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Study of possible contamination of police officers and service vehicles with gunshot residues

Summary

The hereby article presents the analysis of data from literature of the subject, as well as of analyses of material recovered onto microscope stubs from hands of 59 police officers and traces collected from 38 police cars backseats onto ELEVAK instrument cartridges. The stubs were checked for presence of GSR particles and the filters of ELEVAK cartridges – for O-GSR and other substances. Traces were recovered at seven district police stations within Warsaw Municipal area. The analyses were performed with two analytical techniques: SEM/EDX and GC/MS. From 1 to 27 characteristic GSR particles were found on hands of 18% officers. Between 1 and 11 of such particles were detected on the surfaces of 24% car backseats. Traces of diphenylamine, a chemical substance used as a stabiliser in smokeless powders were detected in 13 vehicles, cocaine traces were found in 3 vehicles and THC was found in one vehicle.

Key words: GSR particles, O-GSR, GSR contamination, police officers hands, backseats of service vehicles, SEM/EDX, GC/MS

Introduction

As a result of firing a weapon the shooter becomes contaminated with products of chemical transformation of the propellant and primer, as well as microscopic fragments of metals originating from a cartridge case, projectile and parts of weapon. Those products, as well as metal traces are referred to as gunshot residues. Products resulting from condensation of metal fumes make non-homogenous spherical compositions referred to as GSR (gunshot residues) particles. A smoke cloud carrying some unburnt particles is expelled from the barrel and other openings in the weapon. It carries residues of unburnt smokeless powder, its components such as: stabilisers, plasticisers, sensitisers and compounds resulting from recombination of cellulose nitrocellulose decomposition. Those compounds differing from GSR particles are referred to by "O-GSR" acronym (organic gunshot residues). Basing on results of GSR and O-GSR examination an expert attempts to determine whether a person evidence was recovered from has actually shot a firearm. In addition to that, he/she endeavours to reconstruct the course of incident, most often with help from experts of other specialties, mainly in the area of firearms examination and ballistics. This determination is normally not easy because it is based on many factors and there is not sufficient information as to the impact of each individual factor on the findings. There may be no scientific grounds that would allow, for example, linking gunshot traces with a given weapon or estimating the time that has passed from firing the shot. The most challenging circumstance is a possible transfer of gunshot residues from sources unrelated with the incident onto the clothes or body the examined persons, referred to as "contamination".

From the point of view of examination quality in forensic laboratories the key point is answering the question whether the hands of police officer executing the detention or the service vehicle, i.e. means of transportation may be the cause and source of GSR and O-GSR particles presence on the suspect and estimating of the risk that those factors might influence the results of evidence examination.

Literature review

The issue of possible contamination of a person detained by law enforcement officers has been long present in literature of the subject. In 1995, Gialamas, Rhodes and Sugarman examined 43 policemen from San Diego at the end of the days of duty involving the use of firearms. Three of the examined policemen had one characteristic particle consisting of lead, barium and antimony (PbSbBa) and one consistent particle

each on the hands, in 15 policemen, only consistent particles in a total number of 70 were found, while 25 of the officers had no GSR particles on their hands.

Other Authors (Berk, Rochowicz, Wong and Kopina), also in the United States, in 2007, examined 193 police vehicles and only in two of them, whose seats were covered with fabric single characteristic PbSbBa particles were detected.

A similar result for vehicles was obtained in 2013 also by Gerard, Lindsay, McVicar, Randall and Gapinska, who upon examining the backseats of 18 police vehicles in Toronto detected a characteristic particle only on one of them. The same Authors found GSR particles on the hands of 9 out of 36 examined Toronto policemen, and the number of found particles was in the range between 1 and 15. No GSR particles were detected on the hands of civilian staff working in the same Department. On the other hand, in a group of 8 out of 30 examined policemen from York County the numbers of particles ranged from 1 to 7. In another project carried out in Australia, whose results were published by Cook in 2016, hands of 33 policemen were examined after they had collected and checked their weapons. Obtained results were significantly different from the results reported in the above cited works. Hands of 5 officers were free from characteristic particles, from 1 to 10 characteristic particles were found on 16 of them, from 11 to 99 characteristic particles were detected on 6 of them and over 100 characteristic particles were found on 6 others. It is necessary to emphasise that there was only on one among 33 police officers in this situation on whom no GSR particles were found. On the remaining ones, considerable numbers of consistent particles were found even in cases where there were no characteristic particles.

Research on the level of contamination was also conducted in Europe by Pettersson (2003), who detected 12 and more GSR particles on approx. 25% seats of Swedish Police vehicles.

In Poland similar research was performed by Brożek-Mucha from the Institute of Forensic Expertise in Cracow. According to the data published in 2014, the Authoress analysed 50 samples 31 if whom came from policemen and 19 – from hunters. 18 out of 50 samples comprised characteristic PbSbBa particles, whose numbers ranged from 1 to 100 and were closely correlated with time that has passed from the last shooting or contact with firearms.

