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The Application of a Scanning Electron Microscope With an Energy Dispersive X-Ray Analyser (SEM/EDXA) For Gunshot Residue Determination on Hands For Some Cartridges Commonly Used In Turkey

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The primers of the 10 commonly used cartridges in Turkey, MKE MP5, GECO Luger, FC Luger, WIN Luger, S&B Luger, WRA Luger, FNB Luger, P Luger, KF 80 Luger and SINTOX ACTION Luger were first examined with a SEM/EDXA. Then these cartridges used in test firings and the GSR on the hands of the test shooters was collected using adhesive-coated sample stubs and examined with a SEM/EDXA. Samples were scanned by viewing the BSE (Backscattered electron) image and, brighter and spherical particles were located, and then analysed with an EDXA. The elemental compositions of the GSR of the studied cartridges were found to be compatible with the elemental compositions of their primers. The GSR results showed the following elemental distribution according to individual cartridges; PbSbBa, SbBa, PbSb, PbBa, PbSnBa, SnBa (Pb), BaCaSi, Pb, Ba, Sb, TiZn and Hg.

Keywords: Gunshot residue, Particles, SEM-EDXA, Forensic Science.

Introduction

In crimes involving firearms such as murder, suicide or injuries caused by a gun, the determination of the person who used the gun is very important for shedding light on such events. When a gun is fired, gunshot residue (GSR) particles are deposited on the hand of the shooter. Depending on the origin of the cartidges, the GSR may contain lead, barium and antimony known as "Common GSR Elements", and in addition, it may also contain tin (Sn), zinc (Zn), titanium (Ti), manganese (Mn), mercury (Hg), aluminum (Al), copper (Cu), iron (Fe), silicon (Si), potassium (K) and sulphur (S).[1,2]

In the determination of felons in events in which a gun is used, the analytical methods have to be very accurate and sensitive in order not to accuse the wrong person. Generally Flameless Atomic Absorbtion Spectrophotometers (FAAS), Neutron Activation Analysis Spectrophotometers (NAAS) and

Scanning Electron Microscopes with an Energy Dispersive X-Ray Analyser (SEM/EDXA) are used for this purpose.[3,4,5]

The aims of this study were to use for the first time in Turkey the SEM/EDXA which is a non-destructive sensitive method for GSR examinations, to image the geometrical shapes of the particles, determine the elemental composition of specific cartridges' GSR and to observe the advantages of this non-destructive method over the other bulk analysis methods.

Materials and Method

In this study 10 different types of cartridge commonly used in crime cases in Turkey, obtained from the collection of the Ballistics Department of the Headquarters of Criminal Police Laboratories in Ankara, were used (Table 1). The original primers of these cartridges were first examined in order to compare them with their GSR.

Table 1. Cartridge types

Cartridge types	Calibers & type	Country of Production
MKE MP5	9×19 mm	Turkey
GECO Luger	9×19 mm	Germany
S&B Luger	9×19 mm	Czechoslovakia
FC Luger	9×19 mm	U.S.A.
WIN Luger	9×19 mm	U.S.A.
WRA Luger	9×19 mm	U.S.A.
P Luger	9×19 mm	United Kingdom
FNB Luger	9×19 mm	Belgium
KF 80 Luger	9×19 mm	India
SINTOX ACTION Luger	9×19 mm	Netherland

The primers were taken from the cartridges with a capsule remover. After taking samples with double-sided adhesive coated 12.5 mm-diameter copper-zinc type SEM sample stubs, they were coated with carbon and analysed with a SEM/EDXA. Secondary electron images (SEI) were obtained with a SEM and Dispersive X-Ray (EDX) spectra were obtained with an EDXA.

After test firings with the same cartridges, GSR particles were collected from the thumb/web/forefinger area of the shooter's hand using double-sided adhesive coated SEM sample stubs and coated with carbon. All firings were carried out with the same gun (CZ-75 B Cal. 9) and the shooter's hands were washed thoroughly with soap and water before each firing.

Backscattered Electron Images (BEI) were evaluated for locating the GSR particles in SEM. Bright images of the elements with high atomic numbers facilitated the finding of the GSR particles. After determining the bright particles by scanning, the elemental analysis was carried out with an EDXA. The non-GSR high atomic number elements giving bright images such as Fe, Cu, Zn, Ni, S, K, Al, Si were excluded by EDX analysis. Secondary electron images (SEI) of each determined GSR particle were obtained, and their spherical shapes were observed and they were photographed. EDX spectra of the GSR particles were obtained by EDX analysis.

The Jeol JSM 6400 SEM and Tracor Northern TN 5500 EDX were used for the examination.

