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Profiling Ammunition through the Ballistic Datasets of Four European Countries

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Every year European law enforcement agencies collect numerous spent cartridges at crime scenes and seize thousands of rounds of illicit ammunition, but available statistics on these items are generally not disaggregated and provide little to no information on the specific types of cartridges and ammunition involved. This results in a lost opportunity for monitoring and analysing crime-related trends. As has been demonstrated in areas affected by conflict, studying illicit ammunition has the potential to generate policy-relevant information on sources of trafficking and diversion-of both the cartridges and the weapons that fire them. In order to address this gap in ammunition data, a pilot study has been carried out on the utility of ballistic datasets for profiling illicit ammunition-i.e. analysing key features of recovered ammunition including, among others, its calibre, manufacturer, and year of production (when known). The project focused on four European countries-Denmark, Germany, Sweden, and Switzerland-whose ballistic laboratories were willing and able to share non-confidential subsets of their national databases, together with imagery of documented ammunition headstamps. This paper provides an analysis of 3,130 cartridges documented by the participating laboratories between 2015 and the first quarter of 2020, and discusses the policy and operational implications of this procedure. Most of the ammunition (61 per cent) was recovered in the context of violent types of crime-homicides and assaults, where pistol ammunition calibres were the most prominent. From the 3,130 cartridges, 610 unique headstamps were recorded, resulting in the finding that some varieties of ammunition were used particularly frequently. The year of manufacture could be identified for 28 per cent of the cartridges, and at least 27 pieces of ammunition were produced in the year that the criminal incident took place. Although limited in scope, the dataset also reveals trends in the type of ammunition used, by country and crime category, and over time. It also identifies criminal patterns that are relevant for intelligence-led policing, including the use of non-factory cartridges and the presence of blank ammunition in all four country datasets. Conducting more systematic profiling of the ammunition recovered by law enforcement agencies followed by the similarly systematic sharing of this information should therefore be supported as part of efforts to counter trafficking in and the criminal use of small arms and their associated ammunition.

*Speaker

Keywords: Ammunition trafficking and diversion, Headstamp analysis, Automated Ballistic Identification Systems (ABIS), Illicit ammunition.

The use and understanding of gunshot residue expertise by judicial actors

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In the framework of a joint research between the departments of criminalistics and criminology of the NICC (Belgium), a thorough consultation was carried out of several dozen judicial files for which at least one gunshot residue (GSR) expertise had been requested. The aim of this study was to examine the reception of the GSR reports by the judicial actors (mainly judges, but also prosecutors, police officers and lawyers), with the initial objective of evaluate the impact of the expert opinion on court decisions, but also to question the understanding of the results, their use, and their contribution/relationship to other (forensic) elements of the case. This study was completed by interviews with various judicial actors. The presentation will outline the main findings of the study, with regard to possible over- or even misinterpretations of the results, the use of GSR as evidence in addition or not to other forensic evidence such as DNA or ballistics, and an assessment of the impact of GSR expertise on court decisions.

Keywords: GSR, forensic evidence, reporting, expert opinion, interpretation

*Speaker

Review of the materials presented at the AFTE

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The AFTE is the biggest international professional organization for practitioners of Firearm and Toolmark Identification. It is dedicated to the exchange of information, methods and best practices. Part of the activity of the association is to arrange six-day annual meetings, publication of a peer-reviewed Journal and hosting of an internet forum dedicated to professional issues. This presentation reviews the most interesting materials from the last annual meeting held in Miami and the articles that have been published in the AFTE Journal since the last ENFSI FA/GSR WG meeting in 2019. Also, most important and interesting discussions from the AFTE Forum will be observed.

Keywords: AFTE, review of publications

*Speaker

Complex examination of the death from a blank-firer (case report)

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A dead body of a fifteen years old boy was found in his room laying on a sofa together with a TT pistol near him. There was a wound in the head, fired cartridge case near the body, but no projectile was found in the head during autopsy. Complex examination of this case made by firearms and GSR experts from RFCFS together with medical examiners helped to reveal the truth.

