Donald G. Havekost,[1] *M.S.; Charles A. Peters,*[1] *B.S.; and Robert D. Koons,*[2] *Ph.D.*

Barium and Antimony Distributions on the Hands of Nonshooters

REFERENCE: Havekost, D. G., Peters, C. A., and Koons, R. D., **"Barium and Antimony Distributions on the Hands of Nonshooters,"** *Journal of Forensic Sciences*, JFSCA, Vol. 35, No. 5, Sept. 1990, pp. 1096–1114.

ABSTRACT: Barium and antimony levels from selected areas of the left and right hands of 269 nonshooters provide a database for interpretation of gunshot residue swab analysis results. The database represents a variety of activities of individuals sampled by collectors throughout the United States. Nonshooting exposure to barium and antimony can generally be distinguished from firearms-associated exposure by considering the relative levels of the elements, location on the hands, and condition of the swabs. Consistent definition of sampling procedures and accurate analytical results make this database applicable for interpretation of data generated by most gunshot residue swab examiners.

KEYWORDS: criminalistics, gunshot residues, antimony determination, barium determination

Collection of gunshot primer residue (GSR) from a suspected shooter's hands and quantitative determination of the barium (Ba), antimony (Sb), and, less frequently, lead (Pb) present provide data commonly used to associate the suspect with the recent discharge of a firearm. Currently, GSR collection swab analyses are performed in approximately 50 forensic science laboratories throughout the United States. Interpretation of these analytical results is complicated by the presence of measurable amounts of Ba and Sb on the hands of most persons. An indication of whether a person has been in the environment of a discharging firearm is obtained by comparing the quantities of Ba and Sb removed from the suspect's hands with quantities of these metals removed from the hands of a sample of nonshooters. Ideally, this nonshooter or hand blank database should include people having an environmental exposure to Ba and Sb similar to that of the suspect. Published reports containing amounts of Ba and Sb on the hands of persons not handling firearms are summarized in Table 1 [*1–11*]. Several of these studies were designed to measure the hand blank levels of only a few persons prior to performing test-firing studies, rather than as hand blank surveys, so they contain a limited number of samples. Nevertheless, the studies shown in Table 1 represent the total published hand

This is Publication No. 89-08 of the Laboratory Division of the Federal Bureau of Investigation. Names of commercial manufacturers are provided for identification only, and inclusion does not imply endorsement by the Federal Bureau of Investigation. Received for publication 18 Sept. 1989; accepted for publication 30 Oct. 1989.

[1]Special agent and chemist, respectively, Elemental and Metals Analysis Unit, FBI Laboratory, Washington, DC.

[2]Research chemist, Forensic Science Research Unit, FBI Laboratory, FBI Academy, Quantico, VA.

TABLE 1—*Hand blank studies appearing in the literature.*

No. of Samples	Method of Sample Collection	Method of Analysis	Hand Area	No. of Hands/ Subject	Reference
260	paraffin lift	NAA	back	one	[1]
30	film lift	NAA	thumb-forefinger	?	[2]
40	swab, HNO_3	NAA	thumb-web-forefinger	one	[3]
249	cotton wool, HCl	AAS	thumb-web	one	[a]
12	swab, HNO_3	NAA	back, palm	two	[4]
23[b]	rinse in bag, HNO_3	NAA	whole hand	two	[5]
22	filter paper, HNO_3	NAA	thumb-web-forefinger	16-one/6-two	[6]
18[c]	two swabs, HNO_3	NAA	thumb-web-forefinger	two	[7]
20	water wash	PL	back-thumb	one	[8]
45	tape lift	PL	web-thumb-forefinger-back	one	[9]
32	one swab, HNO_3	NAA	back, palm	two	[10]
73	swab, HNO_3	AAS	thumb-web-forefinger, palm	two	[11]

[a]Renshaw, G. D., "The Estimation of Lead, Antimony, and Barium in Gunshot Residue by Flameless Atomic Absorption Spectrophotometry," Home Office Central Research Establishment, Aldermaston, England, personal communication, 1973.

[b]Not all elements were determined for each sample.

[c]Eighteen samples taken from three subjects over a period of several weeks.

blank experience upon which the GSR examiner must base his or her opinions. The reported studies are characterized by relatively small sample populations and a wide variety in sampling methods, analytical procedures, and results.

In 1982 and 1984, gunshot residue analysts from throughout the United States met at the FBI Academy in Quantico, Virginia, to discuss the state of the art of gunshot residue examinations. They identified the following five limitations in the existing hand blank studies which make them difficult to use for evaluation of GSR test swabs:

1. *Variation in the method of collecting the samples*—As shown in Column 2 of Table 1, hand blank data have been obtained using paraffin casts; hand swabs, with either one or two swabs and various solvents; solvent rinses; and tape lifts as methods of sample collection. Attendees at the meetings agreed that the most universally acceptable method of obtaining hand blank data that can be used across jurisdictional boundaries is using two plastic-shafted, cotton-tipped swabs moistened with 5% nitric acid solution per sampling area.

2. *Variation in instrumental methods, the use of outdated instrumentation, and inclusion of some unreliable data*—As shown in Column 3 of Table 1, existing hand blank results were obtained using neutron activation analysis (NAA), atomic absorption spectrophotometry (AAS), and photoluminescence (PL). GSR examiners generally agreed that most NAA results were reliable, but that variations in extraction and analysis procedures among laboratories made reported Ba and Sb determinations inconsistent when using AAS procedures. Recently, AAS procedures that provide accurate Ba and Sb measurements have been developed [*11,12*]. The close agreement between NAA and AAS results allows NAA hand blank data to be used by laboratories using either method of analysis. The PL method is incapable of determining Sb at hand blank levels or Ba at any level, so it has never been used by operational forensic science laboratories. An additional limitation of some of the citations in Table 1 is that they report only averages or ranges, rather than individual results [*4,5,10*].

3. *Unreported or inadequately documented activities and occupations of subjects*—Previous studies reported the occupation of the person from whom a hand blank sample was taken, rather than his or her activity prior to swabbing, even though it is widely agreed that a subject's activity affects the amounts of Ba and Sb present to a greater extent than does his or her occupation. The selection of activities in previous studies was not representative of the general population. In reports concerned with test-firing studies, subjects for hand blank collection consisted entirely of students or laboratory workers [*4,5,7,8*].

4. *Variation in areas of the hands sampled*—Most previous studies included only backs of hands or one hand only. Moreover, the definition of the areas sampled differed from one investigator to another, particularly when different sampling methods were used. Consistent definitions of hand sampling areas are a requirement of a hand blank database if it is to be used in GSR interpretation. Most examiners currently use both back and palm areas of the hands of suspected shooters in evaluating GSR evidence. The meeting participants felt that useful information would be gained by making both palm to back and right to left hand comparisons.

5. *Failure to consider regional differences*—Previous hand blank studies each used subjects from a specific geographic area. However, environmental levels of Ba and Sb that are reflected in hand blank results may vary from one location to another. Participants in the meetings agreed that samples collected from throughout the country should be compiled into a widely available hand blank database.

A new survey of nonshooters was designed with the goal of overcoming these limitations in available hand blank data. Conventions pertaining to the method of swabbing the

hands, information collected at the time of swabbing, and analytical procedures were agreed upon. None of the previous studies shown in Table 1 meets all of the agreed-upon conventions. FBI Laboratory personnel prepared sample collection kits and sent them to volunteer hand blank collectors. During sample collection, specific information pertaining to the activities of the subject being swabbed was acquired to facilitate interpretation of the results. FBI Laboratory personnel agreed to analyze the swabs and disseminate the results of the study. A total of 667 sample kits were sent to 56 collectors throughout the United States. This report summarizes the results for the 269 swab kits returned and analyzed to date.

Materials and Methods

The sample collection kits assembled by the FBI Laboratory consisted of separately packaged and labeled pairs of swabs and a bottle of 5% nitric acid solution. Each pair of swabs was used for sampling a specific area of the hand. In the first year of this study, the palm and back areas were selected for study. In the second year, an additional optional area was added to provide information requested by several of the seminar attendees. These areas are indicated in Fig. 1. To collect a sample, each swab of a pair was moistened with a few drops of the nitric acid solution and rubbed over the designated sampling area one after the other. The swabs were then placed together in their prelabeled container. One pair of swabs, which was used as a control sample for each subject, contained the swabbing solution only. The sample collector completed a questionnaire about each subject being swabbed. The information obtained is summarized, by example, in the

FIG. 1—*Sampling areas on the right hand.*

upper portion of Fig. 2. All the swabs were packaged in the containers provided and returned to the FBI Laboratory for analysis.

Upon their receipt in the FBI Laboratory, information from the subject questionnaire sheets was recorded, and the swabs were removed from the packages, examined microscopically to determine the degree of utilization and the nature and amount of soiling, and analyzed for their Ba and Sb contents using NAA procedures reported previously [*13*]. A typical report of results is shown in the lower portion of Fig. 2.