In a group of 30% police officers GSR particles were found on the hands, however, if the time that had passed from shooting/contact with firearms was longer than 5 hours, in 16 out of 17 cases policemen's hands were free from GSR particles.

An interesting approach to the question whether GSR traces may be transferred from a police officer to a detained person is presented in the work of Charles and Geusens (2011). An experiment was carried out by conducting two test scenarios. Scenario one, in the Authors intention, assumed low risk of contamination and scenario two involved high contamination risk. 24 counterterrorist operators were divided into two groups: the first one was to perform an arrest of a suspect and the remaining ones were actors. In scenario one, besides weapons and handcuffs, they wore also bulletproof vests, tactical body armour and gloves they had used in service. Before commencing the experiment all the participants had washed their hands. In both scenarios the actors wore disposable laboratory coats. The policemen had taken out and reloaded their weapons prior to the arrest. Samples were taken from both persons hands, body armour and police officers tactical gloves 5 minutes after the arrest. During the service, the policemen had used ammunition with primers referred to as SINOXID, SINTOX by Wallace (1990) and lead-free primers on NONTOX type researched by Hogg, Hunter and Smith (2015). The compilation of results obtained by Charles and Geusens is presented in table 1.

Table 1. Summary of results of experiment concerning transfer of GSR particles made by the Author basing on the publication by Charles and Geusens (2011).

Scenario I			
Policeman – number of particles		Arrestee – number of particles	
Average	Maximum	Average	Maximum
PbSbBa × 2 TiZn × 16	PbSbBa × 16 TiZn × 41	PbSbBa × 3 TiZn × 6	PbSbBa × 13 TiZn × 14
Scenario II			
Policeman – number of particles		Arrestee – number of particles	
Average	Maximum	Average	Maximum
PbSbBa × 66 TiZn × 217	PbSbBa × 320 TiZn × 1550	PbSbBa × 10 TiZn × 28	PbSbBa × 32 TiZn × 127

A characteristic thing is that due to intense training and practically continuous contact with firearms clothes and gear of police officers serving in counterterrorist squads are highly contaminated with GSR particles. No policeman participating in the experiment as the active party was free from contamination with GSR particles. The lowest found level of contamination was one consistent particle made from titanium and zinc (TiZn) specific for SINTOX type primers. Similarly, among the actors in both scenarios there was no case of a person on whom GSR contamination was not found. The only doubt as to the results of reported experiment is evoked by the effectiveness of potential transfer, which practically amounted to 100% in four "policeman-arrestee" pairs as regards to SINOXID type particles. Despite that the results confirmed that as a result of detention, where physical contact of a police officer with the arrestee occurs, transfer of GSR particles from a police officer to the arrestee does occur.

The experimental

The aim of the hereby work was to analyse the level of contamination with gunshot residues of car backseats and policemen hands in Poland. Samples were recovered upon the changing shifts of patrol teams in Patrol and Reconnaissance Departments in seven Police Stations in Warsaw. Traces from each policeman's both hands were collected onto one microscope stub from the areas between index finger and thumb, i.e. the area routinely examined in persons suspected of using firearms. Both officers getting off duty and those starting their shift on a given day were examined. During the process of collection, the policemen were asked to provide concise information on when they had last washed their hands, what type of ammunition they used in their service weapons, what their interests and activities related to firearms were and whether they had used firearms during their service on a given day.

After recovering material from hands, backseats of police cars were sampled. The process was performed with ELEVAK instrument (Filewicz, 2001, p. 100). One sample was collected from each backseat. The traces were drawn off the surfaces as by application of subpressure. Disposable cartridges in ELEVAK instrument are constructed in such a way that microscopic fractions are trapped on the surfaces of two filters of decreasing pore size. Fractions of the sizes below 50 microns reach a microscope stub placed behind the filters. This method of recovery guaranteed even distribution of particles suitable for SEM/EDX analysis on the stub. The filters capture, first of all, such material, as: grains of sand, fibres, plant detritus, dead insects and other traces, that could be analysed by microscopic and chromatographic techniques. The selected method of recovery granted also the possibility of checking for presence of organic gunshot residues (O-GSR) or traces of other controlled substances, such as drugs or explosives.

Summary of selected samples

For the need of the hereby research project traces were collected from the hands of 59 police officers three of which had declared they were active in shooting sport and one was a hunter. None of the police officers shot during the shift but they all had contact with duty weapons during collection or returning firearms. The largest group of police officers – approx. 38% – declared they had washed their hands during previous two hours (fig. 1).

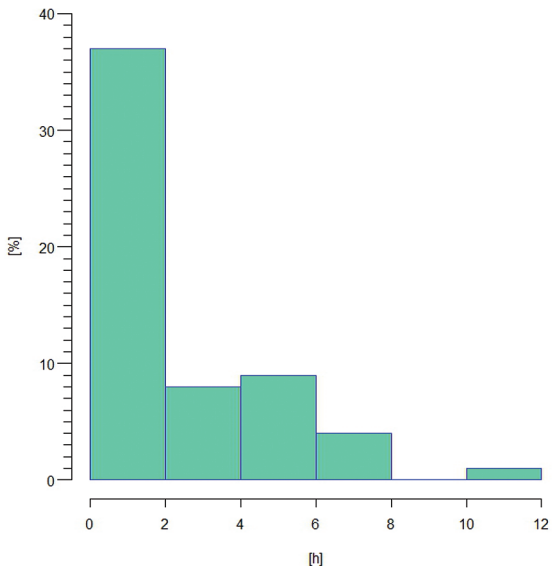

Fig. 1. Declared time that has passed from hand washing.

