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DEPOSITION OF GUNSHOT RESIDUE WHEN FIRING «FORT 12R» AND «AE 790G1» PISTOLS

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Summary. The key element of pre-wound ballistics, which is of particular interest to forensic experts and criminologists, remains the residual components of the shot, represented by small spheroids. And although classically the greatest attention is paid to the so-called «forensic ballistics whales» such as stibium, lead and barium, the very ratio and presence of other trace elements plays an important role in the ability to identify firearms and other circumstances that may be of interest to the police.

Aim of the work. To determine the peculiarities of the deposition of the residual components of the shot, namely, microelements on the tracer object when fired from «FORT 12R» and «AE 790G1» pistols from contact range, 25 and 50 cm.

Materials and methods. 120 gelatin blocks were produced, divided into two groups of 60 blocks each, to be fired from the «FORT 12R» and «AE 790G1» pistols. Within each group, subgroups of 15 blocks are formed depending on the covering material, namely: bare blocks, blocks covered with cotton fabric, denim fabric or leatherette. The blocks in each subgroup were to be shot from different distances: contact range (5 blocks), 25 cm (5 blocks) and 50 cm (5 blocks). After firing, X-ray fluorescence spectroscopy was performed to determine the elemental composition, chromato-mass spectrometric method, and infrared microscopy on a combined IR-Fourier spectrometer to identify gunpowder components. The obtained indicators were subjected to statistical processing in the «Statistica 6.0» program.

Results. The largest number of reliable differences was found in the study of the deposition of such elements as lead and iron, a smaller number in the analysis of zinc, and in the analysis of copper, no differences between the studied groups were found; when analyzing the components of gunpowder, it was established that they are mostly present when contact shots are fired from the «AE 790G1» to the blocks covered with denim fabric.

Conclusions. The revealed numerous reliable differences between the studied groups regarding such elements as lead, iron and zinc allow them to be used for the purpose of further identification of the distance of the shot and the weapon.

Keywords: gunshot residue; gunshot injury, gunshot wounds, non-lethal weapons, firearm, X-ray fluorescence spectroscopy.

Introduction. Injuries caused by firearms are a widespread problem reaching the proportions of a «global epidemic». Data from a 1998-2011 analysis conducted in the United States show that for every 10,000 hospitalizations, there are about 10 injuries caused by firearms. About 60 % of all injuries are the result of assault, 23 % accidents and about 8 % suicide attempts, suicide. It is worth noting that the main age group that suffers this kind of damage is young people (18-24 years old). Also, the average cost of hospitalization per year costs the US budget 679 million dollars [10].

Separately, it should be noted a type of firearm – a non-lethal weapon, which is often in the arsenal of law enforcement agencies [1], or is allowed within the limits of the legislation to be carried by the wider population. However, despite its name as a «non-lethal weapon», in reality it can cause both serious injuries [6] and fatalities [9].

The study of the action of firearms is a complex and complex process, which involves conducting studies of both pre-wound and wound ballistics. In the case of the latter, we are talking about the use of optically transparent substances imitating the tissues of the human body [4] with or without layers of clothing [2]. In the case of pre-wound ballistics research, it is advisable to use a powerful complex of laboratory and visual studies, one of which is X-ray fluorescence spectroscopy, which allows identification of one of the key «witnesses of the shot» – residual components of the shot.

Considering the relevance of the topic, it is necessary to conduct a controlled experiment with the use of domestic samples of non-lethal firearms, which would allow identifying the peculiarities of the deposition of microelements on the trace-receiving surface.

Aim of the work. To determine the peculiarities of the deposition of the residual components of the shot, namely, microelements on the tracer object when fired from «FORT 12R» and «AE 790G1» pistols from contact range, 25 and 50 cm.

Materials and methods. In order to achieve the goal, an experimental controlled firing of 120 gelatin blocks measuring 30x15x15 cm made according to the method of Fackler and Malinowski [3] using gelatin type A 270 Bloom (TM «Junca Gelatines SL», Spain) was carried out. In order to simulate human skin, all blocks were wrapped with a transparent polyethylene film with a thickness of 200 μm. The blocks were divided into 4 groups depending on the type of covering: group 1 – bare blocks (BB), group 2 – blocks covered with cotton fabric (CF), group 3 – blocks covered with denim fabric (DF), group 4 – blocks covered with leatherette (LB). The shooting took place with the use of fixed pistols «Fort 12R» and «AE 790G1», equipped with 9 mm cartridges (elastic bullets of traumatic effect) from contact range, 25 and 50 cm at the base of the Vinnytsia Research Expert Forensic Center of the Ministry of Internal Affairs of Ukraine.