Discussion of Results

A total of 269 hand blank kits collected by 22 contributors have been analyzed to date. Preliminary evaluation of the data indicates that most of the results are low, in the ranges

F.B.I. LABORATORY
ELEMENTAL ANALYSIS UNIT
GSR HAND BLANK DATA

SAMPLE KIT NO. 0210

DATE SHIPPED: 8/4/85
SHIPPED TO: AR 01
DATE RETURNED: 9/16/85
DATE PACKAGED: 10/22/85
DATE ANALYZED: 3/3/86

HANDBLANK SAMPLE INFORMATION
SAMPLE DATE 8/29/85 TIME 2:25 AM/(PM)

PERSON'S NORMAL OCCUPATION INCINERATOR OPERATOR

■ MALE ■ RIGHT HANDED [ ] SMALL HANDS
[ ] FEMALE [ ] LEFT HANDED [ ] MEDIUM HANDS
■ LARGE HANDS

WAS PERSON ENGAGED IN NORMAL OCCUPATION WITHIN LAST TWO HOURS? ■ YES [ ] NO

IF [NO], WHAT ACTIVITY WAS PERSON ENGAGED IN?

HAD PERSON WASHED THEIR HANDS WITHIN LAST TWO HOURS?
■ YES [ ] NO

MISC. NOTES

RESULTS OF MICROSCOPIC EXAMINATION:

SPECIMEN	CONDITION OF SWABS POWDERY/DRY/DAMP				AMOUNT OF SOIL SLIGHT/MOD/HEAVY			SWAB UTILIZATION POOR/FAIR/GOOD		
RIGHT BACK	[ ]	■	[ ]		[ ]	■	[ ]	[ ]	[ ]	■
RIGHT PALM	[ ]	■	[ ]		[ ]	■	[ ]	[ ]	[ ]	■
RIGHT OPTIONAL	[ ]	[ ]	■		[ ]	■	[ ]	[ ]	[ ]	■
LEFT BACK	[ ]	[ ]	■		[ ]	[ ]	■	[ ]	[ ]	■
LEFT PALM	[ ]	■	[ ]		[ ]	■	[ ]	[ ]	[ ]	■
LEFT OPTIONAL	[ ]	■	[ ]		[ ]	■	[ ]	[ ]	[ ]	■
CONTROL	[ ]	■	[ ]	CLEAN	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

RESULTS OF ANALYSIS

SPECIMEN	UG BARIUM	UG ANTIMONY	BA/SB RATIO
RIGHT BACK	.343	.010	31.2
RIGHT PALM	.710	.042	16.9
RIGHT OPTIONAL	1.014	.026	39.0
LEFT BACK	1.006	.037	27.2
LEFT PALM	.513	.022	23.3
LEFT OPTIONAL	.223	.007	31.9
CONTROL	.023	.000	———

FIG. 2—*Sample collection and laboratory results information sheet. The upper portion contains information obtained from the subject at the time of sample collection and the lower portion contains laboratory observations and analytical results.*

typically reported in other hand blank studies. However, a significant number of subjects were sampled who had relatively high amounts of either Ba or Sb or both on at least one of the sampling areas.

Descriptive statistics of all hand blank data as a group are shown in Table 2. The element concentrations are not normally distributed about their mean values, as is indicated by the proximity of the means to the limits of detection and by the maxima being generally about ten standard deviations above the mean. Further indications of the lack of a normal distribution are that the mean values for Ba and Sb for each sampling area are between 3 and 20 times greater than the median values, and the calculated values of skewness and kurtosis are all high and positive, indicating a long positive tailing of both Ba and Sb distributions. Therefore, the mean and standard deviation values are very poor measures of the distributions of elemental contents among the samples, and interpretation of the results based on Gaussian statistical assumptions is meaningless. In other hand blank studies, it has been suggested that logarithmic normal and *t*-distribution models of hand blank data can be used to set threshold levels for interpretation of GSR test swab data [*1,5*]. Although the Ba data in this study are approximately normal following logarithmic transformation, and both Ba and Sb data approximate a *t*-distribution, we have not applied these models to our data and do not recommend this approach for setting threshold values for reasons to be discussed. The descriptive statistics in Table 2 are provided merely to facilitate comparison with hand blank results reported in other studies.

To assist in evaluating the analytical results, we have divided the hand blank data into four groups, as follows. All subjects having less than 0.5 μg of Ba and 0.05 μg of Sb from the sampling areas on the backs of both hands were placed into a low-Ba/low-Sb hand blank group. The remaining subjects were placed into one of three high hand blank groups depending upon which elements exceeded the cutoff values on the back of hand sampling area. The three high hand blank groups consisted of a high-Ba/high-Sb group having greater than 0.5 μg of Ba and 0.05 μg of Sb on the back of one or both hands,

TABLE 2—*Summary statistics of results of analysis of all the hand blank samples; the hand areas are designated R or L, indicating the right or left hand, followed by B, P, or O, indicating the back, palm, and optional area.*

	RB	RP	RO	LB	LP	LO
			Barium			
No. of samples	266	266	161	268	267	160
Minimum, μg	0.000	0.000	0.003	0.001	0.000	0.000
Maximum, μg	13.6	24.5	3.94	1.73	42.5	2.41
Median, μg	0.058	0.089	0.048	0.055	0.081	0.045
Mean, μg	0.22	0.41	0.21	0.16	0.46	0.16
SD, μg	0.91	1.78	0.51	0.28	2.67	0.30
			Antimony			
No. of samples	268	269	162	269	269	162
Minimum, μg	0.000	0.000	0.000	0.000	0.000	0.000
Maximum, μg	4.50	33.1	1.22	10.4	9.05	0.421
Median, μg	0.003	0.006	0.002	0.003	0.006	0.002
Mean, μg	0.030	0.15	0.017	0.050	0.063	0.013
SD, μg	0.276	2.02	0.098	0.637	0.562	0.044

TABLE 3a—*Analytical results for individual hand blank samples in low-Ba/low-Sb category. The analytical results are expressed in micrograms of the element.*

			Barium						Antimony					
Occupation	Activity	Wash	RB	RP	RO	LB	LP	LO	RB	RP	RO	LB	LP	LO
1 HOUSEWIFE	.	.	0.039	0.031	.	0.023	0.030	.	n.d.	n.d.	.	n.d.	n.d.	.
2 RETIRED	.	.	0.060	0.041	.	n.d.	0.033	.	n.d.	0.005	.	n.d.	0.004	.
3 MEDICAL TECHNICIAN	.	.	0.036	0.027	.	0.027	0.026	.	n.d.	n.d.	.	n.d.	n.d.	.
4 NURSE	.	.	0.022	0.049	.	0.037	0.072	.	n.d.	n.d.	.	n.d.	n.d.	.
5 CHEMIST	.	.	0.018	0.050	.	0.020	0.026	.	n.d.	n.d.	.	n.d.	n.d.	.
6 HIGH SCHOOL STUDENT	.	.	0.016	0.049	.	n.d.	0.044	.	n.d.	n.d.	.	n.d.	n.d.	.
7 JR HIGH SCHOOL STUDENT	.	.	0.017	0.015	.	0.020	0.031	.	n.d.	n.d.	.	n.d.	n.d.	.
8 UNEMPLOYED	.	.	0.013	0.030	.	0.010	0.131	.	n.d.	0.003	.	n.d.	n.d.	.
9 FARM WORKER	IN COURTROOM	N	0.190	0.210	.	0.214	0.228	.	n.d.	0.003	.	n.d.	0.003	.
10 COMPUTER PROGRAMMER	EATING	Y	0.379	0.381	.	0.319	0.331	.	0.018	0.022	.	0.013	0.013	.
11 FED LAW ENFOR AGENT	WORK	Y	0.055	0.049	.	0.068	n.d.	.	0.003	n.d.	.	0.003	n.d.	.
12 RADIATION SAFETY OFFICER	WORK	N	0.176	0.096	.	0.150	0.169	.	0.013	0.008	.	0.016	0.011	.
13 ACCOUNTANT	COMMUTING	Y	0.078	0.113	.	0.097	0.112	.	n.d.	0.003	.	n.d.	0.014	.
14 LABORATORY TECHNICIAN	WORK	Y	0.057	0.057	.	0.045	0.046	.	0.005	0.004	.	0.005	0.005	.
15 ACCOUNTANT	COMMUTING	Y	0.026	0.196	.	0.060	0.110	.	n.d.	0.003	.	n.d.	0.011	.
16 HYDROLOGIST	EATING	Y	0.038	0.092	.	0.036	0.070	.	n.d.	0.004	.	n.d.	0.003	.
17 LABORATORY TECHNICIAN	WORK	Y	0.033	0.051	.	0.030	0.028	.	0.003	0.004	.	n.d.	n.d.	.
18 LABORATORY TECHNICIAN	WORK	N	0.064	0.079	.	0.056	0.077	.	0.031	0.038	.	0.011	0.064	.
19 CHEMIST	WORK	.	0.024	0.058	.	0.020	0.036	.	n.d.	0.004	.	0.004	0.016	.
20 PHYSICIST	WORK	.	0.028	0.128	.	0.027	0.074	.	n.d.	0.003	.	n.d.	0.003	.
21 LABORATORY TECHNICIAN	WORK	.	0.049	0.137	.	0.042	0.096	.	0.003	0.010	.	n.d.	0.006	.
22 COMPUTER PROGRAMMER	WORK	.	0.013	0.048	.	0.022	0.035	.	n.d.	0.008	.	n.d.	0.004	.
23 TOXICOLOGIST	WORK	.	0.076	0.167	.	0.045	0.077	.	0.006	0.028	.	0.005	0.016	.
24 CHEMIST	WORK	.	0.043	0.066	.	0.026	0.056	.	n.d.	0.034	.	n.d.	0.025	.
25 LABORATORY TECHNICIAN	WORK	.	0.100	0.164	.	0.119	0.120	.	0.004	0.016	.	n.d.	0.023	.
26 LABORATORY TECHNICIAN	WORK	.	0.061	0.014	.	0.017	0.061	.	0.013	0.008	.	0.003	0.009	.
27 CLERK	.	.	0.032	0.013	.	0.021	0.019	.	n.d.	n.d.	.	n.d.	0.003	.
28 CASHIER	WORK	.	0.317	1.14	.	0.325	2.43	.	n.d.	n.d.	.	0.003	0.008	.
29 RECEIVING CLERK	VIDEO GAME	.	0.369	0.591	.	0.432	0.270	.	0.003	0.004	.	0.004	0.007	.
30 WAITRESS	VIDEO GAME	.	0.131	0.104	.	0.096	0.089	.	0.003	0.005	.	n.d.	0.004	.
31 PIZZA PARLOR MANAGER	HANDLE MONEY	N	0.397	1.02	.	0.480	1.13	.	n.d.	0.007	.	0.004	0.007	.
32 COMPUTER PROGRAMMER	.	.	0.085	0.170	.	0.128	0.073	.	0.003	0.005	.	0.004	n.d.	.
33 JUVENILE	.	.	0.038	0.086	.	0.025	0.032	.	0.003	0.003	.	0.003	n.d.	.
34 UNEMPLOYED	.	.	0.023	0.012	.	0.038	0.034	.	0.038	n.d.	.	0.003	0.004	.
35 TEACHER	.	.	0.015	0.018	.	0.018	0.014	.	n.d.	n.d.	.	n.d.	n.d.	.
36 CLERK SUPERVISOR	.	.	0.021	0.045	.	0.026	0.017	.	n.d.	n.d.	.	n.d.	0.003	.
37 DAIRY FARMER	.	.	0.136	0.114	.	0.127	0.177	.	0.012	0.008	.	0.005	0.006	.