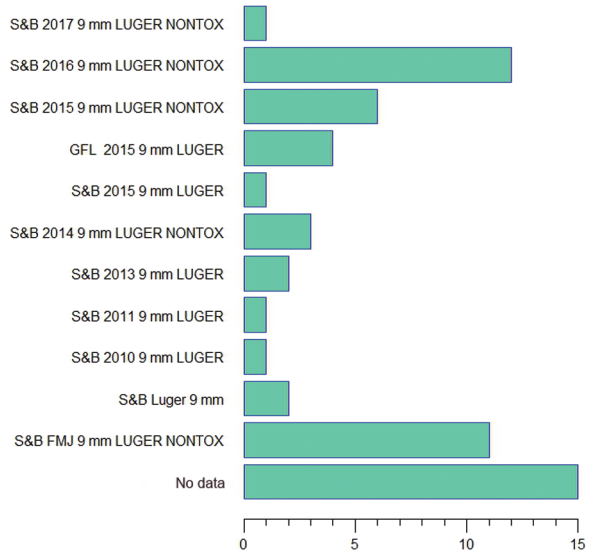

Fig. 2. Types of ammunition on the equipment of examined police officers.

Table 2. Configuration parameters used in SEM/EDX GSR analysis.

Parameter	Value
Accelerating voltage	20 kV
Working distance	15 mm
Scan resolution	1024 px × 1024 px
Magnification	409×
Spectrum acquisition time	1 s
Spectrum processing time	4 s
GSR diameter threshold	1,0 µm
Number of stubs in series	5
BSE Calibration standard	Al/Ni

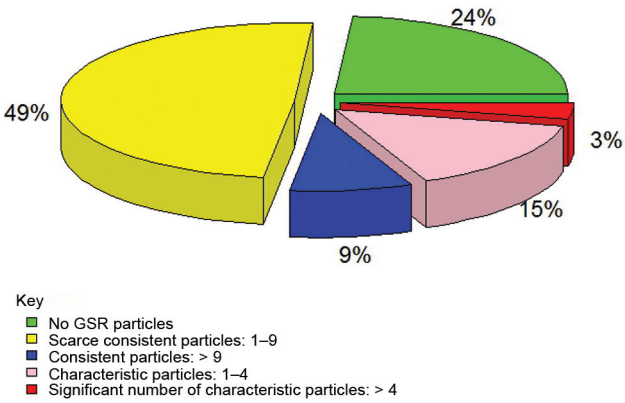

Fig. 3. Summary of the types and numbers of GSR particles found on police officers hands.

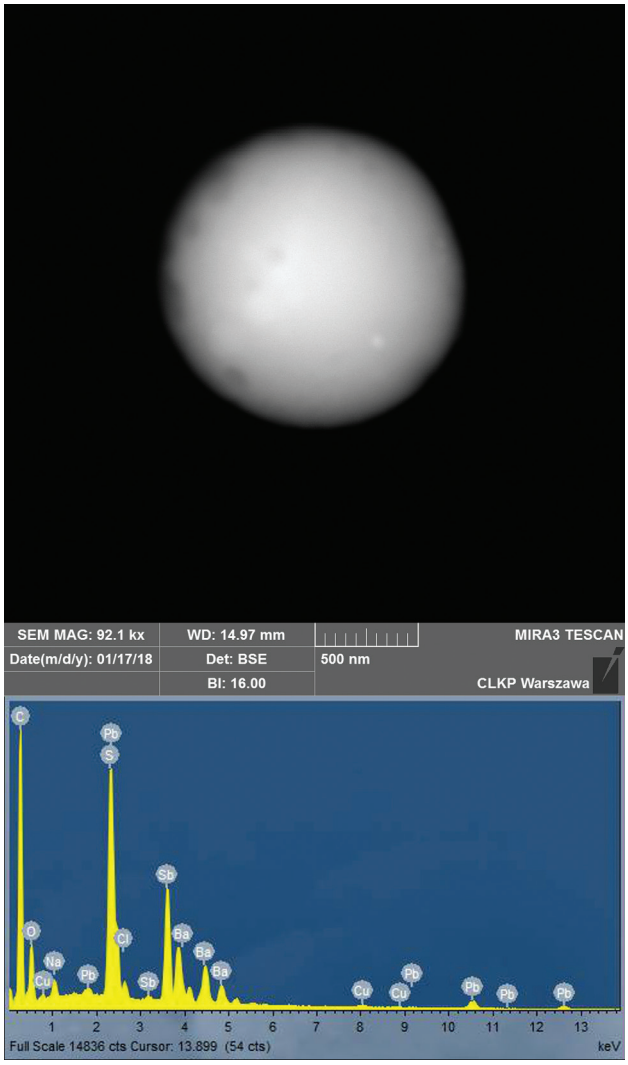

Fig. 4. Image and EDX spectrum of PbSbBa particle detected on the hands of a police officer denominated with S16 code.

