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Survey of Gunshot Residue Analysis in Forensic Science Laboratories

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ABSTRACT: The purpose of this survey was to determine the methods of analysis being used on gunshot residue (GSR) samples in forensic science laboratories across the United States. In addition, the two general techniques of GSR analysis are compared and contrasted. Problems encountered by analysts using scanning electron microscopy/energy-dispersive X-ray analysis (SEM/EDX) are discussed.

KEYWORDS: forensic science, criminalistics, gunshot residue, survey, gunshot residue analysis, forensic science laboratories, bulk elemental analysis, scanning electron microscopy/energy dispersive X-ray analysis

There are two general types of methods currently used for analysis of gunshot residue (GSR) from the hands of a shooter. One type may be termed "bulk elemental analysis techniques" and includes flameless atomic absorption (FAA) [*1*], neutron activation analysis (NAA) [*2*], Inductively coupled plasma/atomic emission spectrometry (ICP-AES) [*1*], and anodic stripping voltammetry (ASV) [*3*]. The other common type of GSR analysis is by scanning electron microscopy with energy-dispersive X-ray (SEM/EDX) analysis [*4*].

Gunshot residue is encountered frequently as evidence in homicide and suicide cases. However, not all forensic science laboratories choose to analyze this evidence. Those that do have a variety of analytical methods to choose from. To determine who is analyzing GSR and by what means, a nationwide survey of forensic science laboratories was undertaken.

The purpose of this survey was threefold:

1. to determine the methods of analysis being used nationwide on gunshot residue samples in forensic science laboratories,
2. to compare and contrast the two general types of methods being used to analyze GSR, and
3. to document the procedures and types of equipment being used in GSR analysis by SEM/EDX in the interest of identifying and resolving common problems for the investigators using these techniques.

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Description of the Survey Instrument

A mail survey was conducted on 200 forensic science laboratories distributed to all 50 states in the United States in November of 1988. The response rate to the first mailing of the survey was 51.0%. A second mailing of the survey in December of 1988 brought the response rate up to 71.5%. A copy of the survey instrument appears in the Appendix.

Results and Discussion

Table 1 gives the percentage of laboratories analyzing gunshot residue and the method used for GSR analysis. A total of 57% of the laboratories responding do not analyze GSR themselves; 52% of those laboratories send GSR samples to either the Federal Bureau of Investigation (FBI) or a state/regional laboratory for analysis. Of the laboratories analyzing GSR, 57% use a bulk elemental analysis technique and 34% employ SEM/EDX alone or combined with FAA. It is of interest to note that while X-ray fluorescence and photoluminescence have been used in the past to analyze GSR, no laboratories indicated the use of those techniques in this survey.

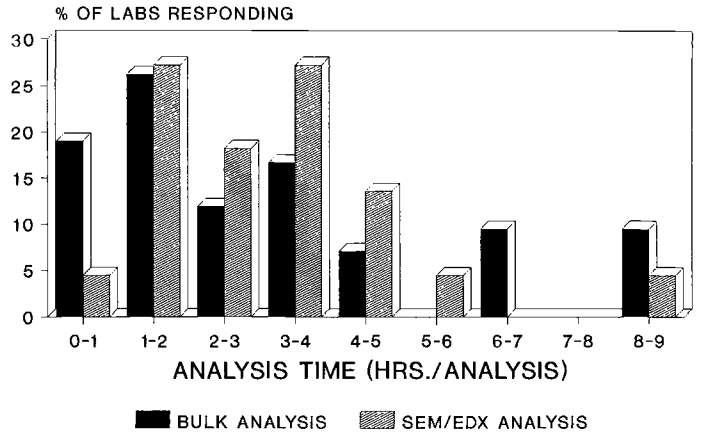
The results of the survey indicate that 31 states have at least one laboratory conducting GSR by one of the methods listed above. Fourteen states had no laboratories conducting GSR analysis by the above methods. In five states, no laboratories responded.

Some interesting results are obtained when GSR analysis techniques are compared. One of the main contentions for using bulk elemental analysis techniques over SEM/EDX in the past has been the shorter analysis times of the former technique. The survey data indicate, however, that on the average, the amount of time spent per analysis using either technique is about the same. In fact, the mean time required to analyze a sample, as well as the mean time spent on GSR analysis per week, was fairly similar for both bulk analysis and SEM/EDX techniques—respectively, 3.0 h per analysis versus 3.1 h per analysis, and 13.3 h per week versus 15.9 h per week (Figs. 1 and 2).