38 CLERK	.	.	0.013	0.029	.	0.025	0.030	.	n.d.	n.d.	.	n.d.	n.d.	.			
39 RETIRED	.	.	0.033	0.037	.	0.028	0.091	.	n.d.	n.d.	.	0.003	n.d.	.			
40 STUDENT	.	.	0.027	0.034	.	0.061	0.111	.	n.d.	n.d.	.	n.d.	n.d.	.			
41 FRUIT GROWER	.	.	0.022	0.027	.	0.034	0.031	.	n.d.	n.d.	.	n.d.	n.d.	.			
42 MINISTER	.	.	0.230	0.183	.	0.191	0.320	.	0.005	0.011	.	0.009	0.014	.			
43 EXHIBITS SPECIALIST	PRINTING	.	0.100	0.136	.	0.070	0.073	.	n.d.	0.008	.	0.004	0.011	.			
44 ILLUSTRATOR	.	.	0.044	0.067	.	0.036	0.049	.	n.d.	n.d.	.	n.d.	n.d.	.			
45 CARPENTER	.	.	0.080	0.180	.	0.060	0.156	.	n.d.	0.012	.	0.003	0.015	.			
46 ENGRAVER	.	.	0.072	0.201	.	0.255	0.201	.	0.005	0.020	.	0.011	0.021	.			
47 FINGERPRINT EXAMINER	.	.	0.024	0.169	.	0.107	0.075	.	n.d.	n.d.	.	n.d.	0.003	.			
48 POLICE OFFICER	.	.	n.d.	0.031	.	0.015	0.010	.	0.007	0.009	.	0.008	0.007	.			
49 ELECTRON MICROSCOPIST	WORK	.	0.065	0.037	.	0.058	0.025	.	0.029	0.026	.	0.030	0.017	.			
50 REAL ESTATE AGENT	HORSE RIDING	N	0.039	0.103	.	0.026	0.098	.	0.010	0.006	.	0.012	0.008	.			
51 NEWSPAPER DISTRIBUTOR	.	.	0.043	0.118	.	0.125	0.364	.	0.038	0.019	.	0.037	0.016	.			
52 GROUNDSMAN	.	.	0.056	0.225	.	0.085	0.395	.	n.d.	n.d.	.	n.d.	0.006	.			
53 CONSTRUCTION	.	.	0.441	0.252	.	0.467	0.311	.	0.022	0.005	.	0.020	0.017	.			
54 OFFICE ADMINISTRATOR	.	.	0.044	0.130	.	0.091	0.124	.	n.d.	n.d.	.	n.d.	0.005	.			
55 DAYCARE OPERATOR	WORK	.	0.071	0.129	.	0.107	0.184	.	0.006	0.008	.	0.005	0.014	.			
56 LAWYER	.	.	0.227	0.152	.	0.128	0.352	.	0.004	n.d.	.	n.d.	0.004	.			
57 AUTO MECHANIC	COMMUTING	.	0.090	0.168	.	0.065	0.069	.	n.d.	n.d.	.	n.d.	0.004	.			
58 ELECTRONICS TECHNICIAN	WORK	.	0.224	1.02	.	0.280	1.05	.	0.018	0.038	.	0.018	0.032	.			
59 GARAGE EMPLOYEE	COMMUTING	.	0.068	0.321	.	0.064	0.088	.	n.d.	0.022	.	n.d.	0.003	.			
60 ELECTRONICS TECHNICIAN	COMMUTING	.	0.101	0.094	.	0.067	0.111	.	0.004	0.005	.	0.003	0.007	.			
61 INVENTORY CLERK	WORK	.	0.045	0.089	.	0.033	0.041	.	0.007	0.024	.	0.006	0.031	.			
62 LAB EVIDENCE EXAMINER	WORK	.	0.056	0.072	.	0.036	0.058	.	n.d.	0.003	.	n.d.	0.003	.			
63 RETIRED	.	Y	0.123	0.121	.	0.089	0.076	.	n.d.	n.d.	.	0.005	n.d.	.			
64 HYDROLOGIST	EATING	N	0.121	0.253	.	0.114	0.341	.	0.003	0.006	.	0.006	0.012	.			
65 COMPUTER PROGRAMMER	.	N	0.214	0.252	.	0.304	0.206	.	0.010	0.011	.	0.005	0.009	.			
66 DEPUTY SHERIFF	WORK	.	0.047	0.050	.	n.d.	0.057	.	0.010	0.012	.	0.005	0.010	.			
67 AUTO MECHANIC	WORK	Y	0.422	0.952	0.314	0.359	0.538	0.329	0.039	0.097	0.026	0.029	0.069	0.065			
68 MACHINIST	WORK	Y	n.d.	n.d.	0.035	0.257	n.d.	0.129	0.013	0.060	0.038	0.011	0.104	0.030			
69 SECRETARY	WORK	Y	0.097	0.094	0.072	0.160	0.148	0.014	0.030	0.041	0.015	0.014	0.057	0.014			
70 VEHICLE MAINT SUPER	WORK	N	0.023	0.015	0.053	0.044	0.020	0.020	0.008	0.006	0.005	0.007	0.005	0.006			
71 LIGHT TRUCK MECHANIC	BATTERY WORK	N	0.341	0.662	0.371	0.360	0.846	0.393	0.021	0.157	0.020	0.033	0.063	0.022			
72 BIKE MECHANIC	.	.	0.197	0.394	0.195	0.219	0.367	0.151	0.003	0.006	0.004	0.003	0.007	n.d.			
73 PRISONER	INCARCERATION	N	0.017	n.d.	0.025	0.037	0.025	0.037	n.d.	0.004	0.003	0.004	0.004	0.004			
74 BIKE SHOPKEEPER	WORK	Y	0.203	0.630	0.301	0.260	0.396	0.210	0.004	0.013	0.008	0.004	0.005	n.d.			
75 ELEVATOR MECHANIC	WORK	N	0.012	0.079	0.062	0.056	0.062	0.054	n.d.	0.005	n.d.	0.003	0.004	0.003			
76 HEAVY TRUCK MECHANIC	WORK	Y	0.272	0.494	0.436	0.269	0.229	0.225	0.012	0.028	0.011	0.006	0.027	0.008			
77 POWER EQUIP MECHANIC	WORK	Y	0.094	0.282	0.063	0.107	0.422	0.066	0.006	0.013	0.005	n.d.	0.024	0.004			
78 STUDENT	ATTEND CLASS	N	0.012	n.d.	n.d.	0.010	0.027	n.d.	0.004	n.d.	0.003	0.004	n.d.	n.d.			
79 STUDENT	EATING	N	0.029	0.038	0.011	0.042	0.022	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.			
80 MEDICAL TECHNOLOGIST	WORK	Y	0.033	0.036	0.014	0.030	0.033	0.016	n.d.	n.d.	n.d.	0.003	n.d.	n.d.			

