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Variation of the chemical contents and morphology of gunshot residue in the surroundings of the shooting pistol as a potential contribution to a shooting incidence reconstruction

Zuzanna Brożek-Mucha [a,b,*]

[a] Institute of Forensic Research, Westerplatte St. 9, 31-033 Krakow, Poland
[b] Jagiellonian University, Faculty of Chemistry, Ingardena St. 3, 30-060 Krakow, Poland

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ABSTRACT

A study of the chemical contents and sizes of gunshot residue originating from 9 × 18 mm PM ammunition, depositing in the vicinity of the shooting person was performed by means of scanning electron microscopy and energy dispersive X-ray spectrometry. Samples of the residue were collected from targets placed at various distances in the range 0–100 cm as well as from hands and clothing of the shooting person. Targets were covered by fragments of white cotton fabric or black bovine leather. In the case of cotton targets microtraces were collected from circles of 5 and 10 cm in radius. Results of the examinations in the form of numbers of particles, proportions of their chemical classes and dimensions revealed a dependence on the distance from the gun muzzle, both in the direction of shooting and in the opposite one, i.e., on the shooting person. The parameters describing gunshot residue differed also depending on the kind of the target substrate. The kind of obtained information gives rise to understanding the general rules of the dispersion of gunshot residue in the surroundings of the shooting gun. Thus, it may be utilised in the reconstruction of shooting incidences, especially in establishing the mutual positions of the shooter and other participants of the incident.

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1. Introduction

The most frequent aspects of firearm-related investigations are the following: detection and analysis of gunshot residue originating both, from the primer and from the propellant, identification of bullet entry holes and shooting distance estimation, linking weapons and parts of fired ammunition with gunshot entries, detection of firearm imprints on the hands of suspects [1]. However, despite the rapid developments in methods of instrumental analysis and useful protocols being recently worked out by forensic chemists, there still remain challenges such as establishing the mutual position of persons involved in a shooting incident.

Gunshot residues (GSR), originating from the primer of firearm ammunition are valuable evidence in cases of shooting. For the purpose of proving that a person was present in a close vicinity of a firing gun, GSR ought to be characterised by both, the specific element content being related mainly to the composition of the primer mixture and their morphology of molten and suddenly cooled droplets of metals revealing sizes in the range from sub-micrometers to several micrometers. The most popular method simultaneously providing information on the two features is scanning electron microscopy combined with energy dispersive X-ray spectrometry (SEM-EDX) [2–6]. Automation of the analytical process of GSR examinations with this method was successfully solved helping an operator in the arduous process of location and chemical classification of particles [7]. Contemporary SEM-EDX systems are able to detect submicron particles and the quality of their performance in GSR search can be measured by means of artificial test sample fulfilling the requirements of standards ISO 5725 and ISO 13528 [8].

The administration of justice frequently asks about the shooting distance, the type and calibre of gun and ammunition, the details of the relative positions of people involved in a crime and finally the reconstruction of the course of an incident. A considerable number of these cases still concerns using Makarov type of pistols and ammunition.

In 1951 the pistol of Makarov (PM) was chosen to be an official weapon of Soviet military and police and its Eastern European satellites and still remains the service pistol of Russian military and police service as well as in many Eastern European Countries and former Soviet Republics, despite of successive replacing them by modern 9 mm Luger parabellum types of hand guns. Today, the Makarov is a popular handgun for concealed carry in the United

* Institute of Forensic Research, Department of Criminalistics, Westerplatte St. 9, 31-033 Krakow, Poland. Tel.: +48 12 422 87 55x185; fax: +48 12 422 38 50.
E-mail address: zbrozek@ies.krakow.pl.

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States. Variants of the pistol remain in production in Russia, China and Bulgaria. The smallest hand gun utilising Makarov ammunition (also called 9 × 18 mm PM) was invented in Poland and has been manufactured at the F.B. Radom plant as the P-64, with 190,000 made between 1966 and 1977 for police and army. Its later modification, called P-83 was also accepted into the inventory of the Polish Army and Ministry of Internal Affairs in 1984 and manufactured until year 2000. In 2002 Polish Police and Army have introduced an ultra-modern P-99 polymer-framed semiautomatic pistol designed by the German company of Carl Walther Waffenfabrik of Ulm, 9 mm Luger calibre, in order to successively replace the service weapon with the one compatible with NATO standards, although, as of 2010 large numbers of P-64 and P-83 are still in Military and Police service in Poland, similarly to situation in other countries of Europe, Asia and America. The appropriate ammunition has been also produced in Poland at Mesko Metal Works, Skarzysko-Kamienna.