During recovery of traces not in every case it was possible to determine what ammunition police officers had in use (fig. 2) and which ammunition their weapons had been loaded with. One-fourth of the participants had already put their firearms in storage or had not collected them. A vast majority had 9 mm Luger ammunition, 68% of which was manufactured by Czech Company Sellier & Bellot. Interestingly, basing on the obtained research sample, it was found that NONTOX ammunition, which does not contain heavy metals, in particular lead, was quite popular.

In the course of examination traces were recovered from 38 backseats of service cars including 37 marked police vehicles. Detained persons had been transported in all of the cars. In the majority of vehicles seats were protected with covers made of artificial leather.

Analysis by means of electron microscopy

Traces collected from 59 policemen and 38 car backseats onto SEM stubs were coated with 10 nm conductive carbon layer by means of QUORUM Q150T ES sputter and coating system. The stubs were examined according to the procedure routinely used in gunshot residue analysis by means of scanning electron microscope (Tescan Mira 3 LMU) coupled with X-Max^N X-ray 80 mm^2 spectrometer of SDD type (Oxford Instruments). The microscope was controlled by software for analysis of gunshot residues, INCA for Windows 7 Issue 21b SP3 version 5.05. The acquisition parameters are presented in table 2.

At the following stage the results of automatic analyses were verified manually in order to confirm morphology and elemental composition of detected GSR particles. That had a particular significance as regards single-component consistent particles, because in that case particles of similar elemental composition may have come from other sources, e.g. from burning pyrotechnical materials and they may have no connection to firearms.

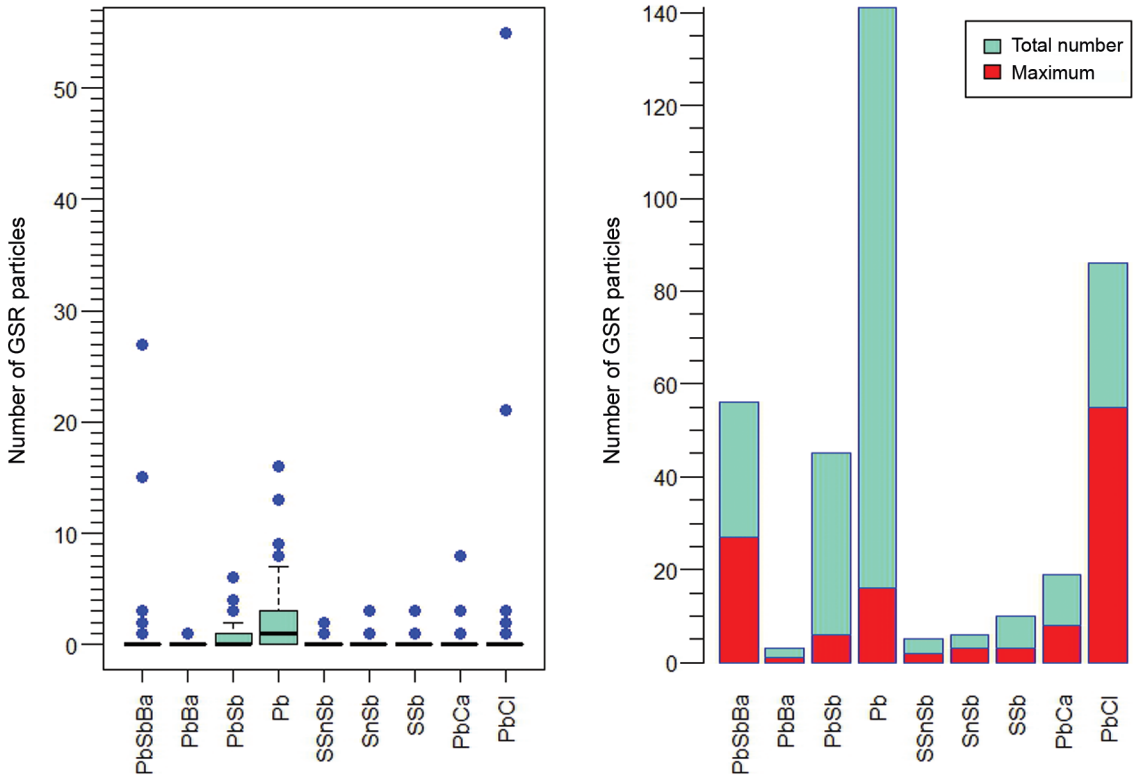

Fig. 5. Numbers of particles found on police officers hands broken into GSR classes.