Analysis Conditions:

Acceleration voltage : 20-25 kV

Scanning rate : 20 frame/sec

Working distance : 39 mm

SEI Magnification : 100-5000 X

Detectors:

1. The lithium drifted silicon crystal of the X-ray detector was kept in liquid nitrogen at a distance of 40 mm from the center of the column.
2. Secondary electron detector.
3. Backscattered electron detector.

Results and Discussion

The EDX analysis results of the original cartridge capsule primers are given in Table 2, and the results for GSR are given in Table 3. Typical photographs of BEI and SEI images and an EDX spectrum of a particle are given in Figures 1, 2, and 3 respectively. In general, the elemental compositions of the original primers were consistent with those of the GSR for the cartridges of MKE MP5, GECO Luger, FC Luger, WIN Luger, S&B Luger, WRA Luger, FNB Luger, P Luger and SINTOX ACTION Luger. However there was a difference between the elemental composition of the original primer and the GSR for the KF 80 Luger cartridge. While Hg was present in the orginal primer, it was absent from the GSR from that cartridge. This was attributed to the evaporation tendency of Hg at room temperature by Zeichner et al.[6]

Table 2. EDX analysis results from the original cartridge primers

Cartridge type	Elements
MKE MP5	Pb, Ba, Sb, S
GECO Luger	Pb, Ba, Sb, S
P Luger	Pb, Ba, Sb, S
WRA Luger	Pb, Ba, Sb, S
FC Luger	Pb, Ba, Sb, S, Si
WIN Luger	Pb, Ba, Sb, S, Si
S&B Luger	Pb, Ba, Sn, Ca, Si
FNB Luger	Pb, Ba, Ca, Si
KF 80 Luger	Sb, Hg, K, Cl, S, Si
SINTOX ACTION Luger	Ti, Zn, Cu

According to the results, the observed elements of the GSR can be grouped as follows:

Common GSR particles; Pb, Ba, Sb (with S), Sb (without S), PbSbBa, SbBa, PbSb, PbBa.

Specific GSR particles: BaCaSi, PbSnBa, SnBa(Pb), TiZn, Hg.

The non-GSR elements which can be found with GSR: Cu, Zn, K, Cl, S, Fe, Ni, Al, Ca, Si.

Table 3. EDX Analysis Results of GSR

Cartridge Type	NP*	Elements (trace)	Sb with S	Other trace elements	Other bright elements
MKE	1	Ba Sb Pb	+**	Cu, Zn	
MP5 Luger	2	Ba Sb Pb	+	Si, Cu, Zn	
	3	Ba Sb Pb	+	Cu, Zn	
	4	Ba Sb Pb	+	Cu, Zn	
	5	Ba Sb	+	Cu, Zn	
	6	Ba (Sb)	+	Si, Al, Cu, Zn	
GECO	1	Ba Sb Pb	+	Al, Cu, Zn	
Luger	2	Ba Sb Pb	+	Cu, Zn	(Cu, Zn), (Fe)
	3	Ba		Al, Cu, Zn	
	4	Ba Pb (Sb)		Cu, Zn	
	5	Ba Sb Pb		Cu, Zn	
P	1	Ba Sb	+	Cu, Zn	
Luger	2	Ba Sb Pb	+	Si, Cu, Zn	
WIN	1	Ba Sb Pb	+	Fe, Cu, Zn	
Luger	2	Ba Sb Pb	+	Cu, Zn	
FC	1	Ba Sb Pb	+	Cu, Zn	
Luger	2	Ba Sb Pb	+	Cu, Zn	(Si, S), (Cu, Zn)
	3	Ba Sb Pb	+	Cu, Zn	
WRA	1	Sb Ba Pb	+	Cu, Zn	
Luger	2	Sb Ba Pb	+	Si, Cu, Zn	
S&B	1	Pb Sn Ba		Si, Cu, Zn	(S, K, Al, Si, Cu),
Luger	2	Sn Pb Ba		Si, Cu	(Ca, Si), (Ni)
	3	Ba Ca	Sn Pb Si	Fe, Cu, Zn	(Cu, Zn)
	4	Ba Ca Si		Fe, Cu, Zn, S	
FNB	1	Ba Ca Si (Pb)		K, Al, Fe, Cu, Zn	(S, Fe)
Luger	2	Ba Ca Si (Pb)		Fe, Cu, Zn	
KF 80	1	Sb Pb K	+	Cu, Zn	(Si, S), (Cu, Zn),
Luger	2	Sb	+	Si, Cu, Zn	(Ca, K, S, Si, Al),
	3	Ba (Sb)		S, Si, Cu, Zn, O	(Al, Si, S, K),
	4	Ba (Sb) Si	+	Si, Cu, Zn, O	(Si, S, Cu, Zn),
	5	Pb (Sb, Ba) K Si	+	Cu, Zn	(Si)
Sintox	1	Ti Zn Cu		Ca, S, Si, Al	[Ca, Si, (Cu, Zn)]
Action	2	Ti Cu Zn		Ca, Cl, Si	[S, K, Ca (Cu, Zn)]
Luger					(Si, S, K, Ca, Al, Fe)

*NP; The Number of GSR particles
**;+; present

All GSR exhibited a spherical structure except one S&B particle. Although generally diameters of 2-10 μm for GSR particles were determined, diameters of up to 50 μm for some GSR particles were also observed.

