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Best Practice Manual

for the Forensic Examination of Inorganic Gunshot Residue by SEM/EDS

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ENFSI´s position on Best Practice Manuals

ENFSI wishes to promote the improvement of mutual trust by encouraging forensic harmonization through the development and use of Best Practice Manuals. Furthermore, ENFSI encourages sharing Best Practice Manuals with the whole Forensic Science Community which also includes non ENFSI Members.
Visit www.enfsi.eu/documents/bylaws for more information. It includes the ENFSI policy document Policy on Creation of Best Practice Manuals within ENFSI (code: QCC-BPM-001).

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The text may be translated into other languages as required. The English language version remains the definitive version.

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BEST PRACTICE MANUAL FOR THE FORENSIC EXAMINATION OF INORGANIC GUNSHOT RESIDUE BY SEM/EDS

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1. AIMS

This Best Practice Manual (BPM) aims to provide a framework of procedures, quality principles, training processes and approaches to the forensic examination. This BPM can be used by Member laboratories of ENFSI and other forensic science laboratories to establish and maintain working practices in the field of forensic examinations of gunshot residue (GSR) using a Scanning Electron Microscope in combination with Energy Dispersive X-ray-Spectrometry (SEM/EDS). References to external information given in this text – and specifically the bibliography references to literature in section 15 – will therefore focus on all aspects of this analysis technique only. The use of consistent methodology and the production of more comparable results will facilitate interchange of data between laboratories.
The term Best Practice Manual is used to reflect the scientifically accepted practices at the time of creating. The term BPM does not imply that the practices laid out in this manual are the only good practices used in the forensic field.

2. SCOPE

This Best Practice Manual covers the analysis of inorganic gunshot residue (GSR) by scanning electron microscopy/energy-dispersive X-ray spectrometry (SEM/EDS) [1]. The analysis is performed using automated software control of both the SEM and EDS systems, to screen the sample for candidate particles that could be associated with GSR. Particles composed of high mean atomic number elements are detected by their SEM backscattered electron signals and an EDS spectrum is obtained from each. The EDS spectrum is evaluated for constituent elements that could identify particle as being linked to gunshot residue. The most important particles are those particles having the appropriate morphology with an elemental composition that is consistent with or characteristic of GSR (see § 12 for discussion on this particular classification of particles). Manual control of the instrument is then used to perform confirmatory analysis and classification of the candidate particles.

3. TERMS AND DEFINITIONS

For the purposes of this Best Practice Manual (BPM), the relevant terms and definitions given in ENFSI documents, the ILAC G19 “Modules in Forensic science Process”, as in standards like ISO 9000, ISO 17020 and 17025 apply.

In this section only the field-specific terms and definitions, which assist in the interpretation of this BPM, are listed (for reference see e. g. ASTM E1588 [1]).

- **gunshot residues (GSR)** – the total residues resulting from the discharge of a firearm. It includes both propellant residues and primer residues, plus metallic residues from projectiles, fouling, etc.
- **stub** - sampling device, consisting of a metal platform covered with an adhesive surface used to collect materials from a solid and dry surface for subsequent SEM/EDS analysis.
- **characteristic particles** - particles that have compositions rarely found in particles originating from any other source than the discharge of a firearm.
- **consistent particles** - particles that have compositions that are found in GSR and also arise from other non-firearm sources. Particles within this group are produced through the operation of a variety of processes, equipment, or devices and can be found in the environment with varying levels of frequency.

- **commonly associated particles** - particles having compositions that are also commonly found in environmental particles from numerous sources. However, when present in addition to particles that are *characteristic of* and/or *consistent with* GSR, these particles
- can be of significance in the interpretation of a population of particles. Consequently, the likelihood that that population is GSR is increased by their presence. In isolation, however, such particles have little significance in the examinations for GSR.
- **morphology** - referring to size, shape, structure, and texture of individual particles of interest.
- **reference material** - material, sufficiently homogeneous and stable with respect to one or more specific properties, which has been established to be fit for its intended use in a measurement process.
- **standardized method** - a method published by a recognized international, regional, or national standard development organization (e.g., ASTM, AOAC or OSAC Registry of Approved Standards).

