Arie Zeichner,[1] *Ph.D.; Nadav Levin,*[1] *MSc; and Michael Dvorachek*[2]

Gunshot Residue Particles Formed by Using Ammunitions That Have Mercury Fulminate Based Primers

REFERENCE: Zeichner, A., Levin, N., and Dvorachek, M., "**Gunshot Residue Particles Formed by Using Ammunitions That Have Mercury Fulminate Based Primers,**" *Journal of Forensic Sciences*, JFSCA, Vol. 37, No. 6, November 1992, pp. 1567–1573.

ABSTRACT: Ammunition having mercury fulminate-based primers are commonly manufactured by Eastern Bloc countries and used extensively in the Middle East. Gunshot residue (GSR) particles formed by firing these types of ammunition were examined. It was observed that much lower percentage of mercury-containing GSR particles were found in samples taken from a shooter as compared to the percentage of such particles in samples from cartridge cases. This fact must therefore be taken into account when interpreting case results. A plausible explanation for the results described is proposed.

KEYWORDS: forensic science, gunshot residue particles, mercury fulminate based primers, ballistics

The detection and identification of gunshot residue (GSR) particles by scanning electron microscopy/energy-dispersive X-ray (SEM/EDX) analysis is now a well-established technique and is applied in many forensic-science laboratories. The mechanism of formation and the criteria for identification of such particles have been described [*1–7*]. It has been reported that it is possible to find discharge particles on a suspect that differ in composition from particles in the cartridge cases found at the scene of the crime. This can result from firing different types of ammunition in the same weapon [*8*].

The purpose of this work is to report on the observation that when firing different types of ammunition having primers containing mercuric fulminate, a much lower percentage of mercury-containing GSR particles was found in samples taken from a shooter as compared to the percentage of such particles in samples from cartridge cases. This effect was first observed in a case of homicide that prompted us to carry out simulated test shots and other experiments to aid interpretation of the results.

The Case

At the scene of a homicide, several 7.62 by 39 mm Russian and Egyptian cartridge cases of the type fired by an AK-47 assault rifle were found. Although this type of

Received for publication 8 February 1992; revised manuscript received 23 April 1992; accepted for publication 27 April 1992.

[1]Head and Scientific Officer, respectively, Toolmarks and Materials Laboratory, Division of Identification and Forensic Science, Israel Police Headquarters, Jerusalem, Israel.

[2]Researcher, Geological Survey of Israel, Jerusalem, Israel.

ammunition may be fired by other weapons, such as the Ruger Mini-14 and the SKS carbines and the RPD machine gun, these weapons were eliminated by the Weapons Identification Laboratory using class-characteristics marks found on the cartridge cases. Several hours after the incident, the suspect was apprehended in his home while showering. In the courtyard, several items of clothes were burning in a fire. The police extinguished the fire with water and the wet remains of the clothes were brought to the laboratory.

Case Examination—Experimental Procedure

After drying, the clothes were sampled for particles using 3M double sided adhesive-coated aluminum stubs. SEM/EDX analyses for GSR particles were carried out by manual search using a CamScan III SEM combined with a Tracor-Northern TN 5500 EDX system.[3]

GSR particles from the cartridge cases found at the homicide scene were sampled using wood sticks and then transferred to aluminum double-sided, adhesive-coated stubs.

The composition of GSR particles from Russian and Egyptian 7.62 mm ammunition was found to be similar and consisted of tin (Sn), antimony (Sb), mercury (Hg), sulfur (S), potassium (K), chlorine (Cl), and copper (Cu) accompanied by small amounts of aluminum (Al), silicon (Si), iron (Fe), and zinc (Zn) (Fig. 1).

The origin of tin in these GSR particles is not from the primer mixture, which consists mainly of mercury fulminate, potassium chlorate and antimony sulfide [*9,10*], but from a varnished lead-tin foil disc that closes off the priming cup from the inside of the cartridge case [*10*]. To confirm this, we dismantled the primer from Russian 7.62 mm ammunition and found that the foil disc was made of tin and the primer composition consisted of the elements: Hg, Sb, K, Cl and S. The tin foil was found also to be present in the mechanism of hand grenades [*11*].

Five GSR particles were found only in the sample taken from the partially burnt jeans. All five particles were without detectable levels of mercury (Fig. 2), while a large percentage of the GSR particles from the cartridge cases contained mercury. It seemed therefore, that significantly less GSR particles containing mercury may be found in the samples taken from a shooter as compared to the amount found in cartridge cases.