X-ray fluorescence spectroscopy using the ElvaX Plus device was used to identify the qualitative and quantitative characteristics of the overlay of elements on clothing and a non-biological human body simulator. In order to detect diphenylamine and centralite, a chromato-mass spectrometric method (Shimadzu GC-2010 Plus apparatus) and infrared microscopy on a combined IR-Fourier spectrometer (Nicolet iN10 apparatus from Thermo Fisher Scientific) were used.

The statistical analysis of the obtained results was carried out in the licensed statistical package «Statistica 6.0» using non-parametric estimation methods. The reliability of the difference in values between independent quantitative values was determined using the Mann-Whitney U-test, and between qualitative values – according to the Weber E.

Research results. The analysis of *lead* deposition indicators revealed the following features:

- when shooting from a distance of 25 cm using the «FORT 12R» pistol, significantly higher values ($p<0,05-0,01$) of the element are observed when shooting at BB than at CF or LB ((84,80 ± 10,38), (67,80 ± 4,97) and (51,00 ± 26,55), respectively); when shooting from a distance of 50 cm using the «FORT 12R» pistol, significantly higher values ($p<0,05$) of the element are observed when shooting BB than CF ((80,20 ± 5,72) and (69,80 ± 4,44), respectively); when comparing the values of the indicator when shooting from «FORT 12R» from different distances, significantly higher values ($p<0,05-0,01$) of the element were found when shooting BBs at contact range than at 50 cm ((87,80 ± 4,38) and (80,20 ± 5,72), respectively), with contact shots in CF than 25 or 50 cm ((92,00 ± 0,71), (67,80 ± 4,97) and (69,80 ± 4,44), respectively), with contact shots in LB than 25 cm ((92,60 ± 8,41) and (51,00 ± 26,55), respectively);
- when shooting at close range using the «AE 790G1» pistol, significantly higher values ($p<0,05-0,01$) of the element are observed when shooting at DF than at BB or CF ((92,40 ± 1,82), (76,60 ± 21,67) and (86,80 ± 5,81), respectively); when shooting from a distance of 25 cm using the «AE 790G1» pistol, significantly higher values ($p<0,05$) of the element are observed when shooting in DF compared to CF ((85,40 ± 11,08) and (66,40 ± 8,56), respectively), significantly ($p<0,01$) lower values of the element when shooting in LB compared to other groups of blocks ((45,60 ± 1,95), (76,60 ± 3,51), (66,40 ± 8,56) and (85,40 ± 11,08), respectively); when shooting

from a distance of 50 cm using the «AE 790G1» pistol, significantly lower values (p<0,01) of the element are observed when shooting at LB, compared to CF and DF ((52,60 ± 5,59), (68,20 ± 5,85) and (73,40 ± 6,11), respectively); when comparing the values of the indicator when shooting with «AE 790G1» from different distances, significantly higher values (p<0,05-0,01) of the element were found when shooting at contact range, compared to 25 and 50 cm in CF ((86,80 ± 5,81), (66,40 ± 8,56) and (68,20 ± 5,85), respectively), when shooting at contact range compared to 50 cm, and 25 cm compared to 50 cm in DF ((92,40 ± 1,82), (73,40 ± 6,11) and (85,40 ± 11,08), (73,40 ± 6,11), respectively), when shooting at contact range, compared to 25, 50 cm and when comparing 25 and 50 cm in LB ((89,20 ± 3,19), (45,60 ± 1,95) and (52,60 ± 5,59), respectively);

- when comparing the values of the indicator when fired from the «FORT 12R» and «AE 790G1» pistols, its values were significantly higher (p<0,05) when fired from the «FORT 12R» when fired at contact range in CF and at a distance of 50 cm in LB ((92,00 ± 0,71) and (86,80 ± 5,81), (78,80 ± 21,58) and (52,60 ± 5,59), respectively).

The analysis of indicators of *iron* deposition revealed the following features:

- when shooting at contact range using the «FORT 12R» pistol, significantly higher values (p<0,05) of the element are observed when shooting BB compared to CF ((10,00 ± 3,81) and (5,600 ± 0,548), respectively); when shooting from a distance of 25 cm using the «FORT 12R» pistol, significantly higher values (p<0,05) of the element are observed when shooting at LB compared to BB and DF ((39,00 ± 23,04), (10,80 ± 10,55) and (14,40 ± 8,41), respectively); when comparing the values of the indicator when fired from «FORT 12R» from different distances, significantly lower values (p<0,01) of the element were found when fired at CF at contact range, compared to 25 or 50 cm ((5,600 ± 0,548), (20,20 ± 2,95) and (21,20 ± 6,50) respectively) and when shooting at LB at contact range, compared to 25 cm ((5,200 ± 5,891) and (39,00 ± 23,04), respectively);
- when shooting at contact range using the «AE 790G1» pistol, significantly higher values (p<0,05-0,01) of the element are observed when shooting at BB or CF compared to DF and LB ((22,20 ± 21,26), (11,80 ± 4,49), (5,600 ± 1,673) and (7,400 ± 1,140), respectively); when shooting from a distance of 25 cm using the «AE 790G1» pistol, significantly higher values (p<0,05-0,01) of the element were observed when shooting BB compared to DF, LB compared to other groups, and CF compared to DF ((17,40 ± 4,67), (4,800 ± 6,573) and (42,80 ± 1,30), (17,40 ± 4,67), (24,80 ± 4,76), (4,800 ± 6,573) and (24,80 ± 4,76), (4,800 ± 6,573), respectively); when shooting from a distance of 50 cm using the «AE 790G1» gun, significantly higher values (p<0,05) of the element are observed when shooting at LB compared to CF or DF ((36,60 ± 8,05), (21,20 ± 5,72) and (18,60 ± 3,78), respectively); when comparing the values of the indicator when shooting with «AE 790G1» from different distances, significantly lower values (p<0,05-0,01) of the element were found when shooting at contact range, compared to 25 and 50 cm in CF ((11,80 ± 4,49), (24,80 ± 4,76) and (21,20 ± 5,72), respectively), when shooting at contact range compared to 50 cm, and 25 cm compared to 50 cm in DF ((5,600 ± 1,673), (18,60 ± 3,78) and (4,800 ± 6,573), (18,60 ± 3,78) respectively), when shooting at close range, compared to 25, 50 cm in LB ((7,400 ± 1,140), (42,80 ± 1,30) and (36,60 ± 8,05), respectively);
- when comparing the values of the indicator when fired from the «FORT 12R» and «AE 790G1» pistols, its values were significantly higher (p<0,01) when fired from the «AE 790G1» at contact range in CF ((11,80 ± 4,49) and (5,600 ± 0,548), respectively).

During the analysis of *copper* deposition indicators, no significant differences or trends to differences between the studied groups were found.

The analysis of *zinc* deposition indicators revealed the following features:

- when comparing the values of the indicator when fired from «FORT 12R» from different distances, significantly lower values (p<0,01) of the element were found when fired at contact range in CF, compared to 25 cm ((2,400 ± 0,548) and (10,40 ± 4,83), respectively);

- when shooting at contact range using the «AE 790G1» pistol, significantly lower values ($p<0,05$) of the element are observed when shooting in CF compared to DF and LB ((0,600 ± 0,894), (2,000 ± 0,707) and (2,000 ± 0,707), respectively); when shooting from a distance of 25 cm using the «AE 790G1» gun, significantly lower values ($p<0,05$) of the element are observed when shooting at BB compared to LB ((4,800 ± 4,025) and (11,60 ± 2,88), respectively); when shooting from a distance of 50 cm using the «AE 790G1» pistol, significantly lower values ($p<0,005$) of the element are observed when shooting at BB compared to CF and LB ((6,000 ± 1,225), (9,000 ± 2,236) and (10,80 ± 3,77), respectively); when comparing the values of the indicator when fired from the «AE 790G1» from different distances, significantly lower values ($p<0,01$) of the element were found when fired at contact range compared to 50 cm when fired at BB, CF and LB (for the latter also at close range compared to 25 cm) ((1,200 ± 0,837), (6,000 ± 1,225) and (0,600 ± 0,894), (9,000 ± 2,236) and (2,000 ± 0,707), (11,60 ± 2,88), (10,80 ± 3,77), respectively);
- when comparing the values of the indicator when fired from the «FORT 12R» and «AE 790G1» pistols, its values were significantly higher ($p<0,05$) when fired from the «FORT 12R» when fired at contact range in BB and CF ((3,400 ± 1,517) and (1,200 ± 0,837), (2,400 ± 0,548) and (0,600 ± 0,894), respectively) and when fired with «AE 790G1» from a distance of 25 cm in LB ((11,60 ± 2,88) and (6,400 ± 4,099), respectively).

The analysis of indicators regarding the deposition of *diphenylamine* revealed that the deposition of this component of gunpowder was observed only when fired at close range in the DF when fired from the «AE 790G1» gun.

The analysis of *centralite* deposition indicators revealed the following features: this powder component was observed when fired from the «FORT 12R» pistol only at CF at a shot distance of 25 cm; when firing from the «AE 790G1» pistol, the centralite was observed when firing at contact range in DF and when firing from a distance of 50 cm in BB and LB.

A. M. Gurov with co-authors in a similar study, when working with «Fort-12» and «Fort-14 TP» pistols, statistically reliable linear multivariate and pairwise regression models were built, which allow calculating the distances of shots from pistols for damage to cotton fabric. It should be noted that in this case the authors used a stereomicroscope to search for residual components of the shot [5].