4. RESOURCES

4.1 Personnel

People are likely to be the most important resource in any forensic application. In order to allow staff to work effectively and efficiently, everybody involved in the process must understand the nature of the tasks and has the competences required to perform them. Therefore, information provided in this manual defines the key roles, responsibilities and also competences required by these persons.

Due to variations in the size of different laboratories and variability within different laboratory systems, absolute standardization of staffing cannot be achieved. It is also accepted that an individual may be responsible for more than one of the defined roles and this document states where this is the case.

In the event that no person in the laboratory is competent to be the GSR analyst/expert, arrangements should be made for a qualified and competent person to be retained from outside the laboratory to perform these duties until the situation can be remedied. The external person should have the same technical responsibilities and authority as an in-house GSR analyst/expert.

4.1.1 Roles and responsibilities

The key roles and responsibilities recognized for laboratories performing GSR examinations are:

- Analyst – an individual carrying out general casework examinations or analytical tests under the supervision of an expert and who is able to provide information to assist with the interpretation of the test results.
- Expert – an individual responsible in a particular case for directing the examination of the items submitted, interpreting the findings, writing the report and providing evidence of fact and opinion for the court.

4.1.2 Competence requirements

The qualifications, competences and experience that individuals require to carry out the various aspects of GSR examination will depend on the demands of the various aspects of the work. This document defines the standards of competence required for individuals to undertake the particular aspects of work, the training required and the assessments that will be applied.

The following experience and areas of competence are expected as the minimum standard for the key roles defined above, in forensic GSR examination:

- Analyst – knowledge of the theories, analytical techniques and procedures (including GSR recovery, QA knowledge, and health and safety requirements) applicable to GSR examination; an understanding of procedures to prevent contamination of samples and systems; the practical skills to operate specialist equipment and to carry out forensic GSR analysis safely and reliably in compliance with laboratory protocols.
- Expert – knowledge of the theories, analytical techniques and procedures (including GSR recovery, QA knowledge, and health and safety requirements) applicable to GSR examination; additional competence in the evaluation and interpretation of findings in GSR cases; an understanding of procedures to prevent contamination of samples and systems; knowledge and experience of the requirements and procedures of the criminal justice system for the presentation of evidence, in both written and oral form.

4.1.3 Training and Maintenance of Competence

Requirements of competence shall be defined by each forensic provider/institute for all personnel involved in the field of GSR examination demonstrating their competence before being allowed to undertake any case work independently. The attainment of these competences shall be recorded.
All personnel involved should also be requested to regularly demonstrate their actual competence to internal or external entities (e.g. national accreditation bodies).
In the field of GSR examinations the following program should be included in the laboratory's guidance to ensure that role holders maintain an adequate level of competence:

Analyst

- participates actively and routinely in GSR casework examination/analysis and quality assurance controls
- is able to provide documentary evidence of active participation in GSR casework
- takes part in appropriate workshops, seminars, meetings, training courses and research and development projects as necessary
- actively maintains a current awareness of pertinent advances in the field

Expert

- participates actively and routinely in relevant aspects of GSR casework examination and management, including quality assurance controls
- is able to provide documentary evidence of active participation in GSR casework
- actively maintains a current awareness of pertinent advances in the field, particularly with respect to the interpretation of findings and the conclusions that can be drawn
- takes part in appropriate workshops, seminars, meetings, training courses and research and development projects as necessary
- should read current journals, books and other relevant literature containing pertinent information relating to GSR examination
- should participate in at least one of the following activities:
  - research and development,
  - publication of a technical paper related to GSR in a recognized forensic journal,
  - presentation of papers or participation in professional meetings/seminars (e.g. Annual Meetings of the ENFSI Expert Working Group Firearms/GSR),
  - technical training events – as a presenter/instructor,
- should be aware of the nationally used police ammunition (e.g. elemental composition in order to assess issues regarding secondary transfer/contamination).