Experiments with Various Types of Ammunition Having Primers Containing Mercury Fulminate

Shooting experiments were carried out with Egyptian and Russian 7.62 mm ammunition (Fig. 3*a,b*) (the same types of ammunition as were found at the scene of the crime) using an AK-47 assault rifle, as well as with Italian and Egyptian 9 mm Parabellum ammunition (Fig. 3*c,d*) using a 9 mm FN semiautomatic pistol. The Egyptian 9 mm and 7.62 mm ammunition used had similar compositions. The composition of the Italian 9 mm ammunition was different in the respect that it did not include tin (Fig. 4).

First, the rifle was thoroughly cleaned and a person with uncontaminated hands fired six rounds of the Egyptian ammunition. Before shooting, a hole was made in a plastic bag that was put on the rifle so that the bag covered the hands of the shooter and the discharge region of gases, but the muzzle was outside the bag. After shooting, the shooter rubbed his hands against the inside of the bag and his hands were sampled by a double-sided, adhesive-coated aluminum stub. The plastic bag was used to increase the number of GSR particles found (in order to improve statistics regarding composition), because

[3]The case occurred in 1986, before the laboratory purchased a CamScan IV SEM equipped with an automated search system. See the subsequent discussion.

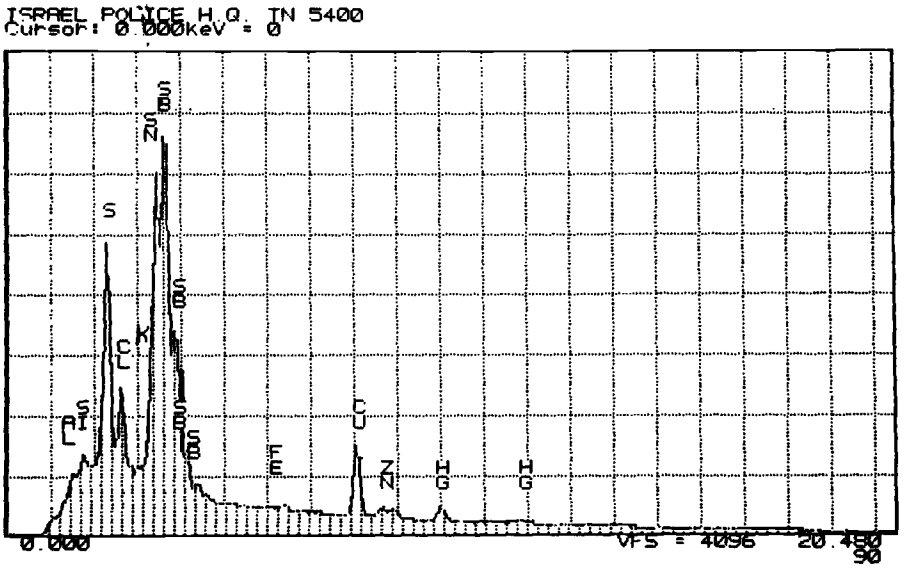

FIG. 1—*EDX spectrum of many GSR particles from Russian 7.62 mm ammunition.*

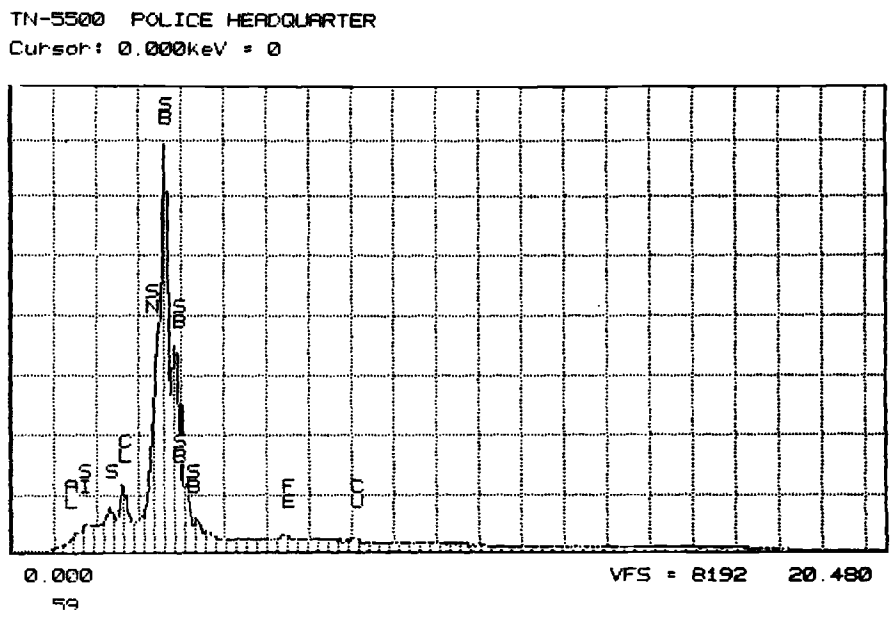

FIG. 2—*EDX spectrum of a typical GSR particle found in the sample from the partially burnt jeans.*

relatively fewer GSR particles are found on a shooter using a rifle as compared to one using a handgun [*1*]. Similar tests were also conducted using the Russian 7.62 mm ammunition.

The shooting experiments with the 9 mm handgun, were carried out in a similar way as with the assault rifle except that three rounds instead of six rounds were fired for each

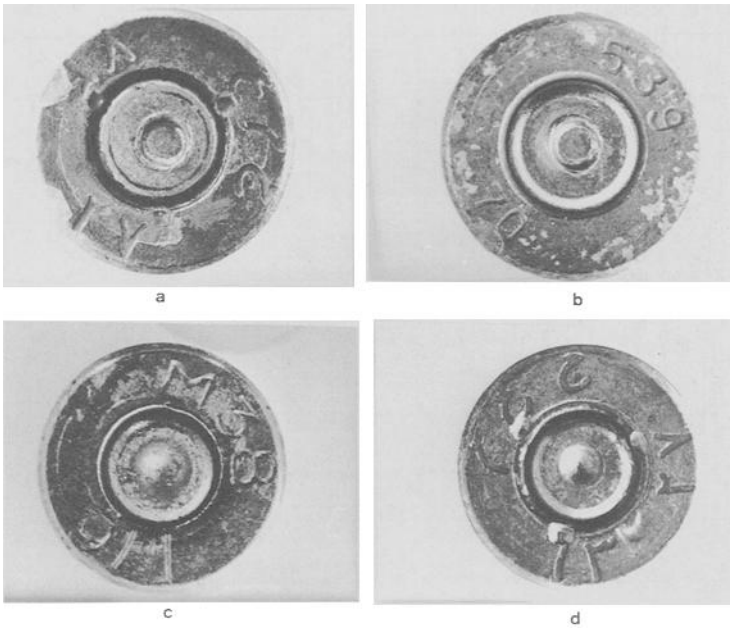

FIG. 3—*Head stamps of the ammunition used in the shooting experiments:*
(a) *Egyptian 7.62 mm ammunition;* (b) *Russian 7.62 mm ammunition;* (c) *Italian 9 mm ammunition;*
(d) *Egyptian 9 mm ammunition.*

