Best Practice Manual for Chemographic Methods in Gunshot Residue Analysis

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Background

This Best Practice Manual (BPM) belongs to a series of 10 BPMs issued by the European Network of Forensic Science Institutes (ENFSI) in November 2015. The series covers the following forensic disciplines:

1. Forensic Examination of Digital Technology
2. Forensic Examination of Handwriting
3. Chemographic Methods in Gunshot Residue Analysis
4. Road Accident Reconstruction
5. Microscopic Examination and Comparison of Human and Animal Hair
6. Fingerprint Examination
7. DNA Pattern Recognition and Comparison
8. Application of Molecular Methods for the Forensic Examination of Non-Human Biological Traces
9. Forensic Recovery, Identification and Analysis of Explosives Traces
10. Forensic Investigation of Fire Scenes which have resulted in Fatalities*
11. Forensic Investigation of Fire Scenes which involve the Clandestine Manufacture of Improvised or Homemade Explosive Devices*
12. Forensic Investigation of Fire Scenes which Involve the Clandestine Manufacture of Illicit Synthetic Drugs*

* *The three specific areas on Forensic Investigation of Fire Scenes (numbers 10 -12) were combined into one BPM 'Investigation of Fire Scenes'.*

In the years 2014 and 2015, so-called Activity Teams have - in parallel - developed the 10 BPMs. The activities were performed within the project 'Towards European Forensic Standardisation through Best Practice Manuals (TEFSBPM)' and co-ordinated by the ENFSI Quality and Competence Committee. The realisation of the BPMs was supported by the Prevention of and Fight against Crime Programme of the European Commission – Directorate General Home Affairs (code: PROJECT HOME/2012/ISEC/MO/4000004278). The core project concept was that the BPMs will enhance the quality of the forensic services available to law enforcement and justice across Europe and thereby encourage forensic standardisation and cross-border cooperation between countries.

ENFSI expects that the issuing of this series will stimulate the improvement of already existing BPMs as well as the creation of new BPMs on disciplines that are not covered yet.

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

Further information
For further information about this publication, contact the ENFSI Secretariat. Please check the website of ENFSI (www.enfsi.eu) for update information.

Best Practice Manual for Chemographic Methods in Gunshot Residue Analysis

CONTENTS

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 chemographical methods in gunshot residue (GSR) analysis that will deliver reliable results, maximize the quality of the information obtained and produce robust evidence. The use of consistent methodology and the production of more comparable results will facilitate interchange of data between laboratories.

This BPM is aimed at experts in the field and assumes prior knowledge in the discipline. It is not a standard operating procedure and addresses the requirements of the judicial systems in general terms only.

The term Best Practice Manual is used to reflect the scientifically accepted practices at the time of creating. Despite its implicit suggestion that alternative, equivalent Practice Manuals are excluded at beforehand, in this series of ENFSI Practice Manuals the term BPM has been maintained for reasons of continuity and recognition.

2. SCOPE

GSR-analysis consists of the visualisation and identification of Gunshot Residue (GSR) deposited on various types of objects and persons (for example victims and suspects). GSR analysis helps in answering the question whether GSR is present on persons or objects in general, or in visualising a distribution of GSR for shooting distance determination (i.e. muzzle to target distance determination).
The document addresses the entire forensic process of GSR investigation from the scene of crime to the presentation of evidence in the courts and so encompasses the systems, procedures, personnel, equipment and accommodation requirements for the whole process.
The law enforcement framework and the legal systems within which a forensic laboratory operates will determine the degree of direct influence that an individual scientist has over each stage of a process. Even when the scientist is not directly involved in a particular stage he or she should still be in possession of comprehensive advice on best practice.
This document only focuses on the chemographic treatment of GSR, and does not cover the Scanning Electron Microscopy/Energy-dispersive X-ray spectroscopy (SEM/EDX) analysis of GSR or the examination of damage in textiles and human bodies caused by ammunition or weapons.

3. DEFINITIONS AND TERMS

For the purposes of this 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 17000 and 17020 apply. In this section only the field specific terms and definitions, which assist in the interpretation of this BPM, are listed.

Gunshot Residues (GSR) – The total residues resulting from the discharge of a firearm. It includes both gunpowder and primer residues, plus metallic residues from projectiles, fouling, etc.
Shooting Distance – refers to the distance between the muzzle of a weapon and the target.
Chemographic method – a method that uses chemical reagents in order to visualize particles that incorporate a selective element or component.

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 the competences required to perform them. Therefore, information provided in this manual defines the key roles, responsibilities and also competences required by these post holders.

Due to variations in the size of different laboratories and variability within different laboratory systems, absolute standardisation 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 Technical Specialist, arrangements should be made for a qualified and competent consultant to be retained from outside the laboratory to perform these duties until the situation can be remedied. The external consultant should have the same technical responsibilities and authority as an in-house Technical Specialist.