4.2 Equipment

The equipment inventory (i.e. SEM/EDS, Carbon-Coater) must be shown to operate properly before being used in casework, and then only within the limits of the performance checks carried out. Minimum requirements for the SEM/EDS system, including system maintenance and quality control, are described in ASTM E1588.

4.3 Reference materials

The following list mentions the minimum set of reference materials which needs to be available to ensure a reliable GSR analysis by SEM/EDS:

- Pure element standard for energy calibration of the EDX detector. (*)
- SEM image calibration standard. (*)
- BSE intensity standard for brightness and contrast adjustments. An appropriate sample is usually supplied with the SEM/EDS package when purchased in the context of GSR analysis application.
- GSR standard for system sensitivity check (as demanded in accordance to
  - ASTM E1588, in particular obtaining a particle detection sensitivity of equal to or better than 1 µm in diameter). (*)

(*) *These may be delivered within the SEM/EDS system package or be acquired from independent sources.*

In addition, extra reference samples may be used in the calibration and routine quality checks of the SEM/EDS system, as specified in the Quality Manual of the individual laboratory. Often, a stub known to contain GSR particles pertaining from a test firing is used for this purpose.

4.4 Facilities and environmental conditions

Laboratory rooms for the examination of items for GSR should be designed for efficient and effective operation.

As the equipment used in the GSR analysis lab is high-end and sensitive to environmental conditions like temperature and humidity, the limitations and requirements listed in the manuals of the equipment must be strictly adhered to. The use of an air filtration system specific to the SEM/EDS lab is advisable. In order to limit the influence of environmental conditions on the performance of the equipment, it is advisable to place it in a separate lab room, or provide enclosures around each SEM/EDS instrument.

Particular consideration must be given to the avoidance of contamination (see also § 8.2.1). This requires the provision of adequate rooms for sampling as well as physical separation of sampling areas to allow for the separate processing of items coming from different suspects (low concentrations of GSR particles) and victims, targets or cartridge cases (high concentrations of GSR particles).

4.5 Materials and Reagents

All materials and reagents used for GSR investigation/examination should be of a suitable quality and should have been demonstrated as fit for purpose.

5. METHODS

5.1 Anti-contamination protocols

Procedures to monitor contamination levels must be established. The absence of GSR particles in the low-contamination areas of the lab should be regularly checked (e.g. by dabbing SEM stubs on the surfaces in question, e.g. the work-bench in front of the instrument, or by placing a blank stub in the near vicinity of the instrument).

The laboratory should provide procedures on how to deal with contamination issues.

5.2 Examination Techniques and Methods

Most commercial-grade SEM/EDS systems are nowadays adequate for GSR analysis and fulfill the criteria set forth in the ASTM E1588 Standard Guide. The automated data collection of GSR involves some portion of the data collection being controlled by instrument automation software. The extent to which the SEM and EDS systems communicate and are integrated varies according to the manufacturers and the capabilities of the hardware and software. The system shall have the ability to recall stage locations of particles for verification and software for particle recognition based on elemental composition using energy-dispersive X-ray analysis.

Minimum requirements, as requested in the ASTM E1588 Standard Guide, are:

5.2.1 Scanning Electron Microscope (SEM)

- The SEM, operating in the backscattered electron imaging mode, shall be configured to detect particles down to at least 1.0 µm in diameter using backscattered electrons (BSE).
- The SEM shall be capable of an accelerating voltage of at least 20 kV.
- The SEM system shall be equipped with a motorized XYZ-stage with automated stage control.

5.2.2 Energy Dispersive X-ray Spectrometry (EDS)

- The detector shall be configured to produce a resolution of better (less) than 150 eV during analysis, measured or extrapolated as the full width at half maximum (FWHM) of the $Mn_{K\alpha}$ peak.
- At a minimum, the EDS spectrum shall be acquired at 20 eV per channel.
- Display of the EDS output shall encompass the X-ray lines of analytical utility, with a minimum range of 0-15 keV.
- Automated systems will also include software capable of acquiring X-ray spectra for a specified collection time or total X-ray counts.
- The instrument shall be capable of recording spectra obtained from the analysis of candidate particles. At a minimum, an automated system shall be capable of storing all of the particle location coordinates for use in a subsequent manual review.