As the results of experimental studies have shown, when performing an examination to determine the distance of a shot, it is possible to use unburned gunpowder particles, which are expediently determined by performing the diphenylamine reaction [7], however, it is necessary to take into account contamination by gunpowder particles that can accidentally fall on the victim’s body and thus distort data interpretation [12].

However, the key role is still assigned to the study of the peculiarities of the deposition of microelements. Thus, it was determined that the residual components of the shot are observed within a radius of 3 cm from the edge of the bullet and their number decreases when the distance of the shot increases from 20 to 60 cm [8].

Turillazzi E. and co-authors [11], when performing a series of experimental shots, established that within the close range of the shot, high concentrations of such elements as Pb, Sb, and Ba predominate, while when the distance of the shot increases, their number, on the contrary, decreases.

Data from Malayan researchers indicate that there is a proportionally linear relationship between the dispersion of GSR particles and shot distance. Thus, the diameter of the GSR distribution and the number of residues remaining on the tracking object during shots decrease at a distance of more than 21 cm, according to their experimental shooting data [14].

At the same time, it is worth noting the almost complete absence of works devoted to the analysis of how different types of fabrics affect the characteristics of the layering of the residual components of the shot [13].

Conclusions. Numerous reliable differences between the investigated groups of blocks were revealed, which allows further identification of the weapon and the distance of the shot depending on the material of the clothing. When increasing the distance of the shot, both with the shots from «Fort 12R» and «AE 790G1», a decrease in the amount of lead is noted, while the amount of iron and zinc, on the contrary, increases. No differences between the studied groups were found in the study of the overlap of the copper element. Gunpowder components are most often observed when close-range shots are fired into denim-covered blocks from the «AE 790G1» pistol.

Prospects for further research. In the future, it is planned to build reliable discriminating models on the basis of the received data, which will allow identification of «Fort 12R» and «AE 790G1» pistols and the distance of a shot from them.

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ВІДКЛАДАННЯ ЗАЛИШКОВИХ КОМПОНЕНТІВ ПОСТРІЛУ ПРИ ПОСТРІЛАХ З ПІСТОЛЕТІВ «FORT 12R» ТА «AE 790G1»

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Резюме. Ключовим елементом передраневої балістики, що становить особливий інтерес для судово-медичних експертів і криміналістів, лишаються залишкові компоненти пострілу, що представлені дрібними сфероїдами. І хоча класично найбільша увага приділяється так званим «китам судової балістики» стибію, плюмбуму та барію, саме співвідношення та наявність інших мікроелементів відіграють важливу роль у можливості ідентифікації вогнепальної зброї й інших обставин, що можуть цікавити органи дізнання.

Мета роботи. Дослідження особливостей відкладення залишкових компонентів пострілу, а саме мікроелементів на трасуючому об'єкті, при пострілах з пістолетів «FORT 12R» і «AE 790G1».

Матеріали та методи. Були виготовлені 120 желатинових блоків, поділені на дві групи по 60 блоків, що підлягали відстрілу з пістолетів «FORT 12R» та «AE 790G1». Всередині кожної групи були сформовані підгрупи по 15 блоків залежно від матеріалу покриву, а саме: голі блоки, блоки, покриті бавовняною тканиною, джинсовою тканиною чи шкірозамінником. Блоки в кожній підгрупі підлягали відстрілу з різних дистанцій: впритул (5 блоків), 25 см (5 блоків) і 50 см (5 блоків). Після відстрілу виконували рентгенофлуоресцентну спектроскопію з метою встановлення елементарного складу, хромато-мас-спектрометричний метод та інфрачервону мікроскопію на суміщеному ІЧ-Фур'є спектрометрі для виявлення компонентів пороху. Отримані показники підлягали статистичній обробці в програмі «Statistica 6.0».

Результати. Найбільша кількість достовірних відмінностей була виявлена при дослідженні відкладання елементів, як-от свинець і залізо, менша кількість – при аналізі цинку, а при вивченні міді будь-яких відмінностей між досліджуваними групами встановлено не було; при аналізі компонентів пороху було виявлено, що вони здебільшого присутні при пострілах з «AE 790G1» впритул у блоки, вкриті джинсовою тканиною.

Висновки. Встановлені численні достовірні відмінності між досліджуваними групами щодо елементів, як-от свинець, залізо та цинк, дозволяють застосовувати їх з метою подальшої ідентифікації дистанції пострілу та знаряддя.

Ключові слова: залишкові компоненти пострілу, вогнепальна травма, вогнепальні ушкодження, нелетальна зброя, вогнепальна зброя, рентгенофлуоресцентна спектроскопія.

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