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USING THE METHOD OF PRINCIPAL COMPONENTS IN STUDY OF THE DATA OBTAINED BY MEANS OF X-RAY FLUORESCENT SPECTRAL ANALYSIS ON THE ELEMENTAL COMPOSITION OF CLOTHING DAMAGES AREAS AT THE SHOOTING OF NONLETHAL ELASTIC BULLETS "TEREN-12P" AMMUNITION

Victor Sapielkin

**Kharkiv Medical Academy for Post-Graduate Education (KhMAPGA), Kharkiv,
Ukraine**

Abstract

This work is executed in accordance with individual subjects "Medico-legal diagnostics of the damages caused at shots by elastic bullets from the smooth-bore weapon of 12th caliber", state registrations number #0111U002178, that is executed on the department of forensic medical examination in KhMAPGA. The definition of scientific-based criteria for objectively diagnoses of cloth damages caused at shots by the "Teren-12P" cartridges elastic bullets, which are in service with the law enforcement agencies of Ukraine, is currently a topical problem in forensic medicine. Using six common samples of clothing fabrics and ballistic plasticine, experimental shots from the "Fort-500A" pump gun were carried out with "Teren-12P" cartridges bullets at distances of 0-15 m. Using X-ray fluorescent spectral analysis (XRF) the elemental composition of bullets, powder gases removed from the gun barrel after the shot, as well as the target fabric before the shots and in the damage areas after the shots were determined. Analysis and processing of the qualitative and quantitative composition of chemical elements in the damage areas was carried out using the chemometric approach – the method of main components. The main criteria for diagnosing cloth damage

by the “Teren-12P” cartridge bullet with the help of XRF, which can be used in the relevant expert studies, are established.

Key words: elastic bullet of nonlethal action, cartridge (ammunition) “Teren-12P”, gunshot clothing fabric damage, X-ray fluorescence spectral analysis, chemometric approach, principal component method.

Introduction. Application by law enforcement authorities officers of regular smooth-bore guns charged with large-caliber elastic bullets cartridges for stopping of group public or mass disturbances nuisance usually results in the nonlethal wounds of many people. As the regular large-calibre cartridges of nonlethal action intended for shots from pump guns “Fort-500” that are the regular weapon of Special Forces of the Ministry of Interior of Ukraine, and other smooth-bore guns of the 12th caliber the common cartridges certified in Ukraine “Teren-12P” which are made by the Research and Production Enterprise “Ecologist” (Kiev) are used at present [1].

Modern researches of gunshot trauma must be based on the complex study of objects with application of the special knowledge in different areas of science and technology, use of highly sensitive apparatus, newest scopes and imitators of biological tissues, innovative biomechanics and digital technologies, mathematical and statistical methods of analysis and others like that. Forensic medical diagnostics of damages in the body and clothing caused by the elastic bullets of middle caliber cartridges of different firms-producers at Ukraine are lighted up in works of domestic specialists on judicial medicine widely enough [2, 3, 4, 5]. However, the scientifically-reasonable diagnostic criteria based on permanent methodological principles that would allow setting the clothing damages caused at shots by the elastic bullets of “Teren-12P” cartridges objectively are not worked out in forensic medicine at present.

Objective: to determine expediency of the use of chemometrical approach – the method of main components (MMC) at processing of the data obtained by means of X-ray fluorescent spectral analysis (XRF) on the elemental composition of clothing damages areas at the shooting of nonlethal elastic bullets "Teren-12P" ammunition.

Material and methods. Targets were made from the next six samples of fabric: artificial leather stretch material on fleece basis (sample "A"), cotton knitting linen (sample "B"), artificial leather material with polyvinylchloride (PVCh) coverage on tissue basis (sample "C"), cloak tissue on the monolayer polyester lining (sample "D"), cloak tissue (sample "E") and camouflaged tissue "Greta" color the "Forest" (sample "F"). The all of above-mentioned fabric have different physico-mechanical and trace-acceptable

characteristics and presently widely used for clothes making [6]. The blocks of ballistic plasticine of "Beschussmasse, 6287156" (a producer is "Carl Weible KG" firm, Germany) certificated by the European committee for standardizations for ballistic researches were used as the basis for targets [7]. Experimental shots were conducted from the "Fort-500A" gun at right angles to the surface of tissue target by series for five shots in every target by the bullets of "Teren-12P" cartridges from nine distances – back-topback, 5 cm, 10 cm, 50 cm, 1 m, 3.5 m, 5 m, 10 m and 15 m. Shot distance of 15 m was select as "maximum" to 20 m minimum distance for application of these cartridges settled by its producer. There was 270 investigational objects at all.