TABLE 3*a*—*Continued.*

			Barium						Antimony					
Occupation	Activity	Wash	RB	RP	RO	LB	LP	LO	RB	RP	RO	LB	LP	LO
81 ARCHITECT	WORK	N	0.011	n.d.	0.016	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
82 MEDICAL TECHNOLOGIST	WORK	Y	0.041	0.089	0.038	0.011	0.078	0.017	n.d.	0.003	n.d.	n.d.	n.d.	n.d.
83 MARKETING	WORK	N	n.d.	0.013	n.d.	n.d.	n.d.	0.013	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
84 ENGINEER	WORK	Y	0.010	n.d.	0.019	0.011	n.d.	0.015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
85 HOUSEWIFE	WORK	N	n.d.	n.d.	0.021	n.d.	0.013	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
86 RECEPTIONIST	WORK	N	n.d.	n.d.	0.011	n.d.	0.015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.003
87 FORENSIC LAB ANALYST	COMMUTING	N	0.136	0.137	0.211	0.138	1.09	0.398	0.014	0.274	0.041	0.014	0.762	0.283
88 STUDENT INTERN	WORK	Y	0.026	0.063	n.d.	0.013	0.048	0.045	n.d.	0.005	n.d.	n.d.	0.006	n.d.
89 STUDENT	NORMAL	Y	0.023	0.026	0.024	0.010	0.031	0.018	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
90 STUDENT	NORMAL	Y	0.027	0.011	0.015	0.015	0.021	0.015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
91 DESIGN ENGINEER	WORK	N	0.033	0.023	0.014	0.019	0.041	n.d.	n.d.	n.d.	n.d.	0.004	n.d.	n.d.
92 DRAFTSMAN	WORK	Y	0.018	0.021	0.021	0.020	0.018	0.025	n.d.	n.d.	n.d.	n.d.	0.004	n.d.
93 NURSE	COOKING	Y	0.071	0.039	0.060	0.051	0.024	0.052	0.003	n.d.	n.d.	0.008	0.006	n.d.
94 JANITOR	WORK	Y	0.296	0.261	0.273	0.259	0.218	0.211	0.008	0.015	0.003	0.009	0.033	0.037
95 CLERK	WORK	Y	0.043	0.026	0.053	0.045	0.072	0.046	n.d.	0.003	n.d.	n.d.	0.003	n.d.
96 DRY CLEANER	WORK	Y	0.088	0.163	0.094	0.068	0.115	0.109	n.d.	0.027	n.d.	0.004	n.d.	n.d.
97 COUNTER CLERK	WORK	Y	.	0.292	0.184	0.163	0.148	0.142	.	0.022	n.d.	0.004	0.005	n.d.
98 FIREFIGHTER	WORK	Y	0.117	0.068	0.140	0.032	0.080	0.054	n.d.	n.d.	0.005	n.d.	n.d.	n.d.
99 CLERK	WORK	N	0.120	0.140	0.388	0.167	0.352	0.117	0.003	n.d.	n.d.	0.006	n.d.	n.d.
100 ACCOUNTING CLERK	WORK	N	0.127	0.156	0.123	0.287	0.195	0.043	n.d.	0.006	n.d.	n.d.	n.d.	n.d.
101 CLERK	WORK	N	0.058	0.052	0.039	0.048	0.067	0.026	0.003	n.d.	n.d.	n.d.	0.004	n.d.
102 BUILDING MANAGER	.	.	0.086	0.204	0.187	0.190	0.217	0.130	n.d.	0.004	0.006	0.005	0.006	n.d.
103 PAINT MANAGER	WORK	N	0.274	0.541	0.129	0.255	0.543	0.113	0.007	0.018	0.006	0.006	0.018	n.d.
104 PAINTER	WORK	N	0.122	0.187	0.168	0.173	0.342	0.197	0.006	0.008	0.005	0.006	0.009	0.004
105 CARPENTER	WORK	N	0.296	0.378	0.330	0.284	0.045	0.204	0.015	0.010	0.015	0.014	0.021	0.013
106 PAINTER	WORK	N	0.215	0.206	0.199	0.229	0.503	0.168	0.013	0.047	0.012	0.009	0.103	0.004
107 LOGGER	WORK	N	0.071	0.137	0.015	0.134	0.188	0.016	n.d.	0.004	n.d.	n.d.	0.008	n.d.
108 SALES	WORK	Y	0.072	0.042	0.041	0.021	0.028	0.012	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
109 AUTO PARTS CLERK	WORK	N	0.112	0.114	0.017	0.100	0.100	.	0.004	0.013	n.d.	n.d.	0.004	n.d.
110 MOTEL DESK CLERK	WORK	N	0.055	0.044	.	0.020	0.101	.	n.d.	n.d.	.	n.d.	0.013	.
111 JEWLERY SALES	WORK	N	0.126	0.140	.	0.091	0.197	.	0.006	0.025	.	0.009	0.065	.
112 BARTENDER	WORK	Y	0.023	0.043	.	0.018	0.023	.	n.d.	n.d.	.	n.d.	n.d.	.
113 ELEMENTARY TEACHER	WORK	N	0.147	0.192	.	0.096	0.162	.	0.003	n.d.	.	n.d.	0.005	.
114 AUTO MECHANIC	WORK	N	0.246	0.366	0.174	0.224	0.562	0.232	0.010	0.017	0.006	0.015	0.053	0.019
115 PRINTER	WORK	N	0.060	0.060	0.040	0.031	0.058	0.037	n.d.	0.006	0.004	n.d.	0.004	n.d.
116 SERVICE STATION MECH	WORK	.	0.247	0.247	0.154	0.165	0.297	0.144	0.007	0.006	n.d.	0.008	0.017	0.004
117 GUN DEALER	WORK	.	0.057	0.119	0.058	0.060	0.095	0.058	0.008	0.035	0.010	0.007	0.027	0.023
118 STUDENT	EXERCISE	N	0.052	0.047	0.075	0.030	0.029	0.039	0.009	0.015	0.012	0.008	0.007	0.009

119 CHEMICAL STOCKROOM CLERK	WORK	N	0.029	0.122	0.064	0.026	n.d.	0.046	0.007	0.008	0.018	0.006	0.010	0.017
120 ARMY PERSONNEL NCO	WORK	N	0.035	0.048	0.035	0.040	0.074	0.021	0.019	0.022	0.020	0.017	0.012	0.018
121 ANALYTICAL CHEMIST	WORK	N	0.065	0.035	0.018	0.015	n.d.	0.044	0.014	0.021	0.010	0.013	0.011	0.016
122 SECRETARY	WORK	N	0.028	0.044	0.023	0.038	0.061	0.016	n.d.	0.005	n.d.	n.d.	0.003	n.d.
123 CUSTODIAN	WORK	Y	0.038	0.079	0.061	0.045	0.091	0.033	0.003	0.010	0.008	0.004	0.006	0.004
124 PASTOR	WORK	N	0.181	0.050	0.018	0.031	0.034	0.021	0.003	n.d.	n.d.	n.d.	n.d.	n.d.
125 .	WORK	Y	0.019	0.041	0.022	0.035	0.084	0.017	n.d.	0.008	0.003	n.d.	0.007	n.d.
126 PHOTOGRAPHER	WORK	N	n.d.	0.030	n.d.	0.030	n.d.	0.032	n.d.	n.d.	n.d.	n.d.	0.006	n.d.
127 MENTAL HEALTH THERAPIST	WORK	N	0.015	0.031	n.d.	0.027	0.043	0.020	n.d.	0.004	n.d.	n.d.	n.d.	n.d.
128 WELDER	DOCTOR VISIT	N	0.017	0.027	0.012	0.025	0.044	0.015	0.003	0.007	n.d.	0.005	0.012	n.d.
129 OFFICE EQUIPMENT SPEC	WORK	Y	n.d.	0.034	0.011	0.012	0.020	0.024	n.d.	0.004	n.d.	n.d.	n.d.	n.d.
130 AIR CONDITIONER MECHANIC	GARDENING	Y	0.099	0.137	0.078	0.136	0.130	0.127	0.008	0.016	0.013	0.021	0.020	0.017
131 .	RELAXING	N	0.021	0.382	0.048	0.033	0.132	0.054	n.d.	n.d.	n.d.	n.d.	0.007	n.d.
132 ADMINISTRATIVE NCO	WORK	N	0.022	0.026	n.d.	0.018	0.028	0.016	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
133 EVIDENCE CONTROL CLERK	WORK	N	0.036	0.029	0.049	0.014	0.048	0.058	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
134 WORD PROCESSOR	WORK	Y	0.052	0.037	0.074	0.023	0.095	0.059	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
135 EVIDENCE CNTROL CLERK	.	Y	0.031	0.056	0.133	0.059	0.064	0.102	0.003	n.d.	0.003	n.d.	0.005	n.d.
136 WORD PROCESSOR	WORK	N	0.033	0.068	0.038	0.050	0.095	0.034	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
137 FORENSIC CHEMIST	WORK	N	0.027	0.043	0.012	n.d.	0.082	0.036	n.d.	0.008	n.d.	n.d.	0.005	n.d.
138 FORENSIC CHEMIST	WORK	N	0.027	0.015	0.023	0.024	0.014	0.026	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
139 LAB AIDE	WORK	Y	0.022	0.030	0.021	0.016	0.035	0.036	n.d.	0.003	n.d.	n.d.	n.d.	n.d.
140 ADMINISTRATIVE NCO	WORK	Y	0.047	0.052	0.042	0.035	0.054	0.026	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
141 FORENSIC CHEMIST	WORK	N	0.026	0.016	0.030	0.039	0.024	0.031	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
142 STUDENT	CLASSROOM	N	0.091	0.028	0.093	0.039	0.049	0.031	0.009	0.006	0.005	0.003	0.006	0.004
143 STUDENT	CLASSROOM	Y	n.d.	0.021	0.048	0.028	n.d.	0.033	n.d.	0.003	n.d.	n.d.	0.008	n.d.
144 STUDENT	CLASSROOM	N	0.051	0.023	0.043	0.027	0.125	0.030	0.004	n.d.	0.005	0.006	0.005	0.003
145 SOUND ENGINEER	WORK	Y	0.040	0.037	0.031	0.024	0.063	0.061	n.d.	0.004	n.d.	n.d.	0.004	0.003
146 ACCOUNTANT	WORK	N	0.024	0.077	0.021	0.039	0.102	0.043	0.006	0.006	n.d.	0.003	0.013	0.003
147 NURSE	WORK	Y	0.045	0.027	0.015	0.026	0.029	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
148 MAINTENANCE MECHANIC	WORK	Y	0.156	0.579	0.144	0.326	0.339	0.167	0.044	0.094	0.040	0.035	0.051	0.023
149 COMPUTER MECHANIC	.	Y	0.023	0.032	0.015	0.024	0.018	0.025	n.d.	0.013	n.d.	0.004	0.021	n.d.
150 FIREARMS EXAMINER	WORK	Y	n.d.	0.154	0.043	0.029	0.014	0.065	0.003	0.007	n.d.	n.d.	0.006	n.d.
151 POLICEMAN	WORK	N	0.030	0.047	0.045	0.027	0.058	0.010	n.d.	0.006	n.d.	0.008	0.004	0.004
152 PHYSICIAN	WORK	Y	0.020	0.058	0.028	0.030	0.067	n.d.	n.d.	n.d.	n.d.	n.d.	0.003	n.d.
153 DRAFTSMAN	WORK	N	0.159	0.183	0.065	0.143	0.366	0.115	0.004	n.d.	n.d.	n.d.	n.d.	n.d.
154 OOCUMENTS EXAMINER	WORK	N	n.d.	0.027	0.034	0.022	0.019	0.045	0.006	0.041	0.031	0.005	0.015	0.015
155 FIREARMS EXAMINER	WORK	Y	0.024	0.189	0.076	0.051	0.105	0.043	0.010	0.026	0.012	0.009	0.025	0.012
156 SEROLOGIST	WORK	N	0.037	0.064	0.045	0.037	0.047	0.025	n.d.	0.006	n.d.	n.d.	n.d.	n.d.
157 FORENSIC CHEMIST	WORK	N	n.d.	0.038	0.021	0.026	n.d.	0.032	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
158 DRIVER	WORK	Y	0.040	0.062	0.061	0.055	0.067	0.034	n.d.	0.005	n.d.	n.d.	n.d.	n.d.
159 NARCOTICS ANALYST	WORK	N	0.072	0.028	0.035	0.042	0.039	0.045	n.d.	0.004	n.d.	n.d.	0.003	n.d.
160 SECRETARY	WORK	N	0.058	0.069	0.056	0.045	0.093	0.028	n.d.	0.010	n.d.	n.d.	0.006	0.003