The correlation of GSR with the original cartridge types was not the purpose of this study. A quantitative approach might be useful for such a correlation, but it was not performed in this study.

Figure 1. Backscattered electron image of a GSR particle (BEI, 600X)

Figure 2. Secondary electron image of a GSR particle (SEI, 1500X

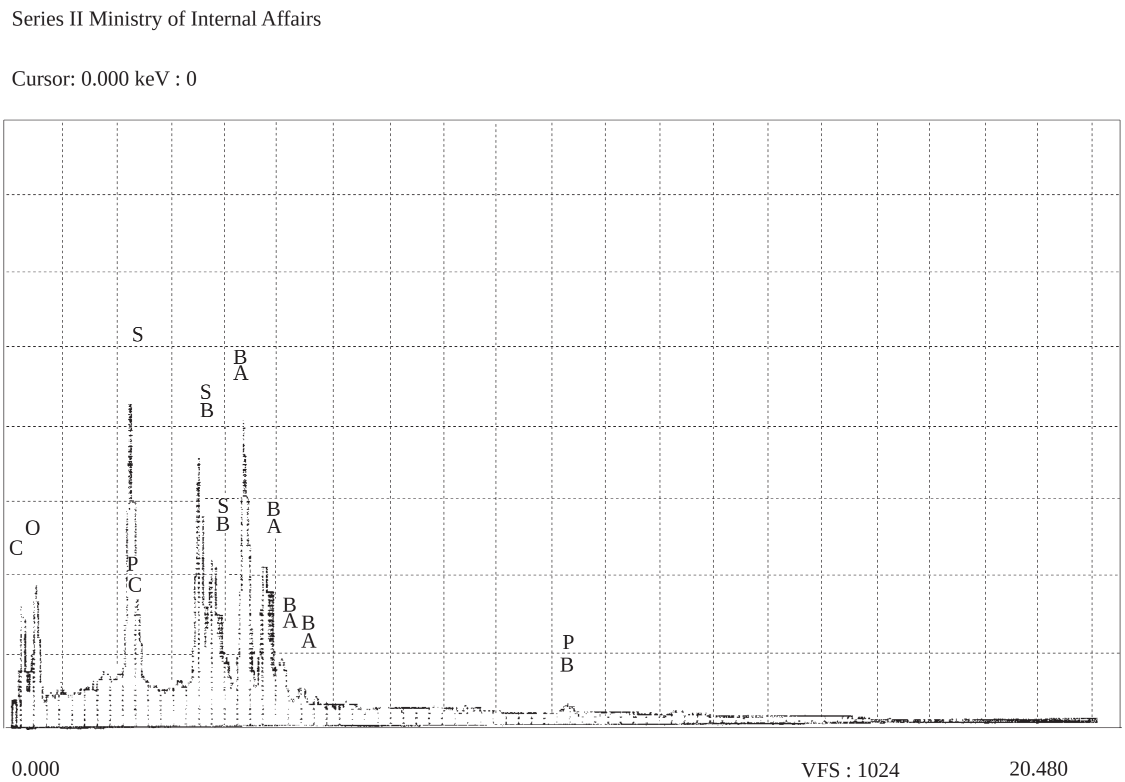

Figure 3. EDX spectrum of a GSR particle

Because the spherical shapes of GSR particles were observed with the SEM, the possibility of detecting contamination from the enviroment as GSR particles was minimized. In this method using a SEM the possibility of obtaining false results originating from the background is eliminated because the elements such as Pb, Ba and Sb can not come together so as to form a spherical particle in the environment.

Another advantage of this method is the possibility of keeping samples for a long period because of the non-destructive analysis system. The carbon coating prevents the removal of GSR particles over time.

It is known that the SEM/EDXA analysis method is advantageous compared with the destructive bulk elemental analysis methods such as NAA and FAAS. The advantages, which were also observed in this study are:

1. SEM/EDXA is a non-destructive method,
2. It is possible to characterize the GSR particles from their spherical images,
3. It is possible to examine all the particles one by one, so the sensitivity increases.

But SEM/EDXA has disadvantages in terms of analysis time compared with the other techniques. If the scanning of the sample is carried out manually as in this study, it takes a long time to locate the GSR particles and sometimes they might not be caught by the analyst.

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