As expected, because of professional contact with firearms, GSR particles were detected on the hands of 45 (76 %) out of 59 examined police officers (fig. 3). The majority of detected particles were non-specific consistent ones, in numbers below 10. Only in two cases, which constituted approx. 3 % of the examined group, a considerable number of characteristic particles were found.

GSR particles predominately originated from two types of primers: SINOXID (particles: PbSbBa, SSb and PbBa) as well as from primers found in "ammunition from, so called, former Eastern Block countries" (Filewicz, 2001, p. 217), which generate, among others, SSnSb and SnSb particles. The remaining particles: PbSb, PbCa, PbCl and Pb are fractions of lead or its alloys, which might have originated from chemical transformations of primer initiating material or, more likely, the cores of projectiles were its source. A morphology of an exemplary characteristic PbSbBa particle and EDX spectrum from its surface were presented in figure 4.

The highest numbers of characteristic particles: 27, one hour after washing hands and 15 in 7,5 hours after washing hands was detected on hands of the police officers who had declared the sport shooting.

On the hands of the third policeman involved in shooting sport only one characteristic particle was observed (4 hours after washing hands) while the hands of police officer – hunter were contaminated with lead particles (Pb and PbSb) in a total number of 11, one hour after washing hands. On each of other police officers, no more than three characteristic particles (one case) were found and over 20 lead particles were detected on two persons. Distribution of results divided into GSR classes was presented in figure 5. In the left part of the figure, Tukey box-plot is presented and the right plot shows the sum of detected particles in individual classes with maximum values. The class of lead and its combinations (alloys) is represented in highest number. In addition

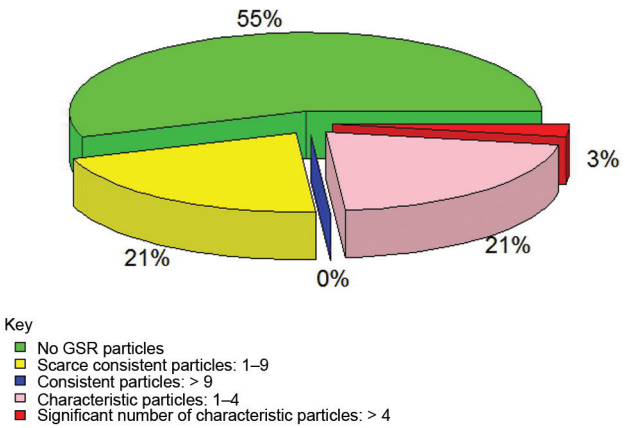

Fig. 6. Types and numbers of GSR particles revealed on police vehicles backseats.

to GSR particles, also environmental particles, mainly brass and iron alloys, were detected on the policemen hands.

The backseats of police cars were characterised by a lower level of contamination with GSR particles than the policemen hands (fig. 6). On 21 out of 38 examined seats no GSR particles were found. In the remaining cases, scarce consistent particles and single characteristic particles dominated. The obtained result is easy to explain because police officers travel on backseats only in case of convoying a detained person. The likelihood of contaminating cars by detained persons is significantly lower due to the decrease in numbers of crimes with use of firearms and thus statistically lower chance of the presence of an individual contaminated with GSR particles.

Despite their lower quantity material recovered from backseats was characterised by a higher divergence of GSR classes than samples collected from the policemen hands. As previously, GSR particles came from SINOXID type primers (PbSbBa, SSb, BaAl and PbBa particles), primers typical for former Eastern Block Countries (SSnSbHg and SnSb), primers of SINTOX type (TiZn particle) and primers of NEROXIN type (Sellier & Bellot, 2015). An example of morphology of a consistent BaCaSi sample from NEROXIN primer and the EDX spectrum from its surface were presented in figure 7.

The remaining particles were, previously mentioned, lead alloys. The number of particles in this group was significantly lower than in case of hands. Just on one backseat quite a large number, i.e. 11 characteristic GSR particles: PbSbBa were found. Similarly as in case of traces on hands, distribution of results broken into GSR classes was presented in fig. 8 where a box-plot can be found, as well as a sums of GSR particles numbers in individual classes. Again, the most numerous GSR class on backseat surface was lead and its alloys. In addition to GSR particles various environmental particles were found on the backseats, with predominance of iron alloys and flint material from lighters. As compared with traces from hands, the number of microfractions of lead was much lower.