Keywords: Firearms, GSR, blank, firer, case report

*Speaker

3D Shooting Incident Analysis and Reconstruction by Means of CloudCompare, an Open-Source Software

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Three-dimensional (3D) data has become common-place in the daily work of the forensic expert, crime scene investigator, shooting reconstructionist, and/or expert in ballistics. With new technologies easily available, 3D data can be easily generated from a variety of vendors. The data can be used in the forensic domain and transferred between different services/sections. A variety of software has been developed to handle this 3D data. Each software package has different characteristics and specifications, and their use is often restricted (not open source), meaning that expensive licenses may be required to unlock the full potential of the software. This technical note aims to present an open-source software solution, which can be easily used to handle 3D data with regard to trajectory reconstruction and ballistic information. The specifications of the software CloudCompare and its application in trajectory reconstruction, ballistic information, and crime scene reconstruction are reported and commented on.

Keywords: Crime scene, Ballistic, 3D, Trajectories

*Speaker

Reconstruction of Shooting Accidents – Case Reports in Limit Conditions of a Single Impact Point

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In order to reconstruct the dynamics of a shooting accident, bullet trajectories are essential and, for each trajectory, at least two impact points are usually needed. In cases where a single impact point is available, the reconstruction becomes more challenging, if even feasible. In this presentation practical cases are reported, in limit conditions of a single impact point. In the first case, a bullet shot the window at the 24th floor of a building. In the second case, while watching television at home with the window open, a man was hit by a bullet, which shortly after caused his death in hospital. In the last one, a woman was victim of a gunshot which accidentally hit a gate, saving her life. In all crime scenes, no other impact was available. In such cases, besides the impact point, further sources of evidence were taken into account, such as projectile deformations, shape of glass reaction to the impact, observations and measures taken in the course of the autopsy, gunshot residues and others. Putting together such evidences, it was possible to identify a limited region from where the shots could had been fired, so giving a fundamental contribution to police investigations.

Keywords: dynamics, reconstruction, gunshot residues, SEM, EDX

*Speaker

3D-Virtual Comparison Microscopy within the Crime Lab

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Objectives: This presentation will educate the attendees about the current state of 3D Virtual Comparison Microscopy (VCM) and how the technology can be used within the crime lab. Attendees will learn how their lab can use VCM to improve comparison, documentation, access, and verification.

Synopsis: 3D Virtual Comparison Microscopy is a powerful tool for microscopic examination which presents an examiner with a highly detailed visualization of a toolmark surface. VCM can provide a number of advantages over LCM in the areas of access, speed, documentation, and quality. For example, after evidence and test fires are scanned at a 3D microscope, the topography data may be viewed down the hall or off-site on a second computer where examiners can annotate the surfaces, link items with common source, capture screenshots, record text notes, and export structured case notes for inclusion in LIMS. Several recent studies, such as our VCM Error Rate Study (VCMERS) and our VCM Topography Resolution Study (VCMTRS) each involving over 100 participants, provide strong support for the quality of VCM examination. These studies establish 3D Virtual Comparison Microscopy as a viable alternative to traditional light comparison microscopy within the discipline of firearm examination. As labs begin to incorporate VCM into their standard operations, many have questions about what is possible and how the technology can be implemented.

In this presentation, through screenshots and examples, we will review the uses of VCM within a lab, covering such topics as hardware and software validation, 3D visualization, establishing common source, documenting conclusions, recording electronic notes, exporting notes and images for LIMS integration, conducting blind verification, sharing data among multiple sites, and enabling remote access. We will also review the use of software for specimen triage, database search, and blind verification. Finally, we will discuss the state of comparison algorithms, scoring, and statistics.

Labs moving to incorporate VCM do not need to implement all presented uses. Some labs may only use VCM for triage or for remote (off-site) access while others will use VCM through their entire examination pipeline from intake through report generation and verification.

PRESENTER:

Ryan Lilien, MD/PhD. Ryan's research expertise focuses on the use of advanced scientific computing and statistical models to solve interdisciplinary research problems. Ryan earned an MD/PhD from Dartmouth Medical School and Dartmouth's Department of Computer Science. Ryan was faculty at the University of Toronto cross-appointed between Computer Science and

*Speaker

the Faculty of Medicine. He has received research funding from the Gates Foundation, NIJ, NIST, and Canada's National Sciences and Engineering Research Council. He is now located in Chicago and serves as Cadre Research's head of research and development while maintaining an adjunct appointment at the University of Toronto. Ryan leads development of the TopMatch-3D High-Capacity system (a 3D imaging and analysis system for firearm forensics and virtual microscopy). He's presented his group's steady progress on developing and validating the system at recent national and regional AFTE meetings. Ryan is also currently a member of NIST's OSAC Subcommittee on Firearms & Toolmarks.