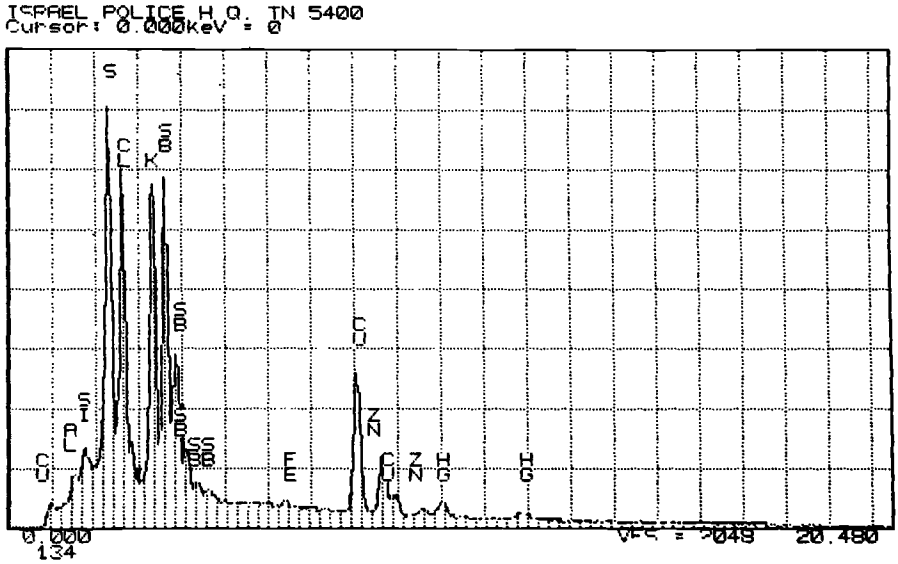

FIG. 4—*EDX spectrum of many GSR particles from Italian 9 mm ammunition.*

ammunition type and no plastic bags were used. SEM/EDX analysis for GSR particles in samples from the hands was carried out using an automated search system attached to a CamScan IV SEM with a motorized stage drive and a four-sample holder combined with a Tracor Northern TN 5500 EDX system [*12–14*]. GSR from the cartridge cases were sampled as described above and were analyzed manually.

It was reported that elemental mercury is formed in the reaction of the decomposition of mercury fulminate [*15*] according to the equation:

$$Hg(CNO)_2 \rightarrow 2CO + N_2 + Hg \quad (1)$$

Oxidation of mercury fulminate was also proposed [*9*] according to the equations:

$$2KClO_3 \rightarrow 2KCl + 3O_2 \quad (2)$$

$$Hg(CNO)_2 + O_2 \rightarrow Hg + N_2 + 2CO_2. \quad (3)$$

To examine the possibility that evaporation of elemental mercury is the reason for finding much less mercury in GSR particles found on the shooter as compared to those in the cartridge cases, 7.62 mm cartridge cases after first sampling were heated in the oven at 360°C for half an hour (boiling point of mercury is 357°C) and then sampled again (second sampling).

The possibility of the evaporation of mercury from particles being on the stub in the SEM (6×10^{-6} mbar vacuum) was also tested with the 9 mm Egyptian ammunition. For this purpose, GSR particles from cartridge cases were sampled on the aluminum stubs coated with carbon conductive double sided adhesive tape (Structure Probe, Inc., West Chester, PA). Use of this tape eliminated the need to coat the stub with carbon and thus the possibility of mercury evaporation from uncoated particles could be examined. The same area (2 by 1.4 mm) on the stub with many GSR particles was examined for composition immediately after the introduction of the stub into the SEM and then again 16 hours later (without the electron beam on). The same area was then kept for one hour under electron bombardment (absorbed current 1nA) and then examined for composition.

Results and Discussion

The results of the experiments are summarized in Table 1. It can be seen that in all cases a much lower percentage of mercury-containing GSR particles was found in samples taken from a shooter as compared to the percentage of such particles in samples from cartridge cases. It can also be seen that heating the cartridge cases at 360°C decreased the percentage of particles containing mercury considerably. This observation supports the claim of the formation of elemental mercury in the decomposition of mercury fulminate as was reported in the literature [*9,15*].

No difference in mercury content was found between the GSR particles examined in SEM/EDX immediately after introduction into the SEM and the same particles 16 h after being in the SEM vacuum and following 1 h of electron bombardment.

An explanation for the difference in mercury content between GSR particles in samples taken from a shooter and samples from cartridge cases may arise from the mechanism of GSR particles formation. As the firing pin strikes the primer housing, the primer explodes and the high temperatures obtained may vaporize the explosion products (GSR particles). Because of supersaturation, the GSR vapors may condense back as droplets [*5*]. As the exploding front comprising these droplets strikes the gunpowder, they are

TABLE 1—*Results of experiments with various types of ammunition.*

Ammunition	Sample from Shooter's Hands		Sample from Cartridge Cases		Sample from Cartridge Cases, After Heating	
	N	% Hg	N	% Hg	N	% Hg
Russian 7.62 mm	40	0	37	95	40	32
Egyptian 7.62 mm	25	12	50	82	45	35
Egyptian 9 mm	83	11	98	100		
Italian 9 mm	28	0	75	93		

N = Number of examined particles. In the case of the Russian and Egyptian ammunition the examined particles were those containing at least Sn and Sb. In the case of the Italian ammunition the examined particles were those containing at least Sb and S.

% Hg = Percentage of particles containing mercury.

exposed to steep rises in temperature and pressure, from the ignition of the propellant. The temperature continues to rise as the gunpowder combustion proceeds [*5,16,17*]. Therefore, GSR particles which are mixed with the burning propellant moving in the barrel and then driven out of the flash gap or ejection port, would probably experience considerably more "heat damage" than GSR particles left in the cartridge case which had effectively less "contact" with the burning gunpowder. Consequently, it would be reasonable to assume that mercury will vaporize more from GSR particles moving with the burning propellant and ejected on a shooter, than from particles left in the cartridge case.