4.1.1 Roles and responsibilities

The key roles and responsibilities recognised 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 tests.
- 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. The 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 would be expected as the minimum standard for the key roles defined above, in forensic GSR examination:

- Analyst – knowledge of the theories, analytical techniques and procedures applicable to GSR examination; 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 health and safety requirements) applicable to GSR examination; additional competence in the evaluation and interpretation of findings in GSR cases; knowledge and experience of the requirements and procedures of the criminal justice system for the presentation of evidence, both written and oral.

4.1.3 Training and maintenance of competence

Requirements of competence should be set for all personnel involved in the field of GSR examination demonstrating their competence before being allowed to undertake any case work. The attainment of competence should 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 programme 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 relevant aspects of GSR casework examination/ analysis and quality assurance trials
- 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 trials
- 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 – where applicable - participate in at least one of the following activities:
- research and development
- publication of a technical paper related to GSR in a recognised forensic journal
- presentation of a paper or participation in a professional meeting/seminar
- technical training events as a presenter/instructor
- the work of an organisation dealing with the technical advancement of forensic GSR analysis
- should also routinely discuss/critique the relevance of selected GSR topics within the GSR laboratory or the ENFSI Expert Working Group Firearms/GSR.

4.2 Equipment

The equipment inventory (i.e. mechanical press, stereomicroscope, drying oven, etc.) should be proven to operate properly before used in casework, and then only within the limits of the performance checks carried out.

4.3 Reference materials

Technical specification for reference materials (for calibration, assessment of a measurement method, or for assigning values to materials) should be defined in detail.

4.4 Accommodation and environmental conditions

Laboratories for the examination of items for GSR should be designed for efficient and effective working.

Particular consideration should be given to the need for avoidance of contamination. This requires the provision of adequate space for searching and physical separation of search areas to allow for the separate processing of items from different suspects (low concentrations) and victims (high concentrations). Procedures to avoid contamination and monitoring contamination levels should be implemented.

4.5 Materials and reagents

All materials and reagents used for GSR examination should be of a suitable quality and have

been demonstrated as fit for purpose.
Reagents should be tested for correct functioning using a reference sample prior to their use in casework.

5. METHODS

Various chemographic methods are available for the visualization of GSR, see table 1 in appendix. The selection of the most appropriate method depends mainly on the chemical composition of the ammunition used in the shooting incident in question.
The principle of the chemographic process is that traces of GSR, which are not visible to the human eye, will form coloured chemical compounds when reacting with selective or specific reagents. Therefore, GSR particles are usually transferred onto a secondary target medium such as: cellulose hydrate foils, filter papers, adhesive foils or photo papers.
In order to give an example of a chemographic method, one of the most common procedures is described below. This is only one example of the method, commonly known as the Sodium Rhodizonate Test.

Sodium – Rhodizonate test for Pb, Ba and Sr: A secondary target medium (here: filter paper) is pre-treated with an acid (here: tartaric acid) and then pressed against the area of interest. A saturated solution of sodium rhodizonate is then sprayed on the paper. If present, lead compounds react to form pink-reddish complexes, while barium and strontium compounds will be visible as orange precipitates.

Other commonly used chemographic methods are the Rubeanic Acid (Dithiooxamide, DTO) Test (for Cu or Ni), and the (Modified) Griess Test for powder particles. See appendix for further information.

In order to avoid potential color fading it is recommended to use the reagent again on the colored items or/and document the colored items by digital scans or photography.

An alternative and non-destructive method for the visualisation of GSR patterns (in shooting distance determination) is an X-ray-fluorescence-system (XRF) with mapping capabilities.

A verification of the coloured GSR particles can be performed by SEM/EDX, or – in case of powder particles – using infrared spectroscopy, GC-MS or LC/MS.

5.1 Peer review

It is particularly important in all forensic examinations for a protocol for case review to be established. This document, therefore, details the requirements for such reviews in the field of GSR examinations. In addition to the institute's normal peer review process, special attention should be given to the chemographic prints and their visual 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 refer to the ENFSI validation document. Suitable reference materials for validation purposes could be cartridge cases, elemental standards, etc.

6.2 Estimation of uncertainty of measurement

The chemographic methods are qualitative chemical analyses. Therefore the use of reference materials in combination with the chemographic treatment of a sample minimizes the risk of false conclusions. All potential uncertainties encountered refer to the uniqueness of a shot, and are larger than the uncertainty of the chemographic method itself.

7. PROFICIENCY TESTING

Proficiency tests should be used to test and assure the quality of the method. A list of currently available PT/CE schemes is available. “Guidance on the conduct of proficiency tests and collaborative exercises within ENFSI” provides information for the ENFSI Expert Working Groups (EWGs) on how to organise effective proficiency tests (PTs) and collaborative exercises (CEs) for their members.

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

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 examiners should wear suitable protective clothing to minimise the risk of GSR transfer from the examiner to the items being examined and secondary transfer between items via the examiner.