Keywords: 3D, Virtual Comparison Microscopy, Firearms, Toolmarks, Algorithms, VCM

Validity and reliability of forensic firearm examiners

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Forensic firearm examiners provide judgments about the source of bullets and cartridge cases. Courts of law rely on their judgments to decide about a person's innocence or guilt.

These examiner judgments are increasingly challenged [1,2] because of the lack of empirical research.

We studied the validity and reliability of the source judgments and degree-of-support judgments of 77 firearm examiners and compared these judgments to the outcomes of a computer-based method. Our study showed that the validity and reliability of the source judgments were quite high, but that examiners are not infallible. The examiners seem to be slightly less proficient at identifying same-source comparisons correctly, while they outperform the used computer-based method at identifying different-source comparisons. The degree of support judgments were not well-calibrated and showed clear signs of overconfidence – as is also seen in other expert populations [3].

Future studies could focus on the comparison of the judgments of experienced examiners to those of novices to study if the examiners' performance and overconfidence is a result of acquired experience and on the merits of performance feedback to calibrate their judgments.

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Keywords: Firearms, validity reliability

*Speaker

Sharing ballistic data across Europe: A prototype network between France and Switzerland using Evofinder®

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Today, there is a real political urge to see the sharing of ballistic data intensify across Europe mostly due to recent events such as terrorist attacks. However, technical constraints remain and two main options are being discussed. The first one relies on a centralized common database, implying a vendor monopoly for all Europe and a unified protocol among member states. The second one advocates for a distributed framework relying on existing national infrastructures and leaving each country responsible for its own protocols. This article describes a prototype network linking Switzerland and France using the Evofinder® system by ScannBI. We will first focus on how this network was set up, and then report some results from tests conducted to assess the viability of the concept. These results demonstrate that the second option cannot be discarded and pave the way for a distributed network. This solution appears to be cheaper, more adaptable and answers the practical needs of member states.

Keywords: European Ballistic database, Evofinder

*Speaker

Computer-aided LEA marking. Automatic search stability increasing

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At the moment bullets identification preparation by Automated Ballistic Identification Systems (BIS) supposes manual marking of areas of interest. This operation is routine and may cause errors due to human factor. The new version of BIS Evofinder provides computer-aided marking for Land Engraved Areas (LEA) on bullet surface. The study analyses how this helps to reduce marking time, increase search effectiveness and reduce impact of human factor on automatic search results.

A database of 1500 background non-matched 9x19mm Luger 6R bullets is used in the research. Test set of 46 matched bullets fired from 23 different guns (2 shots each) are used to measure search effectiveness. Four examiners with different experience in ballistic identification marked test set. Each examiner marked test set twice: in manual mode and with computer aid.

Results of the study show that computer aided marking leads to reductions of marking time (30-50%). At the same time, effectiveness of automatic search is increased 5% average. The most significant increase of search effectiveness (up to 12%) is observed for marking made by non-skilled examiners.

Keywords: Evofinder, Firearms identification

*Speaker

Reference Population Database of Firearm Toolmarks

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The last decade has seen exciting progress in the development of measurement instruments, algorithms, data, and methods to facilitate objective analysis of toolmark comparisons. The primary goal is to provide firearms and tool mark examiners the ability to support their testimonies with objective similarity values and statistically-sound quantitative expressions for the weight of the evidence. The National Institute of Standards and Technology (NIST), Federal Bureau of Investigation (FBI), and the Netherlands Forensics Institute (NFI) have been collaborating to develop the Reference Population Database of Firearm Toolmarks (RPDFT). RPDFT is a system that consists of a reference database of firearm toolmarks (impressed and striated), data processing modules, quantitative similarity metrics, statistical weight of evidence calculation protocols, and a user interface.