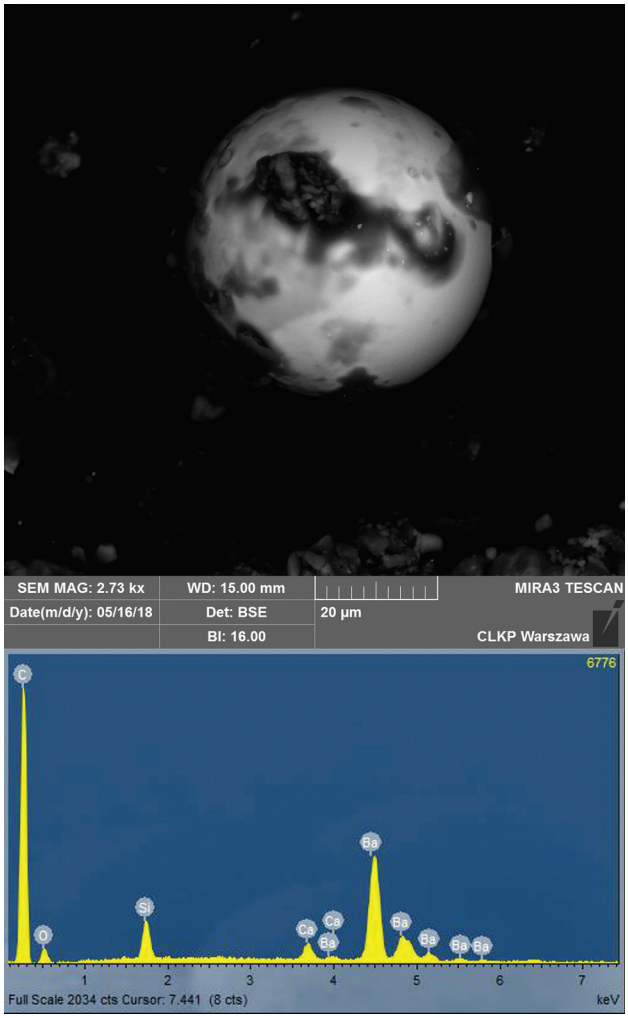

Fig. 7. Image and EDX spectrum of BaCaSi particle detected on car backseat and denominated with K17 code.

Gas chromatography analysis

Filters from ELEVAK cartridges were extracted with methanol, obtained solutions were decanted and filtered. Before the proper examination a blank control sample was made by means of extraction of an empty filter. In the control no components of smokeless powders were determined. The extracts were examined by means

Table 3. Configuration parameters used in O-GSR analysis by GC/MS.

Parameter	Value
Injector	200°C, splitless mode with injection time 1 min
Injection	1 µl, TriPlus autosampler, hot needle technique
Column	RTX-5 ms, 15 m length, inner diameter 0,25 mm, film thickness 0,25 µm
Carrier gas	He, 1,5 ml/min
Temperature programme	isotherm 45°C/1 min, ramp 16°C/min to 290°C, isotherm 290°C/0,5 min (total time 16,81 min)
Other parameters	Ion trap type mass detector, electron ionization, scanning in 29–450 m/z range, solvent delay 2,80 min

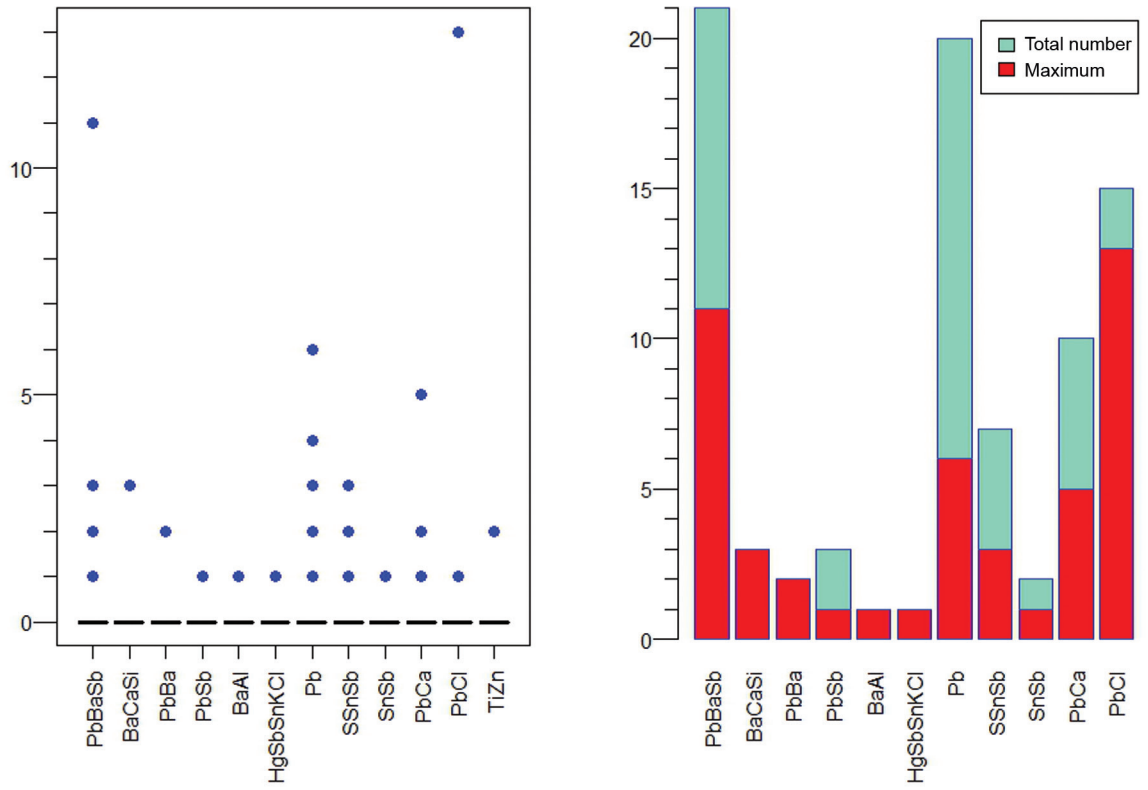

Fig. 8. Counts of particles detected on backseats divided into GSR classes.

of Thermo Finnigan Polaris Q Gas Chromatograph in conditions determined for analysis of, among others, organic gunshot residues. The aim of examination was finding possible components of smokeless powders, such as: diphenylamine, ethyl centralite, methyl centralite, naphthalene and phthalates. Acquisition parameters for the instrument are laid out in table 3.