5.2.3 Sample Placement

- Record the positions of the stubs (sample and standard/reference stubs) on the SEM sample holder when the samples are inserted.

5.2.4 Detection and Calibration

- Particles of GSR are detected by their backscattered electron signal intensity. The absolute signal intensity that a particle produces is related to the electron beam current, mean atomic number, and size of the particle (for particle sizes in the order of the beam diameter). Particles whose mean atomic numbers are high will appear brighter than those of lower mean atomic number composition. As the beam current increases, the signal produced by each particle also increases.
- The brightness and contrast settings (low and high thresholds) of the backscattered electron detector system determine the limits of detection and discrimination of particles based on their mean atomic number. Threshold settings for the backscattered electron signal should be adjusted using a suitable reference sample of known origin (often supplied

by the EDS manufacturer) or elemental standards at the same instrumental settings used for sample analyses. This reference sample should, if possible, be in the microscope chamber at the same time as the samples to be analyzed.

- The backscattered electron detector's brightness and contrast should be set to include the high atomic number particles of interest and exclude low atomic number particles that are not of interest. Typically, high contrast and low brightness settings provide an adequate range between threshold limits for ease of detection. If the beam current is changed or drifts, the brightness and contrast threshold limits, which were based on the previous beam current, could no longer be compatible with the new conditions and should be readjusted. Therefore, it is recommended that beam current measurements can be taken using a Faraday cup, a specimen current meter, or monitored by comparing the integrated counts within the same peak in sequentially collected spectra from a known standard.

5.3 Analysis protocols

The performance of a SEM/EDS analysis of GSR must be documented in an appropriate way.

5.4 Case Records/Documentation

The following documentation is required for at least a selection of the confirmed particles detected:

- Images of the particles showing their morphologies.
- X-ray spectra of the particles, with all relevant elements clearly identified and labeled.

The records and, where applicable, investigation reports obtained during the SEM investigation are part of the case file. The reviewed analysis findings have to be briefly documented in the report for each SEM stub.
A summary of the results and the overall assessment is given in the expert´s report. This usually includes a summary of the particle findings of the individual exhibits (elemental composition, morphology, number of particles found (classified in specified categories, if applicable)) in text or tables. An assessment of the significance of the particles found (in relation to the reference GSR, alternative sources, etc.), as well as information regarding possible alternative sources of the particles and/or contamination sources is given – if appropriate.

5.5 Peer Review

It is particularly important in all forensic examinations that a protocol for case review is established. This document, therefore, details the requirements for such reviews in the field of GSR investigations by SEM/EDS. In addition to the institute's normal peer review process, special attention should be given to the GSR investigations and their interpretation. Records of the peer review have to be documented within the casefile.

6. VALIDATION AND ESTIMATION OF UNCERTAINTY OF MEASUREMENT

6.1 Validation

For the general aspects of validation this document refers to the ENFSI validation document [2]. Validation of the automatic particle detection systems is carried out individually for each SEM/EDS system and documented in the respective system manuals.
A suitable reference material for validation purposes could be a previous ENFSI GSR Proficiency Test Sample. An approach on the use of this type of test samples is shown in [3].

6.2 Estimation of uncertainty of measurement

The examination of GSR by SEM/EDS is a qualitative investigation method. Therefore, the use of reference materials minimizes the risk of false conclusions. Potential uncertainties could be the detection of false positive particles (multiple detected GSR particles) or false negatives (undetected (because of BSE-sensitivity or scanning field gaps) or not correctly classified GSR particles). This can also be derived using a previous ENFSI GSR Proficiency Test Sample as shown in [3].

7. QUALITY ASSURANCE

7.1 Proficiency Testing/Collaborative Exercises

Proficiency tests or Collaborative Exercises should be used to test and assure the quality of the method “Investigation of GSR by SEM/EDS”. The frequency of participation should not exceed 2 years. A list of currently available PT/CE schemes as put together by the ENFSI - Quality and Competence Committee (QCC) is available at the ENFSI Secretariat and via the ENFSI website. “Guidance on the conduct of proficiency tests and collaborative exercises within ENFSI” [4] provides information for the ENFSI Expert Working Groups (EWGs) on how to organize effective Proficiency Tests and Collaborative Exercises.