Elemental composition of bullets from "Teren-12P" cartridges, of gunpowder gases that were withdrawn from the barrel of gun after a shot, and also of fabric in targets of "A" – "F" samples in an initial kind (before the shots) and in the areas of damages after the shots were investigated by the method of XRF using for registration of spectrums the "ElvaX" spectrometer and the licensed software that is supplied together with this device. This spectrometer is intended for nondestructive rapid test of elemental composition and has limits in exposure of admixtures of heavy metals in the easy matrix of 1 ppm, the error in measuring of mass parts of metals presents a 0,1%. The essence of XRF consists in the irradiation of the investigated material fragment with the high-energy (x-rayed) rays and in the registrations of nascent here fluorescent radiation spectrum [8, 9, 10]. The general advantages of using the XRF method in forensic medical expert research before other methods of atomic spectrology are: 1) minimum duration and simplicity of preparation of object. Samples do not need incineration or transformation in solution and are investigated in an unchanging kind, they need to be only dried out to an air-dry state (it takes place automatically if there is a vacuum chamber moving away of moisture); 2) objects of research do not collapse and do not test changes at qualitative and quantitative level during the research (certainly, the fragments of fabric need to be cut out before studying); 3) promptness – the checking time of one spectrum folds a few minutes. Registration of spectrums of the x-rayed fluorescence (XF) for control experience is executed in three separate points of cloths samples. The registrations of the XF spectrums after the shot are carried out from the areas located close to the damages caused by a bullet, which have stratifications look like polymeric bullets material.

The analysis of qualitative and quantitative composition of chemical elements with establishing of internal hidden connections between separate indexes and determination of layers formation patterns are conducted with the use of chemometrical approach – MMC, that is comfortable modern method of statistical analysis, in particular of gunshot residue, for

visualization and interpretation of multidimensional data [11, 12, 13]. The essence of MMC consists in bringing a large array over of the initial coordinates (the amounts of coordinate axes corresponds to the amount of variables in an initial array – N) given to the system, where in the first coordinate axis (first main component) there are most variables of base data in N – a measure space. In the second main component considerable part of remaining variation is described, here the second coordinate axis is perpendicular to the previous one etc. By means of the first two-three main components it is possible visually and quickly to distinguish the objects that differ from the others; to educe the groups of similar objects; to analyze which variables are the most impotent for the results of the research; to set what variables are correlated together and to cast aside part of data as "noise" constituent [14, 15, 16]. Study by the method of MMC and processing of data is undertaken with the use of the licensed statistical package of Statistica 10.0 Enterprise (a developer is a company StatSoft Inc., THE USA).

Results of the research and their discussion. At researches of chemical and elemental composition of the "Teren-12P" cartridge bullet using the methodology of systematic authentication of polymers and XRF it is established that a bullet is made from improved polyvinylchloride which consists mainly of Ca (about 90%), Cl, Sr and Pb, with the admixture of aluminum powder (of about 4 – 6%). As a component parts of gunshot residue from the barrel of "Fort-500A" gun after the shot by the "Teren-12P" cartridge bullet there are educed Fe, Pb and Cu. Absence of furnace (Sb) as one of the component of combustion products can be predefined by the unevenness of its distribution, subzero content or disguise of fluorescence lines of other elements.

Research of the data got with the use of XRF method by means of MMC for the sample "A" is shown in Figure 1.

Additionally it is more evidently represented the information about the elemental composition of the sample "A" in a three-measurable kind. At the construction of three-measurable diagrams the base data about the intensity of XF lines are normalized for every element. It allows imagining simultaneously character of change in intensity of XF lines for elements both with large intensity and with small one, representing them in one system of coordinates. The samples projections in the new system of coordinates (from factor 1 to factor 3) are shown in Figure 1 in the left column, and influence (part) of variables (values of intensity of XF lines of the elements) in the sample "A" is shown in a right column on a projection with a circumference.