TABLE 3a—*Continued.*

Occupation	Activity	Wash	Barium						Antimony					
			RB	RP	RO	LB	LP	LO	RB	RP	RO	LB	LP	LO
161 MANAGER	WORK	N	0.056	0.070	0.019	0.025	0.074	n.d.	n.d.	0.003	n.d.	n.d.	0.003	n.d.
162 .	WORK	Y	0.056	0.049	0.027	0.041	0.039	0.018	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
163 TRANSCRIBER	WORK	Y	0.056	0.197	0.086	0.054	0.210	0.063	0.005	0.009	0.003	n.d.	0.011	0.003
164 DELIVERY DRIVER	WORK	N	0.125	0.280	0.124	0.129	0.303	0.102	0.009	0.019	0.006	0.006	0.010	0.004
165 COPIER REPAIR	WORK	N	0.045	0.094	0.024	0.071	0.067	0.038	n.d.	0.006	n.d.	n.d.	0.010	n.d.
166 HEAVY EQUIP OPERATOR	WORK	N	0.397	0.701	.	0.356	1.51	.	0.010	0.012	.	0.012	0.020	.
167 STATE ATTORNEY GENERAL	WORK	Y	0.054	0.072	n.d.	0.036	0.100	0.042	0.004	0.003	0.003	0.003	0.006	0.003
168 SECRETARY	WORK	N	0.127	0.105	0.040	0.162	0.149	0.076	n.d.	n.d.	n.d.	n.d.	n.d.	0.003
169 TV CAMERAMAN	WORK	N	0.153	0.187	0.084	0.430	0.170	0.126	0.020	0.048	0.007	0.027	0.041	0.012
170 BUILDING MAINTENANCE	WORK	Y	0.172	0.236	0.074	0.100	0.198	0.030	0.015	0.030	0.005	0.013	0.038	0.004
171 DOCUMENTS EXAMINER	WORK	Y	0.068	n.d.	0.044	0.091	0.129	0.194	n.d.	n.d.	n.d.	0.003	0.006	0.003
172 CARPENTER	WORK	N	0.313	0.299	0.340	0.371	0.411	0.516	0.012	0.014	0.007	0.014	0.010	0.011
173 GARDENER	WORK	N	0.355	0.434	0.401	0.273	0.248	0.199	0.024	0.010	0.013	0.017	0.010	n.d.
174 PAINTER	WORK	N	0.111	0.164	0.198	0.226	0.049	0.120	0.012	0.007	0.014	0.009	0.009	0.010
175 TILE INSTALLER	WORK	N	0.238	0.362	0.110	0.205	0.349	0.184	0.005	0.008	0.010	0.009	0.013	0.007
176 PAINTER	WORK	N	0.073	0.117	0.086	0.078	0.104	0.040	n.d.	0.008	n.d.	0.003	0.005	0.003
177 INSTRUMENT REPAIR	WORK	N	.	.	n.d.	0.015	.	0.059	0.009	0.014	0.005	0.005	0.011	0.003
178 SALESMAN	WORK	N	n.d.	0.013	n.d.	0.017	0.019	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
179 MEDICAL TECHNOLOGIST	WORK	Y	0.031	0.079	0.013	0.021	0.050	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
180 .	WORK	Y	0.080	0.106	0.048	0.060	0.081	0.042	n.d.	n.d.	n.d.	n.d.	0.003	n.d.
181 LAB TECHNOLOGIST	WORK	Y	0.049	0.049	0.024	0.035	0.030	0.046	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
182 MEDICAL TECHNOLOGIST	WORK	Y	0.028	0.038	0.036	0.012	0.033	0.010	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
183 PILOT	NOT WORK	N	n.d.	0.012	0.013	0.013	0.010	0.013	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
184 MEDICAL TECHNOLOGIST	WORK	Y	n.d.	0.041	0.017	0.032	0.048	0.020	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
185 HOUSEWIFE	WORK	Y	0.015	0.019	0.015	n.d.	0.014	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
186 MEDICAL TECHNOLOGIST	WORK	Y	n.d.	0.048	0.013	0.027	0.020	0.017	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
187 SECRETARY	WORK	Y	0.024	0.017	0.032	0.017	0.017	0.022	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
188 STUDENT	CLASSROOM	Y	0.042	0.061	0.027	0.015	0.046	0.069	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
189 STUDENT	CLASSROOM	N	0.082	n.d.	0.046	0.049	0.063	0.036	0.007	0.021	0.005	0.010	0.009	0.009
190 STUDENT	CLASSROOM	Y	0.017	0.027	0.017	0.034	0.049	0.019	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
191 STUDENT	CLASSROOM	N	0.056	0.130	0.042	0.051	0.065	0.035	0.009	0.016	n.d.	0.004	0.012	0.007
192 STUDENT	CLASSROOM	Y	0.014	n.d.	n.d.	0.033	0.027	0.031	0.004	n.d.	n.d.	n.d.	n.d.	0.005
193 STUDENT	CLASSROOM	Y	0.023	0.018	0.020	0.022	0.050	0.033	0.004	n.d.	n.d.	0.004	n.d.	n.d.
194 STUDENT	CLASSROOM	N	0.011	n.d.	0.015	0.015	0.032	0.018	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
195 STUDENT	CLASSROOM	N	0.037	n.d.	0.017	0.044	0.080	0.050	n.d.	n.d.	n.d.	n.d.	0.004	n.d.
196 INSTRUCTOR	CLASSROOM	.	0.030	0.055	0.053	0.051	0.051	0.037	0.003	0.016	0.006	0.004	0.010	0.003
197 STUDENT	CLASSROOM	.	0.040	0.083	0.057	0.055	0.071	0.066	n.d.	0.003	n.d.	n.d.	0.004	n.d.
198 STUDENT	CLASSROOM	.	0.033	0.013	.	0.035	0.068	.	n.d.	0.006	.	n.d.	0.003	.
199 STUDENT	CLASSROOM	.	0.025	.	0.021	0.023	0.122	0.024	0.003	0.003	n.d.	n.d.	n.d.	n.d.
200 STUDENT	CLASSROOM	.	0.024	0.074	0.011	0.028	0.074	0.048	0.003	0.006	0.003	n.d.	n.d.	n.d.
201 STUDENT	CLASSROOM	.	0.087	0.057	0.053	0.131	0.329	0.112	n.d.	0.003	n.d.	0.004	0.007	n.d.
202 STUDENT	CLASSROOM	.	0.024	0.118	0.049	0.029	0.135	0.059	n.d.	0.006	0.004	0.003	0.008	n.d.
203 STUDENT	CLASSROOM	.	0.012	n.d.	0.013	0.022	0.069	0.028	n.d.	n.d.	n.d.	n.d.	0.004	n.d.