In the past three years, a reference database infrastructure have been developed to index test fires generated by the FBI according to their class characteristics. The reference database consists of ground truth KM and KNM comparisons and is designed to be filtered according to matching/relevant class characteristics of the evidence being analyzed. NIST and NFI's objective toolmark analysis algorithms and statistical protocols have also been integrated into the database. These allow for quantitative one to one comparisons of firearm toolmarks which are then used in conjunction with the relevant reference populations to calculate its statistical weight of evidence.

The presentation will describe the reference database design, analysis modules, proposed workflow/implementation, statistical analysis, milestones and future plans of RPDFT.

Keywords: Reference database, firearm toolmarks, weight of evidence

*Speaker

Bullet discrimination by using oriented texture

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This research aims at giving more objectivity to the forensic firearms discipline. This is achieved by the use of examiner-independent methods taking advantage of image analysis and machine learning techniques in order to extract and model the oriented texture presented on the land impressions. Individual land images are acquired in 2D grayscale [2048 x 1536 pixels] by using a *Leica DFC 290* camera mounted on a *Leica FS C* comparison microscope. The ballistic signature is obtained by following wavelet decomposition and HOG (Histogram of Oriented Gradients) transformation. For each land the feature vector is made of 7920 *HOG* variables. The machine learning effort aimed at classifying lands first and then to combine the predictions to infer the firearm. The choice of the most accurate machine learning techniques was done using the Caret library in Rstudio. **RDA** (*Regularized Discriminant Analysis*), coupled with **PCA** (*Principal Components Analysis*), was selected for its best accuracy. Experiments carried out on a database of 130 Kalashnikovs gives at least **90.89%** of correct discrimination and increase as function of the number of test bullets used for the learning of the classifier.

Keywords: bullet, firearm, automatic discrimination, machine learning, oriented texture

*Speaker

Reporting Likelihood Ratio (LR) for Case Work in Firearm Evidence Identifications

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Firearm evidence identification was criticized by the National Research Council (NRC) and PCAST report [1,2] on its fundamental assumptions, its procedure involving subjective interpretations and lack of a statistical foundation for estimating the weight of evidence. To address these challenges, researchers of the National Institute of Standards and Technology (NIST) developed Congruent Matching (CM) methods for automatic and objective firearm evidence identification and quantitative likelihood ratio (LR) estimation to support firearm examiner's case work and court testimony [3-6].

The CM methods and LR procedure have some unique features:

- Instead of comparing the entire images [7,8], the CM methods divide it into small units and correlating them by both topography similarity and pattern congruency.
- The similarity score is the number of the CM units qualified by multiple identification parameters with associated thresholds.
- The experimental scores of known-matching (KM) and known-non-matching (KNM) are fitted into a theoretical model by which the LR is calculated.
- The CM methods and LR procedure are supported by the NIST Ballistics Database Testbed (NBDT), which includes: 1) a ballistics image database with various breech face, firing pin and bullet images; 2) a correlation database with multiple algorithms and programs for correlating cells (CMC method), features (CMF method) and profile segments (CMPS method); and 3) a statistical database including statistical models and procedures for estimating error rates and LRs. The NBDT is used to develop and refine algorithms and statistical models for the Reference Population Database of Firearm Toolmarks (RPDFT) [9], a system designed to facilitate the estimation of quantitative measures for the weight of evidence in case work.

Initial tests of CM methods and LR estimations have demonstrated significant advantages:

- Current test results show a clear separation between the KM and KNM images with well-marked samples [5,6], and a small degree of overlap for other datasets.

*Speaker

- The observed KNM distribution is very stable with major scores equal to zero, holding promise for low false positive rates. These distributions furthermore seem to be very stable without significantly observed dependencies on the brand of guns and ammunitions.
- The structure of the NBDT is specially designed with a basic (single) dataset and a control dataset. That can overcome some theoretical and practical problems [7,8] in LR estimation.
- A procedure will be developed to provide an uncertainty estimation for the reported LR values.
- A similarity map is developed to highlight the similar peaks, valleys and dis-similar regions, which can provide a visual support to firearm examiner's case work and court testimony.
- The method brings a potential for fast searching a large ballistics database with a LR report, and for correlating other feature-related forensic evidences.

NIST is working with a Small Business Innovation Research (SBIR) grant recipient to implement the CM methods and LR procedures into a forensic software package aiming to assist firearm examiners in case work and court testimony.

Keywords: Firearm, likelihood ratio, congruent matching, forensics.