7.2. Quality Controls

When conducting automated analysis of GSR, special measures have to be established in order to meet common quality management demands.
This includes e. g. the following:

- Establish a protocol to confirm optimum instrument operation parameters on a routine basis.
- Monitor the EDS X-ray energy calibration and SEM beam current stability regularly. This may be facilitated by the use of appropriate reference materials.
- Analyze a reference material (e.g. a CRM or a GSR Proficiency Test sample) with particles of known size range and composition at regular intervals in order to test the accuracy of particle detection and identification. It is recommended that the reference material has been prepared and mounted in a manner comparable to the collection method in use by the submitting agency. The reference material can be a sample of GSR from a known source (caliber of weapon, ammunition manufacturer, number of rounds fired, collected area from shooter). Additional environmental particles may be added to ensure the inclusion or exclusion of particular classes of particles. Alternatively, a synthetic, simulated-GSR reference sample may be used for this purpose. The frequency of analysis of this sample shall be subject to guidelines set out in the laboratory’s standard operating procedures.
- The incorporation of environmental or control samples into the analytical protocol is recommended in order to monitor the cleanliness of the sample collection or analytical system, or both. An environmental sample may be prepared in a number of ways: for example, it may be an unused stub that has been prepared contemporaneously with the questioned samples or a sample taken from the sample collection or analytical environments (exposed to the air or as a direct sample collection from clean workspace), or both.
- It is recommended to plot and track the results with respect to efficiency of detection of particles using a control chart to identify trends in the performance of the instrument.

8. HANDLING ITEMS

8.1 At the scene

For non-laboratory personnel recovering evidence at the scene, it is recommended that standard operating procedures are in place and fit for purpose sampling kits are made available.

8.2 In the laboratory

8.2.1 Anti-contamination precautions

All items submitted for GSR examination should first be examined for the integrity of their packaging. Any deficiency in the packaging which may compromise the value of a laboratory examination should be communicated to the sender and highlighted within the report.
Laboratory personnel should wear suitable protective clothing to minimize the risk of GSR transfer from the examiner to the items being examined and secondary transfer between items via the examiner.
Benches used for sampling should be rigorously cleaned prior to any examination and the rooms should be cleaned regularly.

8.2.2 Search and recovery / Sampling / Storage and disposal

GSR may be recovered in the laboratory by stubs (e.g. for SEM/EDS investigation prior to a chemographic treatment). After collection of the GSR, the stubs should be placed in the original tubes of the sampling kit, and appropriately labeled.
Sampling should be performed in accordance with the instructions given by the responsible Forensic Institute. It is recommended that sampling of bullet holes with stubs -if necessary- is performed before chemical treatment.
Handling, storage and disposal of samples should be performed in accordance with the instructions given by the responsible Forensic Institute.

9. INITIAL ASSESSMENT

It is recommended – where applicable – to obtain relevant information on the status of the scene, suspects and victims, changes in the urgency for information, contamination issues and impact of results already reported. Information about the type of ammunition used in a specific case should be acquired -if available- in order to assist in choosing the appropriate analytical conditions for the automated run.
Information regarding the intended examination should be acquired before starting any examinations.

10. PRIORITISATION AND SEQUENCE OF EXAMINATIONS

SEM/EDS investigations could have a profound influence on other examinations and vice versa. Depending on the circumstances of the case the requesting authority should decide which type of examination is of prior interest. This decision should be taken following the advice of the expert.

11. RECONSTRUCTION

Not applicable.

12. ASSESSMENT OF RESULTS AND INTERPRETATION

According to the ASTM E1588 Standard Practice [1] the classification of the detected and identified GSR particles is divided into 3 major groups:

- particles classified as *characteristic of* GSR,
- particles classified as *consistent with* GSR, and
- particles classified as *commonly associated with* GSR.

For a currently valid list of commonly accepted as *characteristic of / consistent with / commonly associated with* assessed particles this BPM refers to ASTM E1588 [1].