The term "time required per analysis" is open to interpretation however. It should be noted here that a single "analysis" using the bulk analysis techniques may involve several

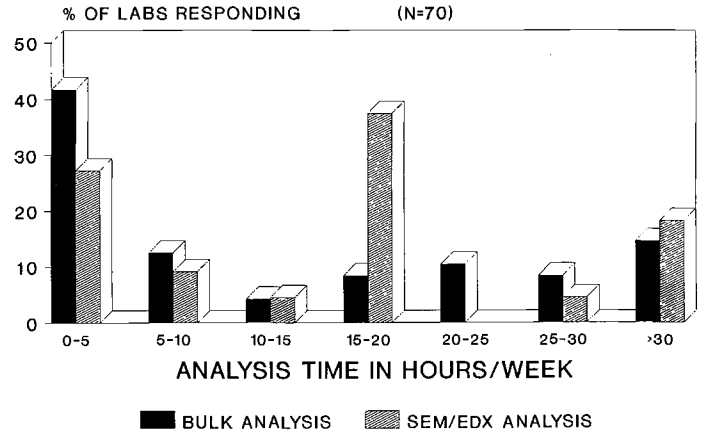
TABLE 1—*Percentage of forensic science laboratories analyzing gunshot residue and the method used for analysis.*

Where Analyzed and Method Used	Laboratories Responding, %	*N*
Where Analyzed		
GSR analyzed in lab	43	144
Sent to FBI	15.3	
Sent to state regional lab	14.6	
Not done	27.1	
Method of GSR analysis		
Flameless atomic absorption (FAA)	48.4	62
Scanning electron microscopy with energy-dispersive X-ray (SEM/EDX) analysis alone	21.0	
SEM/EDX combined with FAA	12.9	
Neutron activation analysis (NAA)	1.6	
Anodic stripping voltammetry (ASV)	4.8	
Microchemical tests	11.2	



BULK ANALYSIS (N=42) MEAN=3.02 S.D.=2.29
SEM/EDX (N=22) MEAN=3.09 S.D.=1.72

FIG. 1—*Time required per analysis for laboratories analyzing gunshot residue.*



BULK ANALYSIS- MEAN=13.3 S.D.=11.6
SEM/EDX ANALYSIS- MEAN=15.9 S.D.=10.6

FIG. 2—*Analysis time in hours per week for laboratories conducting GSR analysis.*

samples, since typically the palm and back of both hands are sampled, and a control sample is collected as well. In contrast, a single analysis using SEM/EDX may involve only the time taken to analyze a single stub (one hand) collected from a suspect. In any case, the time devoted to GSR analysis per week is similar for laboratories whether using bulk analysis or the SEM/EDX technique (Fig. 2).

Survey participants were asked to respond to the questions of how frequently and on what grounds GSR analysis was challenged in court. The response rate for these particular questions was relatively low, but still bears examination. Table 2 shows how frequently GSR analysis is challenged in court, and Table 3 lists the grounds for challenge. Bulk analysis techniques are challenged slightly more often, mainly on the grounds of speci-

TABLE 2—*Frequency of challenge to GSR analysis in court, in number of laboratories reporting.*

Method of Analysis	Frequency of Challenge				
	0%	Rarely (1–10%)	10–30%	>50%	*N*
Bulk analysis[a]	10	12	5	2	29
SEM/EDX alone	3	5	1		9
SEM/EDX with FAA	2	4			6

[a]Includes FAA, NAA, ICP-AES, and ASV.

TABLE 3—*Grounds for challenge in court, in number of laboratories responding.*

Basis for Challenge	Method of Analysis		
	Bulk Analysis	SEM/EDX Alone	SEM/EDX and FAA Combined
Not specific for GSR	10	1	1 (FAA)
Did defendant fire a gun?	4		
Interpretation of threshold level	4		
Interpretation in general		4	3
Evidence consumed	2		
Operator proficiency		1	
EDX sensitivity		1	
Collection technique		1	

ficity. This may be a significant concern with respect to the potential for false positives. SEM/EDX analysis, when challenged, is usually challenged on the examiner's interpretation of the data. Since there are well-defined, accepted, characteristic criteria for defining gunshot residue by this technique, it is less likely to lead to false positives with regard to whether material found on the hand is gunshot residue or not.

Currently, 54% of the laboratories with SEM/EDX capability use their instruments for GSR analysis. Table 4 lists the type of SEM equipment being used by forensic science labs and its age and dependability. The scanning electron microscopes used most frequently throughout the country are listed in Table 4. Tracor Northern was the most frequently used EDX system (35%), with Edax following with 27%, Princeton Gamma Tech with 24%, and Kevex with 15%, (n = 34). The mean age of SEMs being used was 6.57 years, with a standard deviation of 4.77 years and a range of 1 to 20 years, (n = 36). As an estimate of instrument dependability, the mean number of weeks the SEM/EDX system was "down" in 1988 was 2.81 weeks, with a standard deviation of 6.81 weeks and a range of 0 to 40 weeks (n = 30). As far as the type of collection technique being used most frequently by laboratories analyzing GSR by SEM/EDX, a tape lift technique was used by 48% of the laboratories responding; followed by a concentration technique (16%), a glue lift (12%), swabs for FAA and SEM/EDX, (12%), vacuum suction (4%), and other techniques (8%), (n = 25).