Conclusions

This study has shown that when firing ammunition that have mercury fulminate based primers, a much lower percentage of mercury-containing GSR particles are found in samples taken from the shooter as compared to the percentage of such particles in samples from cartridge cases. It is important that this is recognized by the expert when interpreting GSR case results.

Acknowledgments

The authors would like to express their thanks to their colleagues in various laboratories of the DIFS: P. Bergman, P. Enzel, B. Schecter and E. Springer, for their assistance in the experimental work and for fruitful discussion.

References

[*1*] Wolten, G. M., Nesbitt, R. S., Calloway, A. R., Loper, G. L., and Jones, P. F., "Equipment Systems Improvement Program—Final Report on Particle Analysis for Gunshot Residue Detection," Report ATR-77 (7915)-3, The Aerospace Corp., Washington, DC, Sept. 1977.

[*2*] Wolten, G. M., Nesbitt, R. S., Calloway, A. R., Loper, G. L., and Jones, P. F., "Particle Analysis for the Detection of Gunshot Residue, I: Scanning Electron Microscopy/Energy Dispersive X-Ray Characterization of Hand Deposits from Firing," *Journal of Forensic Sciences*. Vol. 24, No. 2, April 1979, pp. 409–422.

[3] Wolten, G. M. and Nesbitt, R. S., "On the Mechanism of Gunshot Residue Particle Formation," *Journal of Forensic Sciences*, Vol. 25, No. 3, July 1980, pp. 533–545.
[4] Wolten, G. M., Nesbitt, R. S., Calloway, A. R., and Loper, P. F., "Particle Analysis for the Detection of Gunshot Residue, II: Occupational and Environmental Particles," *Journal of Forensic Sciences*, Vol. 24, No. 2, April 1979, pp. 423–430.
[5] Basu, S., "Formation of Gunshot Residues," *Journal of Forensic Sciences*, Vol. 27, No. 1, Jan. 1982, pp. 72–91.
[6] Wallace, J. S. and McQuillan, J., "Discharge Residues from Cartridge-Operated Industrial Tools," *Journal of the Forensic Science Society*, Vol. 24, No. 5, Sept./Oct. 1984, pp. 495–508.
[7] Wallace, J. S., "Discharge Residue Particles from Blank Cartridges," *AFTE Journal*, Vol. 18, No. 4, Oct. 1986, pp. 33–38.
[8] Zeichner, A., Levin, N., and Springer, E., "Gunshot Residue Particles Formed by Using Different Types of Ammunition in the Same Firearm," *Journal of Forensic Sciences*, Vol. 36, No. 4, July 1991, pp. 1020–1026.
[9] Sokolov, S., "Sudebnachimiczeskaya Expertiza," (in Russian) p. 145, Moskva 1964.
[10] Wallace, J. S., "Chemical Aspects of Firearms Ammunition," *AFTE Journal*, Vol. 22, No. 4, Oct. 1990, pp. 364–384.
[11] Bergman, P., Springer, E., and Levin, N., "Hand Grenades and Primer Discharge Residues," *Journal of Forensic Sciences*, Vol. 36, No. 4, July 1991, pp. 1044–1052.
[12] Keeley, R. H. and Nolan, P. J., "Automatic Particle Analysis," Metropolitan Police Laboratory Report, 1986, and Report to Interpol Meeting, Paris, 1986.
[13] White, R. S. and Owens, A. D., "Automation of Gunshot Residue Detection and Analysis by Scanning Electron Microscopy/Energy Dispersive X-Ray Analysis (SEM/EDX)," *Journal of Forensic Sciences*, Vol. 32, No. 6, Nov. 1987, pp. 1595–1603.
[14] 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.
[15] Urbanski, T., "Chemistry and Technology of Explosives," Vol. 3, p. 148, Pergamon Press, New York, 1967.
[16] Davis, T. L., "The Chemistry of Powders and Explosives," p. 11, John Wiley & Sons Inc., 1953.
[17] "Military Explosives" Technical Manual No. 9-1910, pp. 36–42, Departments of the Army and the Air Force, Washington, D.C., 14 April 1955.

Address requests for reprints or additional information to
Arie Zeichner, Ph.D.
Toolmarks and Materials Laboratory
Division of Identification and Forensic Science
Israel Police Headquarters
Jerusalem 91906, Israel