According to the ASTM E1588 [1] particles that are identified as *characteristic of* or *consistent with* GSR often show a spheroidal morphology, with a typical diameter between 0.5 µm and 5.0 µm. However, elemental composition is the most diagnostic property to determine if a particle is GSR.
When possible, in order to provide additional forensic value, the elemental composition of the recovered particulate should be compared with case-specific known source items, such as the recovered firearm, spent cartridge cases, or other victim-related items.
Sometimes particles with unusual elemental compositions may be encountered in case work. Under these circumstances, the elemental compositions of these particles should be compared to case-specific sources, such as cartridges or ammunition/firearm test fire deposits.
Additional classifications may be developed for specific types of primer compositions not included in the previous sections. Any new classification should aid in differentiating environmentally or occupationally produced particles that could be found in a sample from GSR. An assessment of the significance of these classifications has to be performed considering relevant research and documentation.

In some cases, it is necessary to interpret the results in the context of the particular circumstances of the case. Evaluation and interpretation of the case findings can require consideration of but is not limited to:

- the type of firearm and ammunition,
- the background information available about the case and the original expectations cumulated during case assessment,
- the risk on contamination,
- the types and number of GSR found,

In addition to the background information provided with the case itself, there are a number of other sources of information available to assist in the interpretation of the GSR evidence; for example:

- GSR reference data bases (https://www.forensic-datahub.eu),
- published literature,
- vendor ammunition data,
- information exchange within the ENFSI EWG firearms/GSR group.

It is recommended - in the final interpretation of the results - to consider all relevant additional information. This may include, for example, the following aspects:

- method, place and time of securing the evidence (in particular, in the case of suspect's hand examinations: the time interval between the shooting incident and sampling),
- handling, transport, storage and packaging of the exhibits (risk of cross-contamination)

- professional and private environment of the sampled person (metal worker, car mechanic, sports shooter, hunter, etc.),
- sampling situation (weather conditions, environmental conditions) as considered relevant to the situation,
- distinction from GSR-like environmental particles such as brake pad particles, airbag particles, or firework residues.

Furthermore, it should be noted that no universal reporting format exists [28]. All assumptions under which the conclusions were drawn should therefore be stated in the report [29].

13. PRESENTATION OF RESULTS

Results can be presented to the court either orally or in writing, but is normally provided in written form, as a statement of evidence or a report.

Written reports should include all the relevant information in a clear, concise, structured and unambiguous manner as required by the country´s relevant legal process. This is done according to the laboratory regulations. Written reports must be peer reviewed (preferably by at least one other GSR expert).

14. HEALTH AND SAFETY

Health and safety considerations are extremely important in all aspects of the work and at all stages of the forensic process.

This may concern in particular the treatment of human tissue. The materials dealt with can be inherently hazardous and/or often found in hazardous circumstances but the exact facts are not always known or communicated to everybody in the process.

Consideration also needs to be given to the fact that materials may have to be handed back to others with no scientific training or particular facilities for handling the materials.

Ultimately, they may go back to members of the public or could be encountered by them in situations such as at court.

There is an obligation on those involved in the forensic process to ensure the safety of anyone handling materials that are inherently hazardous or rendered hazardous by the scientific examinations performed.

Personnel engaged in the examination/analysis of GSR should operate in accordance with the regulations of the pertinent government, environmental, health, biohazard, and safety authorities and laboratory policy.

General laboratory safety manuals should be available to all laboratory personnel. These should contain details of how to conduct a risk assessment and how to develop safe systems of work, both at the scene of incident and in the laboratory.

The risks identified and the safe systems of work should be communicated to all personnel likely to be exposed to the risks. This is especially important when this group includes non-scientists or members of the public (e.g. in court).

The relevant safe systems of work should be documented as an integral part of all standard operating procedures.

A Safety Data Sheet (SDS) file should be maintained for all chemicals used in the laboratory. These data sheets must be readily available to all laboratory personnel.