Benches used for searching should be rigorously cleaned prior to any examination and the rooms should be cleaned regularly, and if necessary disposable bench covers should be used (paper, bench coat, or foil)

Search and recovery / Sampling

GSR may be recovered in the laboratory by stubs (for SEM/EDX investigation prior to chemographic treatment), foil, desensitised photo paper and other suitable sampling material.

Use of special adhesive tape in combination with a stub is usually the method of choice. After collection of the GSR, the stubs should be placed in the original tubes of the sampling kit.

Optical light microscopy can be used to find the GSR on wider surfaces i.e. garments and larger objects. This method can also be used to examine the surfaces of the adhesive tape on the stubs for the presence of fibres, particles or powder.

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 is performed before any chemical treatment takes place.

9. CASE ASSESSMENT

It is recommended that any information on the status of the scene, suspects and victims, changes in the urgency for information, contamination issues and impact of results already reported,

should be obtained at the initial examination.
Information regarding chain of custody and the intended examination should be acquired before starting any examinations.
Information about the type of ammunition used in a specific case should be acquired in order to choose the appropriate chemographic method for the visualization of GSR. For example, this could be achieved by checking the primer composition by SEM/EDX from a cartridge case from the crime scene, or by stubbing from the bullet wipe ring of an entrance hole.

10. PRIORITISATION AND SEQUENCE OF EXAMINATIONS

Chemographical methods could have a profound influence on other examinations and vice versa. Depending on the circumstances of the case the customer should decide which type of examination should be done first. This should be done based on the advice of the expert.

11. RECONSTRUCTION OF EVENTS

Not applicable.

12. EVALUATION AND INTERPRETATION

With appropriate chemographic methods selective elements or components within GSR particles can be visualized.
In general, two main problems can be addressed by chemographic methods:

- The presence of GSR particles.
- The shooting distance determination.

The presence of GSR particles
Since the chemographic reagents are not specific for the visualization of GSR particles but only selective for certain elements or components within GSR particles, SEM/EDX can be used to verify the composition of the coloured particles.

Shooting distance determination
The shooting distance determination is performed by using the distribution/pattern of GSR particles around an entrance hole of a shot. Therefore a series of comparison shots of known distances between muzzle and target material should be produced using parameters as close as possible to the case parameters (e.g. target material, weapon, ammunition, etc.).Both the comparison shot and the case shot should be treated chemographically in the same manner. By comparing the visualized pattern of the case shot to those obtained from the comparison shots, the expert estimates the shooting distance within a specified range.

13. PRESENTATION OF EVIDENCE

Written reports should include all the relevant information in a clear, concise, structured and unambiguous manner as required by the relevant legal process. Written reports must be peer reviewed. Reports should clearly state the results of any evaluation and interpretation of the examination. This is done according to the relevant laboratory regulations.

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. 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 material safety data sheet (MSDS) 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.

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16. AMENDMENTS AGAINST PREVIOUS VERSION

Not applicable (first version)

APPENDIX
LIST OF CHEMOCHAPHIC CHEMOGRAPHIC METHODS

element(s)	transfer medium	diffusion medium	reagent	colours
lead and barium	adhesive foil	polyvinylalcohol layer and acetic/tartaric acid	sodium rhodizonate	reddish-violet / reddish-brown
	filter paper	tartaric acid	sodium rhodizonate	reddish-violet / reddish-brown
	polyethylene photo paper	acetic acid	sodium rhodizonate	reddish-violet / reddish-brown
	cellulose hydrate foil (cellophane)	acetic acid	sodium rhodizonate	reddish-violet / reddish-brown
lead and copper	cellulose hydrate foil (cellophane)	acetic acid	sodium sulfide	brownish-black
copper and nickel	filter paper	acetic acid	dithizone/NaOH	violet
	baryte photo paper	ammonia	dithiooxamide, ethanolic	brownish-grey
	cellulose hydrate foil (cellophane)	acetic acid	dithizone/NaOH	violet
zinc	adhesive foil	polyvinylalcohol layer and acetic acid	dithizone/NaOH	purple red
	filter paper	acetic acid	dithizone/NaOH	purple red
	polyethylene photo paper	acetic acid	dithizone/NaOH	intensive red
	cellulose hydrate foil (cellophane)	acetic acid	dithizone/NaOH	reddish-violet
copper and zinc	filter paper cellophane foil	NaOH	zincone/NaOH	blue
	filter paper	ammonia	chlorindazone DS	blue
antimony	filter paper	acetic acid	phenylfluorone	violet
	baryte photo paper	acetic acid	phenylfluorone	violet
strontium	filter paper	acetic acid	sodium rhodizonate	reddish-brown

material	transfer medium	reagent	colour
nitrocellulose (as nitrite)	Filter paper Desensitized photo paper	Sulfanilic acid acetic acid (diffusion medium)	orange-red
nitrocellulose (as nitrite)	1. adhesive foil	KOH, ethanolic (120° C, 1 h)	violet
	2. baryte photo paper	sulfanilamide (solution in phosphoric acid) + N-(1-naphtyl)-ethylenediamine dihydrochloride (solution in phosphoric acid)	

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