunshot suicide victims. Generally, only one or two flakes were observed. The frequency and quantity of organic flakes observed during this study were slightly less than those observed at The Aerospace Corporation during the investigation of apparent gunshot suicide cases by the scanning electron microscope particle analysis technique. In that work, at least one organic flake was observed on handsamples of 22% (10 of 45) of the apparent gunshot suicide victims. Only about one third of the organic flakes observed visually in test firings could be proven to be of nitrocellulose or nitroglycerine origin by currently used thin-layer chromatographic procedures [10]. The remainder were charred too severely to be taken up by acetone.

Conclusions

From the present limited data, a conservative criterion for presuming that gunshot residue may be present on a sample collected by the adhesive lift technique from the back of a subject's hand appears to be that the lead and antimony levels (as measured by the photoluminescence technique) simultaneously exceed 0.85 and 0.01 μg, respectively. This tentative conclusion is based on the observation that 100% of the samples from control subjects and slightly greater than 90% of the occupational handblanks had both lead and antimony levels below these levels.

The amounts of these elements on the hands of control subjects are expected to be similar to those on the hands of randomly selected members of the general population.

Blood on handsamples has an unfavorable effect on the detectability of lead and antimony by the photoluminescence technique. The effect of blood on these analyses currently constitutes a major problem that must be overcome before the photoluminescence technique can achieve its full potential and be established as a reliable method for the investigation of gunshot suicide cases. The levels of gunshot residue on handsamples from homicide victims under various conditions have not been established. However, under certain circumstances homicide victims might be expected to have levels of gunshot residue on their hands that are consistent with their having fired a gun. Ideally, a reliable analysis method is desired so that the absence of gunshot residue in handsamples from cases involving handgun/cartridge combinations that, in test firings, yield moderate amounts of residue could be taken as possible evidence for a homicide being disguised as a suicide. Clearly, the effects of blood on the detection of lead and antimony must be overcome before the photoluminescence method can achieve this goal.

Either the low pressure oxygen plasma ashing technique, which is currently used to overcome the adverse effects of blood on atomic absorption analyses, or some chemical oxidation technique should be useful in eliminating the effects of blood on photoluminescence analyses. More extensive data need to be collected from suicide cases involving particular handgun/cartridge combinations giving copious lead or antimony levels, or both. These data are needed to establish whether or not the amounts of lead and antimony detected by photoluminescence on the hands of suicide victims decline with increasing time between firing and sampling.

Conclusive identification of organic smokeless powder flakes would be possible at the most for about 7% of all gunshot suicide cases. This low rate of occurrence of organic flakes would not justify the time and effort required for their identification.

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Address requests for reprints or additional information to
G. L. Loper, Ph.D.
Ivan A. Getting Laboratories
The Aerospace Corporation
P.O. Box 92957
Los Angeles, Calif. 90009