In 15 out of 38 analysed extracts no substances in question were found. In 13 samples, diphenylamine was detected in the extract and in 9 out of 13 cases GSR particles were also present on the stub used for collecting material from the same backseat. In addition to that, controlled substances regulated by the Drug Act were revealed: cocaine was present in three solutions and tetrahydrocannabinol (THC) in one. The results are summarised in figure 9.

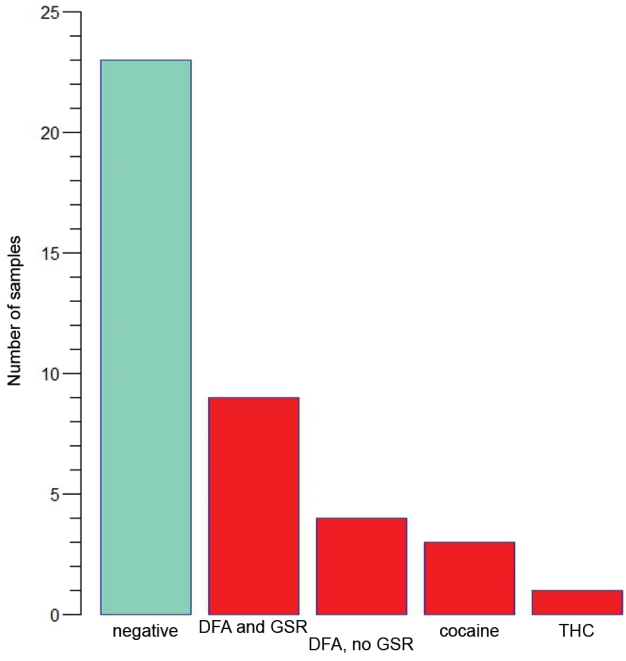

Fig. 9. Results of analysis of extracts made from ELEVAK filters bearing traces collected from backseats surfaces.

Analysis of results

The examinations demonstrated that the policemen hands were contaminated with GSR particles among whom the predominating ones were consistent particles based mainly on lead and its alloys. Despite low specificity of these particles they were found in the results of the majority of positive cases. Basing on the statistics maintained since 2014 it is possible to conclude that these particles constitute 16% of all the identified particles including also those unconnected with firearms and referred to as “environmental”. On the other hand, particles of PbSbBa composition constitute approximately 2% of all the particles, and therefore their occurrence on hands is much lower than of lead. By analysing the box-plot it can be observed that as regards particles containing lead (Pb and PbSb) the median of results in a class differs from zero, which indicates a considerable level of policemen hands

contamination with lead. The traces of antimony in lead may come both from antimony sulphide (III) used as fuel in primer initiating material, as well as projectile cores, because an addition of antimony improves lead hardness. In case of characteristic particles the problem is more complex, because except from two extreme results for police officers involved in shooting sport, the level of contamination with those highly specific GSR particles did not exceed three particles in one person. By comparing the results with those obtained by other researchers (table 4) it is possible to observe that the level of contamination with PbSbBa was comparable with data cited in literature.

An important factor in the analysis of those results was also the cultural context because, as compared with the United States or Australia police officers in Poland much rarer use firearms during their duties.

However, no relation between the number of GSR on the hands and the time, which has passed from the last hand washing; its visualization is presented in figure 10.

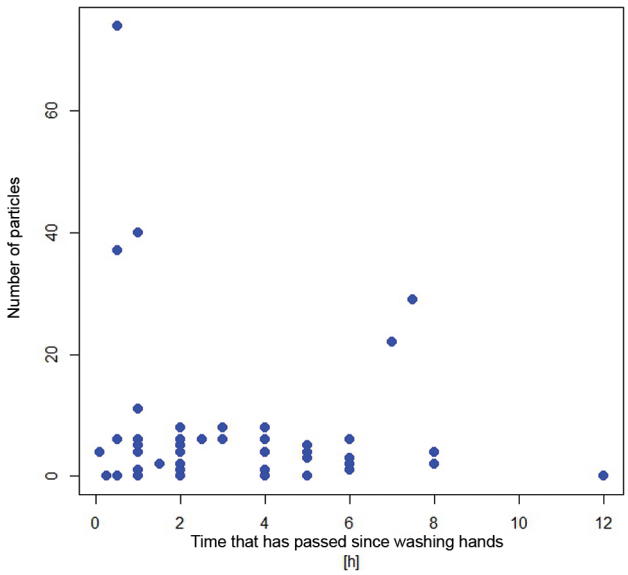

Fig. 10. Relation of the number of detected GSR particles on the hands with time that has passed from the last hand washing.