It was observed that 9 mm Makarov ammunition of this manufacturer produces none or very small numbers of the particles simultaneously containing lead, antimony and barium being characteristic gunshot residue [9–12]. Although this property was found to be interesting for distinguishing them from GSR originating from other types of ammunition [13–17], it always caused difficulties in the interpretation of the results of GSR examinations obtained for samples collected from suspect's hands taking into account the formal approach of the evaluation of GSR. As the formal scheme of data interpretation underestimates the evidential value of GSR originating from ammunition other than traditionally primed with lead, antimony and barium compounds, another approach, called "case-to-case", was suggested by Romolo and Margot [18] and adopted by many experts. An individual treating of a case requires not only utilisation of information included in case files, e.g., the autopsy report, but also a knowledge on the spatial expansion of GSR originating from certain type of gun and ammunition used in the crime scene.

The majority of studies on the spatial expansion of GSR performed so far concerned their presence at certain distances from the shooting gun [19]. An interesting idea on the distribution of numbers of characteristic particles in the surroundings of the shooting person was assembled performing single experiments in controlled conditions, including preparation and distribution of horizontal accumulating targets around the shooter at various heights [20]. An attempt was also done to extract information on various features of gunshot residue originating from a 9 mm Luger ammunition and deposited on materials being normally obtained as evidence: the shooter's hands and clothing as well as the victim's clothing that acted as vertical targets. Distribution of particles on targets and on the shooting person, i.e., hands and the forearm, arm and back parts of the upper clothing revealed a significant dependence on the shooting distance. It has been found that numbers of particles, the mutual proportions of their chemical classes and their sizes varied with the distance from the shooting gun [21]. Moreover, the mutual proportions between lead particles originating from the bottom of the projectile and antimony particles originating from the primer have shown the opposite course of changes. Rijnders et al. also studied GSR samples taken from seven different locations around and in the firearm using SEM-EDX method. For the same ammunition they found high correlations between samples taken from external positions (such as hands of shooter, bullet-entrance holes) but poor correlation between internal samples (such as firearm barrel, cartridge case) and external samples. A high degree of association was found between samples that simulated victim and shooter. They concluded that GSR comparison studies are meaningful but care needs to be taken when choosing suitable exhibits. External samples (such as hands of shooter, bullet-entrance holes) are more suitable candidates than internal samples (barrel of the firearm, cartridge case) for evidence material [22].

In opposition to the opinion of Rijnders et al. [22], the author of the current work recons that examination of GSR originating from the cartridge cases are always very informative and important evidence material, even when great differences occur in comparison to the airborne GSR. That has been supported by a comparative study of the chemical contents and morphology of airborne particles and these taken from inside the cartridge case published elsewhere [23]. The distribution of the chemical elements in the gunshot residue is determined by two main factors: the direction of the movement of the expanding products of the burning propellant at the stage of internal ballistics and subsequent interactions with the materials that were applied to construct the gun and ammunition. Whereas the elemental contents of the residue present inside the cartridge case resembles the primer composition, the particles leaving the gun muzzle are usually enriched with material originating from the other parts of a cartridge: the case, the bullet core and jacket and the debris deposited on the internal walls of the muzzle.

The subsequent phenomena taking place during cartridge discharge, being very dynamic and complex in nature, were so far rare subject of studies performed by GSR examiners for better understanding their dispersion in the vicinity of the shooting gun. Basu made inferences on a three-stage combustion process of the primer and the propellant taking into account the morphology of GSR collected from the shooter's hands and distributions of lead, antimony and barium in the cross-sections of particles by means of SEM-EDX, as well as the temperatures of melting and evaporation of these metals [24]. Studying GSR collected from shooter's hands with the use of ammunition, fabricated by addition of various metals or metal compounds to the propellant or the projectile, Wolten et al. have found that materials of the projectile (e.g., lead and copper) clearly contributed to the metallic GSR. However, their quantity depended on the melting and evaporation temperatures as well as the chemical affinity of metals originating from the primer to lead and copper of the projectile core and jacket, and so the possibility of constituting alloy systems [25]. Bhattacharyya presented theoretical modelling of the phenomenon of GSR deposition on targets in the close-range shooting distances adopting the kinetic theory of gases and considering discharge products as a gaseous system that moves with a high velocity in the direction of shooting, in which the particular velocities of the constituent particles reveal a Maxwellian distribution [26]. However, the presented model did not reproduce analytical data in the form of concentration of antimony on the subsequent targets; neither did the model later modified for collisions of the metallic and the air particles [27]. The observed differences between the measured and the calculated concentrations of antimony increasing with the shooting distance may have resulted from the variation of shapes, sizes and mass of particles that were not taken into account in the model as well as a possible range of particle velocity affecting the adhesion of a particle to the target. Particles of both, lower and higher velocity than this range would not adhere to the target or reflect from it.

In this view the only attempt to recognize variation of the chemical contents of GSR particles with the distance from the firing gun, both in the direction of shooting and the opposite one was demonstrated in publication [21]. The obtained results revealed their importance as potential contribution to reconstruction of mutual positions of the shooter and other persons present at the crime scene. In spite of growing interest in distribution of GSR, among other burning questions related to GSR examination reviewed recently by Dalby et al. [28], any solution to this forensic problem has not been approached before.

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