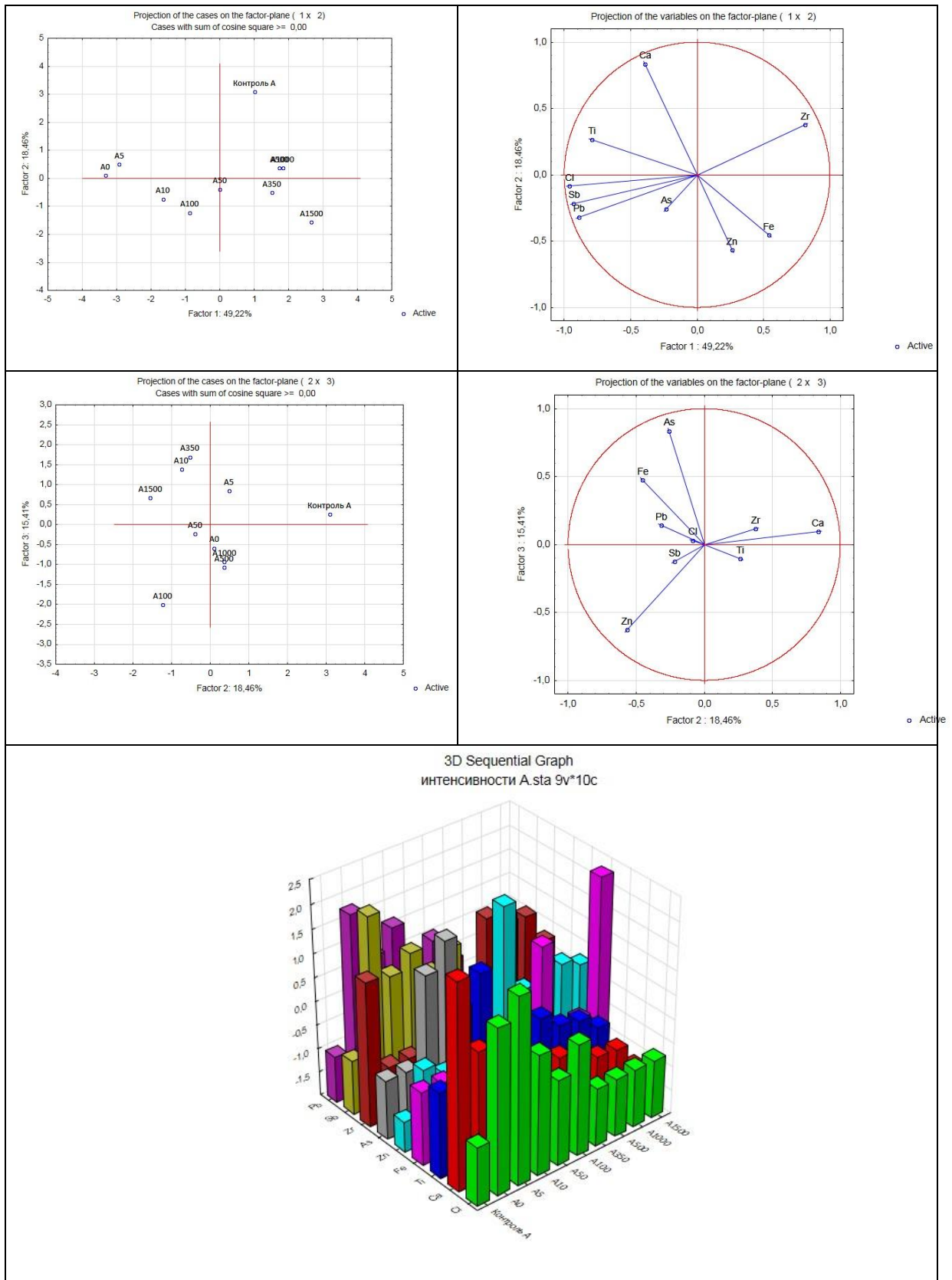


Figure 1. Research of elemental composition of damages areas in the sample "A" fabric by means of MMC

For forming of projections there are used data concerning the first three main components (factors), that stipulate more than 80% of variations of the proxy variables (a concrete value for every factor is indicated near its name, based on data of calculations).