A potential problem in using SEM/EDX for GSR analysis is the variation between laboratories in determining the minimum number of particles analyzed to confirm gunshot

TABLE 4—*Laboratory SEM equipment, age, and dependability*

	Laboratories Responding, %	Mean	Standard Deviation	N
Make of SEM used				
ISI	28.6			35
Amray	22.9			
Cambridge	14.3			
Hitachi	11.4			
Camscan	8.6			
Etec	5.7			
JEOL	5.7			
Bausch and Lomb	2.9			
Make of X-ray analyzer				
Tracor Northern	35.3			34
Edax	26.5			
Princeton Gamma Tech	23.5			
Kevex	14.7			
Age of SEM, years				
1–5	55.6	6.57	4.77	36
6–10	30.6		(5.0 = median)	
11–15	8.3			
16–20	5.6			
Time SEM/EDX was down, weeks				
0 to 1	26.7	2.8	6.8	30
1 to 2	26.7		(1.5 = median)	
2 to 3	24.3			
3 to 4	13.3			
4 to 5	6.7			
40	3.3			

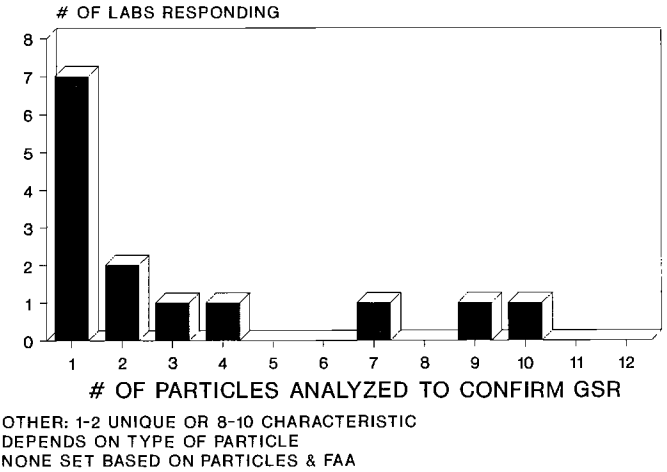


FIG. 3—*Variations in the minimum number of particles analyzed by SEM/EDX to confirm GSR.*

residue (Fig. 3). A total of 41% of the laboratories responding reported that finding one particle which meets the shape and elemental characteristics of GSR is enough to confirm GSR on the hand (n = 17). However, the range of responses to this question ran from 1 to 10 particles. Some responses gave options such as, "1 to 2 unique" or "8 to 10 characteristic particles," "depends on the type of particle," or "none set, based on particles and FAA."

Since a single particle can be identified as GSR by the SEM/EDX technique, by definition GSR has been confirmed on the hand. Of course, experts differ in opinion on the interpretation and significance of finding a single GSR particle on the hand.

Other problems cited by laboratories using GSR analysis by SEM/EDX were the following:

1. *Glue lift efficiency drops with wet, bloody, or dirty hands.* A possible solution to this problem would be to use a stickier medium such as 3M adhesive transfer tape, although dirty hands will remain a potential problem.

2. *Nucleopore filters tend to clog in the concentration technique.* This observation is in agreement with the findings of Zeichner et al. [5]. Their recommendation was to eliminate the concentration step and observe the glue or tape lift directly. Dennis Ward at the FBI Laboratory in Washington, DC and Loren Sugarman at the Orange County Sheriff–Coroner Department, Santa Ana, California, suggest that the centrifugal force used in concentration can be critical. Too high of a gravity force may pellet cause debris to pellet on the filter.[2]

3. *Lengthy analysis times and the analysis itself can be fatiguing to the operator, especially on negative samples. An observation was also made that it is difficult to find a method conducive to both SEM/EDX and FAA.* A possible solution to this problem, which is currently being used in some laboratories, is to collect samples for SEM/EDX from the web area of the hand and possibly the face. In addition, swabs from the back and palm of the hands are collected. FAA is then used as a screening technique and only potential positive samples are analyzed by SEM/EDX. Dr. Robin Keeley from the Metropolitan Police Forensic Science Laboratory (Scotland Yard) points out, however, that FAA is a relatively insensitive technique with respect to GSR. One may actually have over 100 particles of GSR (assuming an average particle size of 3 μm) and still fall below the threshold level for lead, barium, and antimony to be detected by FAA.[3]

4. *GSR is collected too long after the incident occurs.* This is an inherent problem. Stressing the need for collecting samples as soon as possible would be helpful.