All chemicals, biohazards and supplies should be stored and disposed of according to the appropriate government regulations and laboratory policy. Laboratory personnel should be responsible for maintaining their assigned work areas in a safe, clean and orderly manner.

Appropriate protective clothing and safety equipment such as gloves, gowns, ear protectors, overalls, masks, face protection, safety cabinets and eye baths, as outlined in the various procedures, should be made available near the work sites by the laboratory management. It is the responsibility of the laboratory personnel to use them where required.

15. REFERENCES

Related documents (valid in their latest version):
All hyperlinks and web addresses shown in this document are current as of the publication date of this BPM.

[1] ASTM E1588-20 - Standard Practice for Gunshot Residue Analysis by Scanning Electron Microscopy/Energy Dispersive X-Ray Spectrometry. (2020). https://www.astm.org/Standards/E1588.htm

[2] Guidelines for the single laboratory Validation of Instrumental and Human Based Methods in Forensic Science; QCC-VAL-002; http://enfsi.eu/wp-content/uploads/2017/06/Guidance-QCC-VAL-002.pdf and GUIDEANCE – ANNEX; http://enfsi.eu/wp-content/uploads/2017/06/Guidance-QCC-VAL-002-Annex.pdf

[3] Ritchie N, DeGaetano D, Edwards D, Niewoehner L, Platek F, Wyatt M. 'Proposed Practices for Validating the Performance of Instruments Used for Automated Inorganic Gunshot Residue Analysis'. *Forensic Chemistry* 20 (2020): 100252. https://doi.org/10.1016/j.forc.2020.100252

[4] Guidance on the Conduct of Proficiency Tests and Collaborative Exercises within ENFSI; QCC-PT-001; http://enfsi.eu/wp-content/uploads/2017/07/QCC-PT-001-_-Guidance-on-PT-CE.pdf and http://enfsi.eu/wp-content/uploads/2017/06/External-proficiency-tests-and-collaborative-exercises-PT-CE-providers-28Nov2018.xlsx and http://enfsi.eu/wp-content/uploads/2017/06/Proficiency-tests-and-collaborative-exercises-PT-CE-provided-by-ENFSI-01Oct2018.xlsx

There are many books, journals and individual papers published on the subject of examination of GSR by SEM/EDS. It is impossible to compile a complete list of all of these. The following list contains some of the significant publications that relate to the examination of GSR by SEM/EDS.

[5] SWG-GSR-Guide for Primer Gunshot Residue Analysis by Scanning Electron Microscopy/Energy Dispersive X-Ray Spectrometry. (2011). https://1c77fca5-e602-4926-94ed-07d228d3b16e.filesusr.com/ugd/4344b0_8b0e218ea94a475199b243c6bceda5d3.doc?dn=FINAL%20GUIDE%2011-29-11.doc

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[8] Romolo FS, Margot P. 'Identification of Gunshot Residue: A Critical Review'. *Forensic Science International* 119 (2001):195-211. https://doi.org/10.1016/S0379-0738(00)00428-X

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[11] Chang KH, Jayaprakash PT, Hooi Yew C, Lim Abdullah AF. 'Gunshot residue analysis and its evidential values: a review'. *Australian Journal of Forensic Sciences* 45, No. 1 (2013): 3–23. https://doi.org/10.1080/00450618.2012.691546.

[12] Rijnders M, Stamouli A, Bolck A. 'Comparison of GSR Composition Occurring at Different Locations around the Firing Position'. *Journal of Forensic Sciences* 55, No. 3 (2017): 616–623. https://doi.org/10.1111/j.1556-4029.2009.01292.x.

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Review papers covering the advances in the field of gunshot residues are published in the proceedings of the triennial **Interpol Forensic Science Managers Symposium** and can be found at https://www.interpol.int/How-we-work/Forensics/Forensic-Symposium.

16. AMENDMENTS AGAINST PREVIOUS VERSION

- This document was thoroughly revised by the ENFSI EWG Firearms/GSR and those revisions are incorporated in the new version 02. The revision was made following the new "ENFSI Template for Field Specific Best Practice Manuals" (QCC-FWK-003). Because the revisions were so extensive, the amendments are not separately listed.