204 STUDENT	CLASSROOM	.	0.017	0.016	.	0.022	0.035	.	n.d.	0.004	.	n.d.	n.d.	.
205 EXPLOSIVES EXAMINER	WORK	N	0.089	0.086	0.043	0.089	0.067	0.092	n.d.	0.003	0.004	0.006	0.005	0.004
206 SECRETARY	WORK	.	0.087	0.053	.	0.082	0.069	.	0.003	n.d.	.	n.d.	0.005	.
207 LEGAL INTERN	WORK	.	0.086	0.134	.	0.098	0.135	.	0.007	0.013	.	0.003	0.009	.
208 SECRETARY	WORK	.	0.077	0.182	.	0.085	0.129	.	n.d.	0.005	.	n.d.	n.d.	.
209 ATTORNEY	WORK	.	0.027	0.039	.	0.020	0.058	.	0.003	n.d.	.	n.d.	n.d.	.
210 CHEMIST	WORK	.	0.071	0.075	.	0.059	0.084	.	n.d.	0.004	.	n.d.	n.d.	.
211 RADIOCHEMIST	.	.	0.072	0.102	.	0.100	0.056	.	n.d.	0.004	.	n.d.	n.d.	.
212 ANIMAL HANDLER	WORK	Y	0.152	0.197	0.053	0.052	0.323	0.101	0.003	0.003	n.d.	n.d.	0.006	0.003
213 CLERK/TYPIST	WORK	N	0.059	0.117	0.054	0.055	0.160	0.032	n.d.	0.003	n.d.	0.003	0.003	n.d.
214 DIRECTOR OF DORMITORY	WORK	Y	0.022	0.033	0.029	0.065	0.063	0.020	n.d.	n.d.	0.003	n.d.	n.d.	n.d.
215 REACTOR OPERATOR	WORK	.	0.109	0.093	.	0.058	0.079	.	0.024	0.047	.	0.010	0.026	.
216 HOUSEWIFE	.	.	0.068	0.063	.	0.040	0.050	.	0.006	0.005	.	0.006	0.005	.
217 REACTOR OPERATOR	WORK	.	0.136	0.157	.	0.125	0.247	.	0.039	0.035	.	0.037	0.026	.
218 MAILROOM CLERK	WORK	N	0.088	0.271	.	0.083	0.101	.	0.006	0.111	.	0.003	0.013	.
219 MAILROOM CLERK	WORK	N	0.058	n.d.	.	0.058	0.084	.	0.008	0.015	.	0.007	0.010	.
220 CHEMIST	WORK	.	0.071	0.094	.	0.060	0.100	.	0.005	0.055	.	0.004	0.032	.
221 LAB EVIDENCE EXAMINER	WORK	.	0.051	0.061	.	0.055	0.048	.	0.008	0.042	.	0.016	0.044	.
222 RECEPTIONIST	WORK	.	0.170	0.277	.	0.280	0.233	.	n.d.	0.009	.	0.003	0.004	.
223 RECEPTIONIST	WORK	.	0.125	0.181	.	0.085	0.131	.	0.006	0.010	.	n.d.	0.009	.
224 CHEMIST	WORK	.	0.059	0.182	.	0.057	0.123	.	0.009	0.055	.	0.017	0.022	.
225 COLLEGE STUDENT	WORK	.	0.101	0.211	.	0.221	0.374	.	0.004	0.009	.	0.005	0.016	.
226 HEALTH PHYSICIST	WORK	.	0.054	0.080	.	0.039	0.117	.	0.016	0.031	.	0.020	0.071	.
227 REACTOR OPERATOR	WORK	.	0.045	0.023	.	0.042	0.038	.	0.004	0.012	.	n.d.	0.005	.
228 SR. REACTOR OPERATOR	WORK	.	0.024	0.062	.	0.017	0.037	.	n.d.	0.005	.	n.d.	n.d.	.
229 HEALTH PHYSICIST	WORK	.	0.067	0.102	.	0.065	0.092	.	0.015	0.030	.	0.026	n.d.	.
230 REACTOR OPERATOR	WORK	.	0.110	0.058	.	0.038	0.037	.	0.007	0.018	.	0.006	0.025	.
231 SR. REACTOR OPERATOR	WORK	.	0.033	0.044	.	0.042	0.046	.	0.009	0.007	.	0.015	0.016	.
232 SR. REACTOR OPERATOR	WORK	.	0.079	0.168	.	0.047	0.163	.	0.030	0.062	.	0.014	0.049	.
233 CHEMIST	WORK	Y	0.090	0.121	0.022	0.073	0.105	0.062	0.004	0.007	n.d.	0.004	0.015	n.d.
234 HEALTH PHYSICIST	WORK	.	0.162	0.410	.	0.274	0.470	.	0.010	0.143	.	0.020	0.022	.
235 ELECTRICIAN	WORK	N	0.301	0.703	0.366	0.239	0.441	0.332	0.077	0.078	0.020	0.017	0.036	0.010
Summary statistics															
Minimum			n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum			0.441	1.14	0.436	0.480	2.43	0.516	0.044	0.274	0.041	0.037	0.762	0.283
Mean			0.081	0.13	0.071	0.085	0.14	0.067	0.005	0.012	0.004	0.005	0.013	0.006
Standard deviation			0.087	0.17	0.089	0.096	0.24	0.082	0.008	0.027	0.008	0.007	0.052	0.025

Footnotes to Table 3a-d:

Occupation is that occupation in which the subject is normally employed.
Activity is that in which the subject was engaged immediately prior to sampling. Work signifies performing regular occupation.
Wash signifies whether subject washed hands in the two hours immediately prior to sampling.
RB, RP, etc refer to sampling hand and area as shown in Figure 1, ie. RB is back of right hand.
. signifies data not collected
n.d. signifies not detectable, barium less than 0.01 μg or antimony less than 0.003 μg.
Cond is microscopic observation of swab on a scale from 1 for very slightly soiled to 7 for very heavily soiled.
a signifies sample in which barium could not be determined because of a high copper background.

TABLE 3*b*—*Analytical results for individual hand blank samples in the high-Ba/low-Sb category.*

			Barium						Antimony						
Occupation	Activity	Wash	RB	RP	RO	LB	LP	LO	RB	RP	RO	LB	LP	LO	Cond
1 SERVICE STATION ATTENDANT	WORK	.	0.890	0.483	.	0.335	0.669	.	0.031	0.038	.	0.023	0.084	.	4
2 PIZZA PARLOR MANAGER	HANDLE MONEY	N	0.246	3.47	.	0.924	6.53	.	0.005	0.010	.	0.006	0.015	.	2
3 AUTO MECHANIC	WORK	.	0.527	1.31	.	1.13	1.75	.	0.004	0.032	.	0.012	0.030	.	3
4 AUTO BODY REPAIR	WORK	N	1.38	3.83	0.709	1.50	1.23	0.986	0.023	0.063	0.009	0.017	0.020	0.026	6
5 ROAD SIGN REPAIR	SUPERVISOR	N	0.391	0.863	0.376	0.561	2.29	0.543	0.010	0.140	0.005	0.014	0.132	0.004	4
6 WELDER	WORK	N	0.905	0.257	0.228	0.168	0.579	0.253	0.039	0.020	0.010	0.020	0.029	0.019	7
7 TIRE REPAIR	WORK	N	0.882	1.02	0.577	0.654	1.26	0.756	0.024	0.023	0.012	0.018	0.022	0.015	7
8 AUTO MECHANIC	WORK	N	1.20	2.13	1.46	1.52	2.23	1.37	0.042	0.160	0.052	0.032	0.083	0.042	6
9 AUTO MECHANIC	WORK	Y	1.07	2.48	1.56	0.847	2.03	2.41	0.036	0.047	0.044	0.027	0.042	0.090	5
10 AUTO MECHANIC	MANAGER	N	0.319	0.537	0.481	0.541	0.416	0.498	0.011	0.039	0.018	0.027	0.020	0.016	4
11 LOCKSMITH	FLOOR WORK	N	0.716	1.26	0.576	0.682	1.15	0.451	0.031	0.070	0.025	0.036	0.082	0.009	3
12 BRICKLAYER/GARDINER	SHOP/DRIVE	N	0.566	0.362	.	0.316	0.795	.	0.005	0.003	.	0.004	0.008	.	4
13 PAPER KILN OPERATOR	WORK W/ BACL2	Y	13.6	2.05	0.423	0.545	0.845	0.477	0.005	0.008	n.d.	0.004	0.004	0.005	2
14 INCENERATOR OPERATOR	WORK	Y	0.343	0.710	1.01	1.01	0.513	0.223	0.011	0.042	0.026	0.037	0.022	0.007	6
15 METAL WORKER	WELD/CUT/GRIND	N	0.863	1.38	1.12	0.560	0.847	0.397	0.030	0.056	0.039	0.014	0.026	0.024	5
16 WOOD WORKER	TABLE SAW	N	0.870	0.726	0.785	0.724	1.13	0.297	0.015	0.071	0.035	0.047	0.060	0.020	4
17 .	WORK	N	0.444	0.536	0.475	0.539	0.225	0.499	0.022	0.029	0.023	0.025	0.025	0.020	6
18 HEAVY TRUCK MECHANIC	BRAKE WORK	N	1.46	13.4	3.94	1.73	42.3	1.23	0.036	0.122	0.032	0.035	0.103	0.029	5