On the basis of processing and analysis of data about elemental composition in the contact area of the "Teren-12P" cartridge bullet with the targets of fabric samples "A" – "E", that included the visual estimation of the got results and application of chemometrical approach (MMC), the following is set. The next features of exposure of chemical elements are testify about the traces of the "Teren-12P" cartridge elastic bullet on clothing fabric in a place them credible contact: 1) if there is Cl in fabric composition at the control measuring the intensity of its XF lines after the shot diminishes or quite not fixed, in default of Cl in fabric composition at the control measuring its XF lines can appear after the shot; 2) intensities of XF lines of Ca are systematic diminish or quite not marked after the shot; 3) in default of Fe in fabric composition at the control measuring its XF lines can appear after the shot from any investigational distance, at presence of Fe in fabric composition at the control measuring the increase of intensity of its XF lines is marked at the close shot and were weaker than initial intensity at the increase of shot distance; 4) XF lines of Zn were not marked in fabric composition at the control measuring, after the shot the XF lines of Zn were registered in 44 cases from 54; 5) XF lines of As were not marked in fabric composition at the control measuring, after the shot the XF lines of As were registered in 23 cases from 54; 6) XF lines of Sb were not marked in fabric composition at the control measuring, after the shot the XF lines of Sb were registered in 20 cases from 54 to all shot distances, 17 cases (85%) from that were made on distance to 1 m; 7) XF lines of Pb were not marked in fabric composition at the control measuring, after the shot the XF lines of Pb were registered in 47 cases from 54; 8) the content of Ti were diminished in 29 cases from 45. At research of samples "B" Ti was found neither to nor after the shot. Thus, reduction the XF lines intensity of Ti should be considered only as an additional sign in relation to the contact with the "Teren-12P" cartridge bullet.

As XF lines intensity of Zr and Br can both diminish and increase, exposures of these elements are not informing in relation to the bullet contact with fabric. Ac, Sr, Ce, Re and Cu, were though noticed on occasion in gunshot residue, but on results of our research can not be used as signs of contact of bullet with clothing fabric. On occasion an exception can be done for Cu, which stably appeared in combustion products of gunpowder in the barrel channel.

A presence or absence of chemical elements are signs, certain totality of which is faithful for the results of shots from every distance for the samples "A" – "E": 2 signs – 1

(1,8%); 3 signs – 9 (16,7%); 4 – 11 (20,4%); 5 – 16 (29,6%); 6 – 12 (22,2%); 7 – 5 (9,3%). Thus, in more than 98% of shots cases from different distances there is totality at least 3 signs, and in 81% of shots cases it is observed 4 or more signs that together with results of forensic medical, criminalistics, chemical and ballistic expert examinations can be used for confirmation the fact of shot exactly by the "Teren-12P" cartridge bullet.

Pb is the basic element at a shot by unshelled bullet on clothing fabric. The content of Pb exceeds 90% and approached to 100%. And at a shot by covered bullet Cu and Zn are mainly determine. In the composition of the "Teren-12P" cartridge bullet the content of Pb set through the XRF method does not exceed 50% and Cu and Zn does not appear. Thus, elemental composition based on XRF data can be used as a sign by means of that it is possible to distinguish the contact place of fabric with the "Teren-12P" cartridge bullet from the contact place with covered or unshelled metallic bullet.

Conclusions and prospects for further researches in this direction.

The application of XRF method is expedient for the decision of question, if the damages on the separate clothing areas are made by the "Teren-12P" cartridge bullet. Qualitative and quantitative indexes of elemental composition in the sites of damage and in a control test (on an intact area), allow to decide the question, if these damages could appear from the shot by the "Teren-12P" cartridge elastic bullet. Data about quantitative content of elements have to be represented as intensity of XF lines but not as normalized content. The lines intensity characterizes the absolute elemental composition in organic material (tissue, layering of bullet material), the educed character of change in which (structure) testifies to possibility of realization the shot by the "Teren-12P" cartridge bullet.

The main criteria for diagnostics and authentication of clothing fabric damages by the "Teren-12P" cartridge bullet by means of XRF are next results of research:

- reduction the intensity of elements lines that being in a control test. Calcium, titan, chlorine and iron (the last two can be absent in a control test) are mainly include to these elements;

- appearance of elements, which were absent in a control test – there are mainly iron, chlorine, zinc, arsenic, furnace, lead, copper. Iron forms the part of alloys, and a copper is marked in layers of gunpowder combustion products in the barrel channel. Other elements can be contained in composition of the bullet or definitely to accompany the shot.

Although calcium is contained in composition of the "Teren-12P" cartridge bullet material, data about reduction the content of calcium on the damaged area surface (in

comparing to the control test) are one of the most recreated (were observed in 90,7% of experiments).

Appearance of furnace on the damaged area is the indirect sign of the close distance (to 1 m) shot. In 85% of experimental researches at the shot from a less than 1 m distance there was appearance of furnace that forms the part of percussion cap substance to the cartridge.

Conclusion about belonging of elemental composition that was educed in the clothing fabric damage area to the "Teren-12P" cartridge bullet can be set forth only in a credible form because of the influence on composition and number of the bringing elements of amount of trace formation conditions.

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