5. *Cigarette lighter flint particles mimic GSR in morphology and increase analysis time.* This is an interesting observation for which there is no proposed solution at this time.

Conclusions

Data on gunshot residue analysis were obtained from a mail survey of 200 forensic science laboratories in the United States, with a response rate of 71.5%. Over half of the laboratories responding do not analyze GSR themselves: 52% of those laboratories send GSR samples either to the FBI or to a regional laboratory for analysis. Of the laboratories analyzing GSR, 57% use a bulk elemental analysis technique and 34% employ SEM/EDX alone or combined with FAA. It is of interest that the mean time required to analyze a sample, as well as the mean time spent on GSR analysis per week, was fairly similar for both bulk analysis and SEM/EDX techniques. Currently, about half

[2]Personal communication, 1988.
[3]Personal communication, 1989.

of the laboratories with an SEM/EDX use it for GSR analysis. Bulk analysis techniques are challenged slightly more often in court, mainly on the grounds of specificity. This may be a significant concern because of the potential for reporting false positives. A number of problems and potential solutions encountered by investigators using the SEM/EDX technique for GSR analysis were discussed. With the commercial availability of automated gunshot residue programs for SEM/EDX equipment, a shift toward this type of analysis may appear in the future. An additional survey to address this new capability might be useful.

Acknowledgments

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APPENDIX

1988 GUNSHOT RESIDUE ANALYSIS SURVEY

1. Please circle the type/types of analysis currently being used in your laboratory on gunshot residue (GSR) samples. A) NAA B) FAAS C) SEM-EDX D) Other (Please describe)

_____

2. Approximately how much time per week is devoted to GSR analysis? _____

3. Approximately how much time is required per analysis?

_____

4. How frequently is your current method for analysis of GSR challenged in court and on what grounds? _____

_____

_____

_____

_____

_____

The following questions need only be answered by laboratories equipped with an SEM.

5. Please indicate the make and model of your SEM._____

_____

6. If your microscope is equipped with X-ray analysis capability, please indicate make and model. _____

7. If possible, please indicate how old the above instrument is._____

8. In the past year please estimate the number of weeks the SEM-EDX was "down" due to mechanical or electrical failure _____

_____

9. If examining GSR by SEM-EDX, please indicate the sample collection and processing technique used most frequently.

_____ A) The Vistanex adhesive lift, followed by sample concentration.

_____ B) A tape lift method.

_____ C) A glue lift method.

_____ D) Other (Please explain) _____

_____

_____

10. Please indicate the minimum number of particles analyzed to confirm gunshot residue in your lab. _____

11. For GSR samples being analyzed by SEM-EDX:

A) Approximately how much time per week is devoted to this type of analysis _____?

B) Approximately how much time is required for a positive (evidence of GSR) analysis _____?

12. Please describe any recurring problems and/or solutions you have found in either collection or analysis of GSR by the SEM-EDX technique. _____

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References

[1] Koons, R. D., Havekost, D. G., and Peters, C. A., "Analysis of Gunshot Primer Residue Collection Swabs Using Flameless Atomic Absorption Spectrophotometry and Inductively Coupled Plasma-Atomic Emission Spectrometry: Effects of a Modified Extraction Procedure and Storage of Standards," *Journal of Forensic Sciences*, Vol. 34, No. 1, Jan. 1989, pp. 218–221.

[2] Hoffman, C. N., "Neutron Activation Analysis for the Detection of Firearm Discharge Residue Collected on Cotton Swabs," *Journal of the Association of Official Analytical Chemists*, Vol. 56, 1975, p. 1388.

[3] Brihaye, C., Machiroux, R., and Gillain, G., "Gunpowder Residues Detection by Anodic Stripping Voltammetry," *Forensic Science International*, Vol. 20, 1982, pp. 269–276.

[4] Wolten, G. M., Nesbitt, R. S., Calloway, A. R., Loper, G. L., and Jones, P. F., "Final Report on Particle Analysis for Gunshot Residue Detection," Report ATR-77(7915)-3, Aerospace Corp., El Segundo, CA, Sept. 1977.

[5] Zeichner, A., Foner, H. A., Dvorachek, M., Bergman, P., and Levin N., "Concentration Techniques for the Detection of Gunshot Residues by Scanning Electron Microscopy/Energy Dispersive X-ray Analysis (SEM/EDX)," *Journal of Forensic Sciences*, Vol. 34, No. 2, March 1989, pp. 312–320.

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