TABLE 3*c*—*Analytical results for individual hand blank samples in the low-Ba/high-Sb category.*

			Barium						Antimony						
Occupation	Activity	Wash	RB	RP	RO	LB	LP	LO	RB	RP	RO	LB	LP	LO	Cond
1 INSTRUMENT SERVICE ENGR	WORK	N	0.151	0.106	.	0.236	0.131	.	0.077	0.054	.	0.212	0.109	.	.
2 RADIO TECHNICIAN	.	.	0.242	0.607	.	0.437	0.903	.	0.027	0.062	.	0.052	0.125	.	5
3 AUTO MECHANIC	WORK	Y	0.443	1.51	.	0.342	1.46	.	0.354	0.717	.	0.126	1.58	.	5
4 TELEPHONE CABLE MAINT	COMMUTING	N	0.056	0.114	.	0.164	0.207	.	0.247	0.019	.	0.034	0.029	.	.
5 TELEPHONE PREWIRER	WORK	Y	0.295	0.809	0.286	0.382	0.746	0.242	0.062	0.178	0.032	0.050	0.413	0.024	4
6 TELEPHONE PREWIRER	WORK	N	0.227	0.627	0.128	0.184	0.478	0.037	0.251	0.214	0.024	0.043	0.148	0.010	4
7 PLUMBER	WORK	Y	a	a	a	a	a	a	4.50	33.1	1.22	10.4	9.05	0.421	7

TABLE 3*d*—*Analytical results for individual hand blank samples in the high-Ba/high-Sb category.*

			Barium						Antimony						
Occupation	Activity	Wash	RB	RP	RO	LB	LP	LO	RB	RP	RO	LB	LP	LO	Cond
1 STEAM FITTER	WORK	N	0.638	0.698	.	0.413	0.626	.	0.089	0.275	.	0.087	0.074	.	7
2 SAND BLASTER/PAINTER	WORK	Y	0.516	1.03	2.06	1.13	2.21	0.501	0.054	0.111	0.048	0.051	0.061	0.013	7
3 TELEPHONE PREWIRER	WORK	N	0.627	1.66	0.338	0.400	1.55	0.184	0.151	0.416	0.066	0.137	0.623	0.146	4
4 ELECTRICIAN	WORK	N	0.343	0.420	0.268	0.589	0.533	0.153	0.051	0.052	0.030	0.069	0.068	0.025	4
5 CARPENTER	WORK	N	4.09	24.5	3.57	1.42	6.30	0.918	0.109	0.306	0.040	0.040	0.233	0.018	3
6 CEMENT LABORER	WORK	N	0.843	1.16	0.602	0.460	0.776	0.493	0.056	0.077	0.033	0.023	0.080	0.022	7
7 CARPENTER	SAW/HAMMER PLYWD	N	3.03	5.33	1.39	1.68	2.27	1.31	0.188	0.135	0.229	0.190	0.168	0.174	7
8 SMALL APPLIANCE REPAIR	WORK	.	0.666	0.862	0.552	0.737	2.70	0.370	0.056	0.085	0.049	0.081	0.130	0.047	7
9 MECHANIC	MUFFLER/OIL/BELT	N	1.16	0.849	1.10	1.32	1.00	1.11	0.070	0.034	0.055	0.154	0.054	0.065	7

a high-Ba/low-Sb group, and a low-Ba/high-Sb group. Subjects with one hand in the high-Ba/high-Sb group and the other in some other group were classed as high-Ba/high-Sb. Subjects with one hand in either high-low group and the other hand in the low-low group were classed in the appropriate high-low group. Individual results for each subject in the four groups are shown in Table 3. Not all sampling information is shown in Table 3 because of space limitations.

Several generalizations can be made concerning the results shown in Table 3. Most significantly, using the cutoff limits selected, 235 of the 269 hand blank subjects, or about 87%, are in the low-low hand blank group. It is important to consider how samples are collected before placing undue emphasis on the distribution of samples in this and other studies. In our experience, sample collectors tend to select as subjects either acquaintances, who generally fall in the low hand blank group, or subjects suspected of being "problem cases," such as automobile mechanics and others with high exposure to environmental sources of Ba or Sb or both. Sample contributors tend to concentrate on subjects from one or the other, but not both of these groups. The distribution of subjects between the high and low hand blank groups is highly biased by this collection procedure. Consequently, it is likely that the high hand blank group is overrepresented in this study and that the positively skewed frequency distribution of all samples is not representative of the total nonshooting population. Survey data such as these cannot be used in a statistical model based on any assumed distribution to set thresholds for distinguishing firearm discharge from environmental exposure unless it can be demonstrated that the subjects were randomly selected from the nonshooting population. Despite this limitation, we still observed that the four hand blank groups agreed reasonably well with the ranges reported in other studies. The threshold values selected to divide the groups are arbitrary, but are the levels of Ba and Sb above which many examiners begin to attach significance. The discussion which follows is based upon the divisions made in Table 3.

Low-Low Hand Blank Group

Summary statistics for the 235 low hand blank samples are given in the lower portion of Table 3*a*. As for all the hand blank samples as a group, the frequency distribution for the low hand blank group in all sampling areas is positively skewed. That is, most results are very low, with only a few results above the mean value. Changing the cutoff values from 0.5 and 0.05 to 0.2 and 0.02 for Ba and Sb, respectively, only decreases the number of samples in the low group from 235 to 190. The frequency distribution of the 190 samples remains positively skewed, however. The Ba and Sb differences among individual samples in this group are not significant because of their proximity to the analytical detection limits and the variability normally observed in repeated sampling of the same person [7].

High Hand Blank Groups

Along with the analytical results shown in Tables 3*b* through 3*d* for the three high hand blank groups, we have also listed the test subject's occupation, whether the person was actively engaged in that occupation, whether the subject washed his or her hands in the two hours prior to sampling, and the appearance of the swabs recorded during microscopic examination. Other factors such as handedness and hand size are not included in Table 3 because of space limitations. Their roles will be discussed separately.

Several observations can be made about the high hand blank samples as a group. First, the occupations represented in the high hand blank groups are those in which a practitioner's hands get dirty, such as mechanics, or they represent unusual exposure to Ba or Sb, such as the use of barium chloride ($BaCl_2$) by a paper mill worker. Second, the

condition of the swabs in these groups was, in general, very dirty and well used. Third, the geographic location is misrepresented because collectors in a few areas collected suspected "worst-case" samples, while others only collected samples from readily available colleagues. As examples of this we offer the observations that 11 of the 34 samples in the three high-level categories were submitted by a single hand blank collector, and the 9 high-high samples by only 4 collectors. Observation of the data shown in the high-level groups does indicate, however, that some activities are more likely than others to contaminate the hands of nonshooters with high levels of Ba or Sb or both.

Only the samples in the high-high category are of concern to the GSR examiner as potentially being misinterpreted as positive indications of the presence of GSR. Of primary significance is the fact that only 9 of the 269 subjects in this study fall into the high-high category. Blind adherence to the selected threshold levels would incorrectly classify these 9 subjects as positive for the presence of GSR. Further consideration of these samples in light of several criteria based upon test-firing and other interpretational experience is warranted. Data from hundreds of test-firings using ammunition containing both Ba and Sb indicate that the mass ratio of Ba to Sb on swabs containing GSR is almost always in the range of 1 to 10.[3] Of the 9 subjects in Table 3*d*, Subject 2 (left hand), Subject 7 (right hand), and Subjects 5, 6, and 9 have Ba/Sb ratios greater than 10 in most or all sampling areas. A constraint to fixed application of this ratio rule is that the test-firing data were obtained using a shooter with clean hands. In case situations, environmental levels of Ba and Sb present prior to shooting can affect the postdeposition ratios. In general, Ba is more prevalent than Sb in the environment, so Ba/Sb ratios greater than 10 are possible in actual shooting situations.

A second consideration used in differentiating between environmental and firearm-discharge-derived Ba and Sb is the observation from test-firing studies that shooters normally exhibit higher levels of Ba and Sb on the backs of their hands than on the palms [*11*].[3] Of the nine subjects in Table 3*d*, only Subjects 4 (left hand) and 9 had higher levels of both Ba and Sb on the backs than on the palms of their hands. A constraint to the palm/back rule is that test-firing results are generally obtained immediately after firing, with little or no additional handling of the firearm or ammunition. It is well documented that with the handling of a used firearm, the passage of time, and the resumption of normal activities following a shooting, GSR deposits from the back of the hand are frequently redistributed to other areas, including the palms. It is not unusual to find higher levels on the palms than the backs of the hands of known shooters in actual case situations. A third criterion developed from observation of swab kits and their usage is that swabs which appear to be very dirty during microscopic examination often contain greater levels of Ba and Sb than less well-used or otherwise cleaner swabs. As shown in the last column of Table 3*d*, of the nine samples, only Nos. 3, 4, and 5 are less than very heavily soiled. All of these factors must be considered in combination with other case-related factors, such as the time between the shooting and sample collection, the type of firearm, and the activity of the subject, before forming an opinion concerning the presence of GSR based upon high levels of Ba and Sb.

