Forensic Chemistry 1 (2016) 22–30

Contents lists available at ScienceDirect

Forensic Chemistry

journal homepage: www.elsevier.com/locate/forc

Development, design, and realization of a proficiency test for the Forensic Determination of Shooting Distances – FDSD 2015 ☆

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ARTICLE INFO

Article history:
Received 27 April 2016
Received in revised form 15 June 2016
Accepted 27 June 2016
Available online 4 July 2016

Keywords:
Forensic science
Gunshot residues
GSR
Firearms
Shooting distance determination
Muzzle-to-target distance
Lead distribution
Proficiency testing
ENFSI
ISO 5725
Statistical evaluation
z scores
Chemographic coloring
Chromophoric reaction
Sodium rhodizonate

ABSTRACT

Within the framework of the ENFSI Expert Working Group Firearms/GSR a novel proficiency test on the *Forensic Determination of Shooting Distances – FDSD 2015* – was implemented. This proficiency test was developed out of collaborative studies which were previously carried out by a number of pre-selected ENFSI laboratories. The aim of this test was to assess the laboratories' performance in visualizing the lead patterns on a shot object, and compare the questioned patterns with provided test shot patterns. The participating laboratories were requested to estimate the presumed shooting distance following their individual laboratory specific methods (SOPs) for shooting distance/muzzle-to-target determination. The submitted results were compiled by means of z scores according to the IUPAC and EURACHEM guidelines, and an extended statistical evaluation was performed. This is one of the first proficiency tests in the field of qualitative forensic methods where z scores were successfully utilized. This paper summarizes the results of the study and presents the overall performance of the participating laboratories.

The determination of the shooting distance (i.e. muzzle-to-target distance) between a firearm and a target is a question that is answered in many forensic science laboratories. The method that is applied in most cases is based on the chemographic treatment of a secondary trace carrier on which the gunshot residues (GSR) are transferred to in a previous step. This carrier is treated with a coloring agent reacting with metals present in the deposited gunshot residue particles and thereby rendering the microscopic particles visible to the naked eye [1–4].

Within the framework of the ENFSI Working Group "Firearms/GSR" a proficiency testing scheme concerning the determination/estimation of the shooting distance was set up and performed with financial support of the European Union (project 2011/ISEC/AG/2489). The aim of this project was not a competition between laboratories, but the promotion of quality in chemographic GSR investigation.

In recent years, to our knowledge only one other proficiency testing program is offered in the area of shooting distance determination [5]. Although this test is commonly accepted by the forensic community, a significant problem remains in the preparation of suitable GSR test samples meeting the necessary requirements of

☆ This work was performed with the financial support of the Prevention of and Fight against Crime Programme, European Commission – Directorate-General Home Affairs; project no. HOME/2011/ISEC/AG/4000002489.
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http://dx.doi.org/10.1016/j.forc.2016.06.002
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a proficiency test. This is especially with regard to the requested homogeneity of the sample material [6]. Compared to other proficiency tests, where homogenous source material can be divided into multiple identical samples, it is a major problem to prepare suitable – i.e. identical – test items for a proficiency test on shooting distance determination. In the preparation of test samples with "real" gunshot residues there is always a large statistical variance in the deposited GSR patterns. This is because the exhaust of GSR during a gunshot is not fully reproducible. Furthermore, since chemographic methods are destructive, it is not possible to use a single GSR sample (i.e. a material with a real bullet entrance hole which is initially carefully checked by the organizer of the study) distributed in succession to all participating laboratories for investigation (so-called round-robin study). The idea of using artificial samples is based on an existing proficiency test [7] for the identification of microscopic GSR particles by means of Scanning Electron Microscopy equipped with X-ray micro-analysis (SEM/EDS).

Various chemographic methods are available for the visualization of GSR [4]. The selection of the most appropriate method depends mainly on the chemical composition of the primer/ammunition used in the shooting incident in question. The principle of the chemographic process is that traces of GSR, which may not be distinguishable from other debris particles for the human eye, will form colored chemical compounds after having reacted with a specific reagent. Before the coloration step, however, the particles need to be treated with an acidic solution. The reaction products are then transferred by diffusion to a secondary target medium such as filter paper, desensitized photo paper, or cellulose hydrate films. The most commonly used coloring method for the element lead uses the sodium rhodizonate complex [1–3]. After treatment, lead compounds in GSR particles, if present, will form pink-reddish complexes, while barium and strontium compounds will be visible as orange precipitates. An alternative and non-destructive method for the visualization of GSR patterns in shooting distance determination is an X-ray-fluorescence-system (XRF) equipped with mapping capabilities [8].