Design and Use of 3D-printed Firearms on the Internet

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Since the first 3D-printed firearm, named Liberator, was published, and successfully tested, countless new designs for said firearms and weapon components have been created and made publicly available. These new 3D-printed firearms, which are praised by their designers as even more reliable, can be found on the Internet with little effort. Press reports have shown that various models of 3D-printed firearms have already been confiscated by police forces around the world. So far, forensic studies have addressed this set of problems relatively little, whereby for the most part only the Liberator has been examined in detail and three other designs were only included a few times. The rapid pace of this development poses new challenges for forensic investigations and unveil new spheres of investigation regarding 3D-printed firearms.

A research initiative has been launched with the primary objective of establishing an inventory of 3D-printed firearms plans, as well as other related files in the Clear Web. The gathered files and information were organized and analysed. The second objective was to determine whether the results from previous studies on Liberators are also produced and observable when using other models of 3D-printed firearms. In this respect, a total of six different 3D-printed firearms – PM422 Songbird, PM522 Washbear, TREVOR, TESSA, Marvel Revolver and Grizzly Handgun – were produced on a material extrusion type 3D-printer (Prusa i3 Mk3s, PLA).

When researching the Clear Web, over 160 entries were collected, 105 of which represent unique 3D-printed firearms designs. When interpreting further data, several sources of supply (e.g., Google Drive, Github, YouTube) were identified and trends were recognised, which for example provided information about the popularity of a specific model or the activity of designers. Experiments with the printed firearms showed that they are indeed functional, but that, depending on the model, they suffer different levels of damage when fired. They were all rendered inoperative after one discharge. As in other studies, the firing and the resulting ruptures on the 3D-printed firearm or its components projected polymer parts and fragments of different sizes and in different quantities into the immediate environment. The parts and fragments could be physically matched, allowing the reconstruction and identification of the 3D-printed firearms. Elements of ammunition also showed traces of deposited polymer on the surface and cartridges showed either signs of tears or swellings. Further experiments are currently being conducted to clarify the variability of functionality and the traces left by the discharge of different 3D-printed firearms.

Keywords: Additive manufacturing, Homemade firearms, OSINT, Crime scene investigation

*Speaker

How to create new classes and optimise classification schemes in automated GSR SEM/EDS analysis.

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The talk will highlight some aspects of a possible way to create new classes or to optimise ammunition classes for the usage in SEM/EDS GSR analysis software. By investigating a large number of airborne GSR particles, that were collected in a special way, a good statistical base was found to distinguish the borders of the particle cloud that has to be described by selective criteria. By testing the new class against other well-known particle samples, the integration in a formerly used classification scheme can be validated and the class criteria can be refined. The benefit of the use of such an optimised class scheme will be explained. The necessity to critically question whether the delivered basic GSR scheme is still addressing the labs demands is discussed as well.

Keywords: expanding classification schemes / GSR / optimization of SEM/EDS GSR investigation

*Speaker

How to perform a combined analysis of inorganic and organic GSR?

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Following the discharge of a firearm, two categories of compounds may be released into the environment, the inorganic, and the organic gunshot residue (I and OGSR). To date, forensic laboratories mainly analyse IGSR using scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM/EDS). The analysis of OGSR, for example with the liquid chromatography-tandem mass spectrometry (LC/MS-MS), is still rarely carried out although it would bring relevant additional information. While this may be attributed to the fact that both analyses required additional cost and time it may also be explained by the fact that some loss either in IGSR or OGSR is expected if a collection device (i.e., stub) has been analysed in sequence. In the last few years, several studies proposed methodologies for the combined analysis of IGSR and OGSR but, none of them seems to allow the complete recovery of both types of GSR.

Thus, in order to select an appropriate combined protocol that can be implemented in practice, it is important to compare promising methodologies and evaluate which one minimises the loss of both types of GSR (knowing that IGSR analysis is a routine protocol and, must be prioritised over OGSR). Three protocols were tested in this work:

- Fifty-fifty: One stub is used to collect the GSRs. One half is analysed for IGSR, while the other is analysed for OGSR.

- Sequential analysis: One stub is used to collect the GSRs and then, analysed in sequence first the detection of IGSR, and then the analysis of OGSR.