This could have been caused, first of all by inability to determine precisely the time of hand washing. Due to relatively low level of GSR particles on policemen hands the presence of those particles may have been caused also by continuous auto-contamination by uniform parts and the firearm in holster, and remain at a constant level. Despite contact with firearms at the time if its submission and collection, which entailed checking of and contact with the weapons, a high levels of GSR (over 100 particles) referred to by some of the cited sources, were not determined in any of the police officers.

The level of GSR contamination of the car backseats is almost three times higher than of the hands of policemen, regarding the numbers of detected characteristic particles. Except of two stubs, the numbers of GSR were lower than 10 and did exceed 2 characteristic particles per vehicle. Besides GSR, on 13 backseats traces of diphenylamine were found. It is a chemical compound widely used as stabiliser in smokeless powders and besides this application it is hard to point to any other rational explanation of this substance presence in police vehicles. The presence of diphenylamine in 9 out of 13 cases was linked to revealing GSR particles on the backseats, which reinforced the hypotheses on ballistic origin of that compound. Also cocaine and tetrahydrocannabinol, the biologically active substance in hemp plants were detected. The presence of traces of narcotic substances derives from the profiles of detained persons most often travelling as passengers in police cars. The level of contamination with GSR particles of Polish police cars is higher than that reported by the researchers from North America and similar to that recorded for vehicles of the Swedish Police (table 5).

It is desirable to consider the implication of the above results on issuing opinions on trace material recovered from persons suspected of using firearms. According to the applied methodology the presence of as few as three characteristic particles, five, or more consistent two-component particles, or ten, or more consistent single-component particles makes it possible to formulate a positive result of qualitative test for presence of gunshot residues. If during activities necessary to detain a suspect, for example with administrating handcuffs, physical contact of

Table 4. Occurrence of characteristic particles on policemen's hands in relation to data from literature.

	Gialamas et al. (1995)	Gerard et al. (2013), Toronto	Gerard et al. (2013), York County	Cook (2016)	Brożek-Mucha (2014)	Hereby study
Percentage of police officers with PbSbBa on their hands	7%	25%	60%	67%	30%	18%
Number of PbSbBa	<2	<8	<16	from 1 to over 100	from 1 to over 100	1–27

Table 5. Frequency of occurrence of characteristics particles on backseats of police cars, as compared to literature data.

	Berk et al (2007)	Gerard et al (2013)	Pettersson (2003)	Hereby study
Percentage of vehicles with PbSbBa on backseats	1%	6%	25%	24%
Number of PbSbBa	<2	<3	12 and more	1–11

a policeman with a suspect takes place, the possibility of transferring GSR particles ought to be taken into consideration. If a police officer making an arrest did not use a firearm, the number of transferred GSR particles cannot be of significance because the contamination of police officers hands is at the level of a few characteristic particles. This risk increases if an arrest is executed by an counterterrorist squad or police officers who may bear a larger number of GSR on their bodies (sport shooting, hunting). If we refer the above conclusions to the ones reached by Sebastien Charles in the first scenario on might state that the final level of arrestee's contamination can be similar to that of the hands of the police officer and in these cases a false positive result is realistically possible.

The risk of contaminating a detained person caused by his/her transportation on the backseat of a police car seems much lower, than that entailed by physical contact. Only in 2 out of 38 vehicles the number of GSR particles would be sufficient for effective contamination of a detained person so that the first kind of error might occur. Even then the chance of transferring particles onto the areas of hands where GSR are usually deposited as a result of shooting would be lower than contamination of transported person's clothes.

Final results

The contamination of policemen hands and backseats of police cars is a fact confirmed by research. Its level is not as high as for the chance of transferring gunshot residues from a police officer to the detained person or from a police car to the transported individual should discredit every performed examination for the presence of GSR. The risk, however, exists and its minimising requires undertaking complex activities by law enforcement authorities. A positive step towards that direction, already implemented in Warsaw police garrison is the use of lead-free ammunition by policemen. A wide use of lead-free ammunition by police officers is favourable due to lower toxicity of powder gas and reduces the risk of contaminating third persons with GSR particles. An ideal situation would be using such ammunition by the entire force and assuming a target of implementation of police ammunition primer doping programme in order to be able to identify GSR particles originating from service weapons. It would be also advisable to perform forensic procedures, such as recovery of traces from hands, at the scene, if feasible in a given case. That would limit losing of traces and their uncontrolled transfer during transport. In justified cases, it would be also useful to collect control samples from police officers making the arrest.

If detained person's garment is to be the object of further examinations, not only chemical analyses, police cars seats should be protected with disposable covers or the suspect should wear a disposable overall.

Sources of figures and tables:
Figures 1–10: *author*
Table 1: *Charles, Geusens, 2011*
Tables 2–5: *author*

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Translation Ewa Nogacka