Effects of Other Variations

The data in this study were collected to consider the effects of several variables on the levels of Ba and Sb on hand blanks. However, the interdependency of the sex, geographic location, hand size, and hand washing with the occupation and activity makes it difficult to discern the separate effects of these variables. Nevertheless, the effects of each variable

[3]FBI Laboratory unpublished data, Washington, DC, 1989.

were considered independently using distribution-free approaches. These results and the effects of other variables are discussed in the following sections.

Sex—The levels of Ba and Sb are significantly lower for females than for males when considering either the low hand blank group or the entire hand blank group. For example, the median Ba and Sb levels on the backs of all female hands were 0.042 and 0.001 μg, respectively, and the corresponding male levels were 0.068 and 0.005 μg. This probably reflects differences in occupation and activity between the women in the study, who were predominantly housewives, students, and secretaries, and the men, who had a greater representation of high-exposure occupations and activities, such as machinists, mechanics, and heavy-equipment operators.

Washing—Subjects who reported washing their hands in the two hours prior to sampling had lower levels of Ba and Sb on the backs (medians: Ba, 0.041; Sb, 0.002 μg) than subjects who had not washed their hands (medians: Ba, 0.081; Sb, 0.005 μg). It has been reported [7] and is generally accepted that washing of hands removes some portion of the Ba and Sb contained thereon. We expect this generalization to apply to environmental exposure as well as to GSR-derived Ba and Sb. Some of the highest Ba and Sb levels were found on subjects who reported washing their hands. Clearly, the amount of Ba and Sb remaining after washing hands depends upon how the washing is done. The measured levels are also affected by the activity between the time of washing and the time the hand sample was obtained. It is interesting to note that many of the subjects who reported washing their hands within the two hours prior to sampling produced very dirty swabs.

Hand Size—The levels of Ba and Sb on the back of the hands increase as the hand size increases from small to medium to large. The differences are significant for Ba (medians: small, 0.042; medium, 0.054; and large, 0.064 μg), but within the analytical uncertainty for Sb (medians: small, 0.002; medium, 0.003; large, 0.005 μg). This may be a true effect of hand size but is also a reflection, at least in part, of the greater proportion of females and their lower exposure environments in the small-hand group. In some instances, very high values were observed for small or medium hands which were particularly dirty.

Back, Palm, and Optional Area Distributions—For the samples in this study, the palms had significantly higher values than the backs for both Ba (medians: back, 0.055 μg; palm, 0.085 μg) and Sb (medians: back, 0.003 μg; palm, 0.006 μg). Optional hand blank areas have about the same amounts of Ba and Sb as the backs of hands. However, there are not enough optional area samples to date to make a definitive statement as to their potential usefulness.

Element Ratios—As discussed previously, the ratio of Ba to Sb on the back of the hand area of a shooter is normally in the range of 1 to 10 for samples taken immediately after firing. Of the hand blank samples in this study, 28% of the back of the hand areas have Ba/Sb ratios between 1 and 10. The other samples cover the entire range from no detectable Ba to no detectable Sb.

Handedness—There are no significant relationships among the levels of elements found on the right and left hands of the subjects in this study and their stated hand preference. The median differences between the backs of the left and right hands is zero for Ba and Sb for both right- and left-handed subjects.

Geographic Distribution—Effects of the location from which the samples were collected cannot be discerned in this study because of the differences in persons selected for sampling by the various collectors. Apparent higher results in some geographic locations, in comparison with others, occurred because of conscious efforts by collectors to sample either "high-risk" or "average" activity persons but generally not both.

Activity—A wide range of activities are represented in these hand blank data. While generalizations concerning activity are difficult to make, there is some indication that activities such as working as an auto mechanic, electrician, or construction worker have a tendency to result in higher levels of Ba and Sb on the hands. It is significant to note, however, that most activities in the high hand blank groups also occur in the low-low group. Thus, automobile maintenance work, for example, does not guarantee the presence of high levels of Ba or Sb on a person's hands.

Summary

Samples are collected from the hands of suspected shooters and submitted to the forensic science laboratory to determine if sufficient evidence is present in the samples to place the suspect in the environment of gunshot primer residue. A major concern of the GSR examiner involves his or her ability to distinguish between evidence of gunshot primer residue and an environmental false positive. Statistical modeling of average hand blank values to find threshold numbers to use for all cases is neither wise nor statistically valid because hand blank subjects are not randomly drawn from and representative of the nonshooting population. Instead of using any statistical model, we suggest a common-sense approach based upon experience gained in evaluating hand blank and test-firing swabs. Multiple factors must be considered during the process of forming a critical opinion regarding the most likely source of high levels of barium and antimony on samples from a suspect's hands. The most important of these factors are case information, microscopic examination data, quantitative analysis data, hand blank data, and firearm test-firing data.

Acknowledgments

We gratefully acknowledge the participants of the 1982 and 1984 GSR seminars at the FBI Academy for their helpful input during the planning stages of this project; John W. Kilty for his encouragement and helpful suggestions during the implementation stages of this project; the volunteer participants who collected the hand blank samples; the technical staff of the FBI Laboratory, who assisted in kit preparation, documentation, and analysis; and E. Roger Peele, Robert C. Halberstam, John P. Riley, and Dean D. Fetterolf for offering critical comments on the manuscript.

References

[1] Schlesinger, H. L., Lukens, H. R., Guinn, V. P., Hackleman, R. P., and Korts, R. F., "Special Report on Gunshot Residues Measured by Neutron Activation Analysis," U.S. Atomic Energy Commission Report GA 9829, National Technical Information Service, U.S. Department of Commerce, Springfield, VA, 1970.

[2] Albu-Yaron, A. and Amiel, S., "Instrumental Neutron Activation Analysis of Gunpowder Residues," *Journal of Radioanalytical Chemistry*, Vol. 11, 1972, pp. 123–132.

[3] Midkiff, C. R., "Barium and Antimony for the Detection of Firearms Discharge Residue: Expected Handblank Levels," *Identification News*, Vol. 23, May 1973, pp. 9–10.

[4] Cowan, M. E., Purdon, P. L., Hoffman, C. M., Brunelle, R., Gerber, S. R., and Pro, M., "Barium and Antimony Levels on Hands: Significance as Indicators of Gunfire Residue," *Journal of Radioanalytical Chemistry*, Vol. 15, No. 1, 1973, pp. 203–218.

[5] Krishnan, S. S., "Detection of Gunshot Residue on the Hands by Neutron Activation and Atomic Absorption Analysis," *Journal of Forensic Sciences*, Vol. 19, No. 4, Oct. 1974, pp. 789–797.

[6] Cornelis, R. and Timperman, J., "Gunfiring Detection Method Based on Sb, Ba, Pb, and Hg Deposits on Hands: Evaluation of the Credibility of the Test," *Medicine, Science, and the Law*, Vol. 14, No. 2, April 1974, pp. 98–116.

[7] Kilty, J. W., "Activity After Shooting and Its Effect on the Retention of Primer Residue," *Journal of Forensic Sciences*, Vol. 20, No. 2, April 1975, pp. 219–230.

[8] Jones, P. F. and Nesbitt, R. S., "A Photoluminescence Technique for the Detection of Gunshot Residues," *Journal of Forensic Sciences,* Vol. 20, No. 2, April 1975, pp. 231–242.

[9] Nesbitt, R. S., Wessel, J. E., Wolten, G. M., and Jones, P. F., "Evaluation of a Photoluminescence Technique for the Detection of Gunshot Residue," *Journal of Forensic Sciences,* Vol. 22, No. 2, April 1977, pp. 288–303.

[10] Rudzitis, E., "Analysis of the Results of Gunshot Residue Detection in Case Work," *Journal of Forensic Sciences,* Vol. 25, No. 4, Oct. 1980, pp. 839–846.

[11] Newton, J. T., "Rapid Determination of Antimony, Barium, and Lead in Gunshot Residue via Automated Atomic Absorption Spectrophotometry," *Journal of Forensic Sciences,* Vol. 26, No. 2, April 1981, pp. 302–312.

[12] Koons, R. D., Havekost, D. G., and Peters, C. A., "Analysis of Gunshot Primer Residue Collection Swabs Using Flameless Atomic Absorption Spectrophotometry: A Reexamination of Extraction and Instrument Procedures," *Journal of Forensic Sciences,* Vol. 32, No. 4, July 1987, pp. 846–865.

[13] Kilty, J. W., "A Review of the FBI Laboratory's Gunshot Primer Residue Program," *Crime Laboratory Digest,* Vol. 13, No. 2, April 1986, pp. 54–61.

Address requests for reprints or additional information to
Robert D. Koons
Forensic Science Research Unit
FBI Laboratory
FBI Academy
Quantico, VA 22135