1. Materials and methods

1.1. Sample material

The sample sets were designed by the Bundeskriminalamt (BKA), and then printed at the Leibniz Institute for New Materials (INM) in Saarbrücken, Germany, using a screen printing method based on a German patent entitled "*Production of identical particle distribution images comprises visualizing a real lead particle distribution using a known chemographic method, and further processing*" [9]. The test samples consisted of a twill-cotton fabric of at least 20 cm × 20 cm in size which was screen printed with a latent lead-containing paste. The lead containing particles in the paste will display an intensely colored pattern when a test sample is treated with chemographic methods according to the participants' standard operating procedures for shooting distance determination by lead pattern visualization.

The GSR distributions on the test fabrics were obtained from real shots, fired from a Glock 19 semi-automatic pistol and using Geco caliber 9 mm × 19 FMJ ammunition.

For each distance, multiple shots were taken at the same distance to ensure reproducibility, and the most representative shot was chosen for further processing. The GSR patterns were transferred from the fabric to photo paper and visualized by the rhodizonate method as applied by the BKA. The patterns were digitally scanned as color images and thereafter rasterized via Adobe Photoshop in several image processing steps. To improve the visual impression, the samples were screen-printed in a 2-step process using two different lead compounds in order to mimic different levels of saturation. Each print was checked by milli-XRF with elemental mapping capabilities to ensure the quality of the preparation process.

Each participating laboratory received 14 pieces of fabric (12 test shots and 2 case shots) containing lead distributions that mimic the lead distribution pattern of a particular shooting incident. The bullet hole, located in the middle of the sample, was marked by a black circle. Twelve samples were marked as test shot series with the corresponding shooting distance printed in black in the lower left corner. The other two samples were regarded as case shots and only labeled as "A" or "B" (see Fig. 1 for the 25 cm case shot).

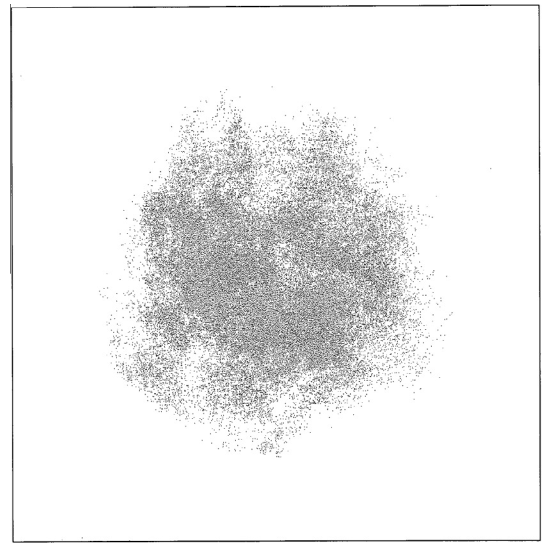

Fig. 1. Binary image of GSR pattern of case shot **A** (25 cm) as used for the screen printing.

1.2. Performance of the proficiency test

In total, 49 laboratories participated in this proficiency test, 45 of which returned results. Among them there were 40 ENFSI laboratories from 22 different countries and 5 laboratories from outside Europe.

The sample sets were shipped to the participating laboratories on 03 February 2015. They were accompanied by a color calibration chart, a test description, and a questionnaire. The completed questionnaire had to be returned by 20 March 2015 at the latest.

Each of the participating laboratories received an identical set of samples. The laboratories were asked to treat the samples analogously to real-life GSR-containing fabric samples and examine them according to the laboratory's standard procedure for chemographic investigations of GSR on fabric [2–4]. The participants were requested to indicate the shooting range for each of the two case shots using the 12 reference test shots. The 12 test shots were fired from distances of:

2, 5, 10, 15, 20, 30, 40, 60, 80, 100, 150, and 200 cm.

The shooting distances of the two case shots were:
25 cm (labeled in this publication as **case shot A**), and
50 cm (labeled in this publication as **case shot B**).

Based on the experience of the first collaborative study with this test sample performed by a small number of participants [10], the participants were asked to categorize their analytical findings in tables provided in the questionnaire (see Table 1). This categorization is required in order to enable a further z score assessment (see for Section 2.3).

Therefore, the participants first were asked to rank each case shot between two neighboring test shots, based on the characteristic changes of GSR patterns with increasing distance. Hereinafter the result of this task is referred to as the *analytical result of the best allocation to a shooting distance class*.

Secondly, for each case shot, the participants had to estimate the shooting range by providing a minimum and maximum shooting distance taking into account the variability of GSR patterns of shots at the same distance. Hereinafter the result of this task is referred to as the analytical result of the *estimated range of the case shot distance*. This would represent the estimated range for the corresponding case shot (A or B) as being stated in the forensic expert's opinion report.

The participating laboratories who submitted their results within the deadline are listed in Table 2. In this study all participants used a chemical method for the visualization of the lead pattern, except one who used milli-XRF with mapping capabilities.

2. Statistical evaluation

The statistical evaluation comprised on one hand the exploratory data analysis and on the other hand a statistically reliable assessment of the laboratory's performance. The evaluation was applied to both case shots and both analytical results, separately.