- Reversed sequential analysis: One stub is used to collect the GSRs and then, analysed in sequence first the extraction of OGSR, and then the detection of IGSR.

The first protocol is easy to implement. However, the quantity of both types of GSR is divided by two leading to an approximate loss of 50%. The sequential analysis represents an interesting alternative if the losses during the first analysis (SEM/EDS) can be minimised. Carbon coating was used to reduce OGSR loss in the vacuum during IGSR analysis. The reversed analysis is particularly promising as IGSR are neither lost nor displaced on the stub. However, the modified extraction procedure of OGSR can lead to lower recovery rates. The advantages and disadvantages of each protocol will be discussed from a forensic perspective.

*Speaker

Keywords: Firearm discharge residue, SEM/EDS, liquid chromatography, mass spectrometry

Low Budget High-Speed Photography to Explore GSR Propagation

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High-speed photography is a powerful but expensive tool to analyze e.g. the function and ejection of a firearm or the behavior of a projectile on impact. This requires frame rates of 10 000 fps and faster and very intense illumination, which results in expensive specialized equipment. If you are just interested how the GSR plume behaves when a weapon is fired, such high frame rates are usually not needed. A frame rate of 1000 fps is enough to analyze how far the GSR plume travels and how GSR deposits on the shooter's hand.

Some standard compact digital cameras (e.g. Sony RX100 V) are actually able to record videos with up to 1000 fps. Combined with standard flicker-free LED-panels one can observe the propagation of the GSR cloud easily for budgets of less than 2500 euros. Of course, image quality will not reach the results of specialized high-speed equipment by far. However, a lot of important information for GSR case work can be gathered with the described method.

The presentation will show set up camera and lighting, process the obtained videos. The achieved results will be presented, too.

Keywords: High, speed photography, GSR propagation, shooting distance determination

*Speaker

Survey of gunshot residue prevalence on the hands of individuals from various population groups in and outside Europe

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The results of a study which was conducted by 32 participating forensic laboratories, mainly from Europe will be presented. In this EU-funded study the prevalence of the most common types of Gunshot Residue (GSR) particles was investigated in various subpopulations. Specimens were collected from the hands of more than 1300 persons using carbon stubs. Subsequently the stubs were analysed for the presence of PbBaSb particles using scanning electron microscopy coupled to energy dispersive X-ray analysis (SEM/EDS). An in-depth statistical evaluation of the obtained results was performed to estimate the prevalence of gunshot residue in specific sub-groups as well as in the general population. A customized logit model was applied on the present data set in order to identify important population characteristics and differences between the various sub-groups. The observed variability of the results due to laboratory, country and sample effects was found to be significant indicating that these parameters should be taken into account in the interpretation of the results in casework. <https://doi.org/10.1016/j.forc.2021.100308>

Keywords: Gunshot residue, SEM/EDS, Prevalence, Police officers, Logit model

*Speaker

How gunshot residue examinations, handkerchief and road traffic control enlightened a homicide behind locked door? A case study

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The body of a shot woman was found behind locked door of her house by her family members after about 24 hours since the assessed time of death. No gun or spent cartridge cases were found at the crime scene. A great number of probes related to the victim and her house were collected. Soon farther probes were secured from two suspected men being partners of the victim, the present and the former one. Specimens with micro-traces from hands and faces of the men were collected in addition to samples of microtraces from the interior of two vehicles belonging to the former partner as well as numerous items of his garments. All the secured specimens and several volumes of case files that included very interesting information were directed by the prosecutor to the Institute of Forensic Research, Krakow for multidisciplinary examinations: genetic, fingerprints, analysis of blood pattern and gunshot residue (GSR). Detailed questions concerned finding the physical evidence of the relation between the suspects and the time and scene of the crime. A great number of GSR samples provided and these collected during optical examinations of the probes in the laboratory were subjected to thorough examinations by means of scanning electron microscopy coupled with energy dispersive X-ray spectrometry [1-3]. Moreover unburned propellant grains were spotted on the upper garment of the victim and identified by means of infrared spectroscopy. Thus, they contributed to enlightening some aspects of the studied shooting incident [4]. Apparently, findings of the analysis towards GSR were the only obtained physical evidence that provided several connections between the former partner of the victim and the time and place of the crime. These will be presented in details in the view of the circumstances of the incident.

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1

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