Best Practice Manual for the Forensic Recovery, Identification and Analysis of Explosives Traces

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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.

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CONTENTS

1. AIMS

This Best Practice Manual (BPM) aims to provide Forensic Science Providers (FSP) and individual practitioners, who are involved in the investigation (scene and laboratory-based) of explosives-related incidents, with a framework of procedures, quality principles, training processes and approaches for the forensic recovery, analysis and identification of explosives traces from forensic evidence. It can be used by Member Laboratories of ENFSI and other interested parties within the investigative process for awareness of best practice in relation to trace explosives investigation.

The BPM proposes working practices that will deliver reliable results, maximise the quality of information obtained and produce robust evidence for the judicial process.[1] The use of consistent methodology and the production of more comparable results will facilitate interchange of data between laboratories.

The term BPM is used to reflect the scientifically accepted practices at the time of creating this manual and does not imply that the practices described within it are the only good practices used in the forensic field. In this series of ENFSI Practice Manuals, the term BPM has been maintained for reasons of continuity and recognition.

2. SCOPE

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 judicial systems in general terms only. It:

- addresses the principal forensic processes associated with the recovery of explosives traces from related evidence (at the crime scene and within the laboratory), including sampling, sample processing / analysis, interpretation and the presentation of evidence;
- does not cover activities associated with the first response to, or general management of explosives-related crime scenes, the investigation of bulk explosive materials, or the trace impurity profiling / individualisation of explosives (see references 1 – 6 for further information);
- does not consider any precursor materials associated with illicit manufacture of explosives (see reference 7 for further information).

3. TERMS AND DEFINITIONS

For the purposes of this BPM, the relevant terms and definitions given in ENFSI documents, the ILAC G19 “Modules in Forensic Science Process”, and in standards such as ISO 9000, ISO 17000, ISO 17020 and ISO 17025, apply.

Additionally, within the context of this BPM, the following definitions apply:

- explosives **traces** are extremely small quantities of explosive material, typically in the sub-microgram range and not visible to the naked eye;
- **bulk** quantities of explosives are visible to the naked eye;
- **low** explosives (or deflagrating explosives) are chemical substances/mixtures, which under no condition can support a detonation wave. This type of explosive can burn in the absence of air or in confinement; but when confined can burn to deflagration; [4]

[1] It is recognised that forensic explosives investigation is heavily dependent on the jurisdictional expertise and experience of forensic scientists and on the capabilities available to them, e.g. appropriate facilities, scientifically acceptable analytical methods. Unique requirements in different jurisdictions may also dictate the practices followed.

- **high** explosives are chemical substances/mixtures that support a detonation wave, irrespective of the ambient conditions of confinement; [4]
- **deflagration** is the rapid burning, faster than open-air burning of the material but slower than the detonation or explosion of high explosives; [4]
- **detonation** is a violent chemical reaction taking place within a chemical compound, or a physical mixture, involving the generation of heat and pressure, which proceeds from the reacted material toward the unreacted material at supersonic velocity. [4]

4. RESOURCES

Management of the resources required for explosives trace investigation must take into consideration the appropriate and applicable areas of the ISO 17025 quality standard and must be fully documented under the FSP's Quality Management System (QMS). However, it should be recognised that many aspects of explosives scene investigation are not specifically addressed in this standard. Further information relating to the standards required for crime scene investigation may be found in ISO 17020.

4.1 Personnel

Table 1 defines the key competencies required by forensic practitioners that conduct trace explosives investigation as part of their role. Broadly, these competencies relate to those required for sampling and sample processing (both at the crime scene and in the laboratory), those relating to chemical analysis, and those required for evidential interpretation and reporting to the national judicial system.

Due to variations in the size of different laboratories and variability within different laboratory systems, absolute standardisation of practitioner competence cannot be achieved. It is also accepted that individuals may be responsible for more than one of the defined roles.

4.2 Equipment

The FSP's procedures for anti-contamination, as documented within its QMS, must be applied to equipment entering a trace explosives environment (see section 10.1 and 10.2).

Appropriately maintained equipment, used in conjunction with validated methods, must be employed in trace explosives investigation, and these must be operated within the limits of the method. If a validated method is not available, the FSP must make best efforts to establish a suitably validated method, where appropriate.

The recommended equipment required for conducting trace explosives investigation (at the scene and laboratory) is covered in more detail in Appendix 1. Additionally, the following references provide detailed information about these techniques. [8 – 10]

4.3 Reference materials

Standard reference materials / solutions are an essential requirement for ensuring the precision of test measurements in trace explosives analysis, especially in relation to qualitative identification by direct comparison. They must be obtained from reputable sources and be supplied with appropriate documentation, including quality assurance certificates, to ensure traceability to national and/or international standards.

Where reference materials are not commercially available, as can often be the case for unusual or sensitive explosives, in-house authentication of the purity, composition and longevity of reference materials/solutions must be conducted using appropriate chemical *(to be continued on page 7)*

Role	**Key competencies**
All roles	Knowledge of the Health and Safety issues relating to explosives, i.e. toxicity, and experience in the handling of explosives
	Knowledge of the physical and chemical properties of industrial, military and typical home-made explosives (HME)
	Knowledge and awareness of anti-contamination measures
	Awareness of the evidential requirements of wider forensic disciplines associated with explosives investigations, e.g. DNA, fingermarks
	Knowledge of the working practices, roles and responsibilities of a multi-agency response to an explosives-related incident
	Trained according to a structured and documented training plan, in accordance with the quality practices of the organisation
Crime Scene Attendant	Health and safety issues associated with structurally damaged buildings, including but not limited to bio-hazards, asbestos, gas, spilled inflammable liquids, live electrical wiring, etc.
	Knowledge and familiarisation with the recognition of components of explosive devices, including detonators, construction of unconventional explosive devices
	Knowledge and competence to differentiate between high, low explosives and deflagration of combustible air mixtures
	Knowledge and competence to draw a conclusion on the type of explosive used and to estimate the size of the original charge based on an inspection of the post-explosion scene
	Knowledge and competence in trace explosives sampling
Forensic Analyst	Knowledge and awareness (including the limitations) of the analytical methods available within the organisation and the wider discipline
	Understanding how the sequence of analyses would impact the outcome of investigations
	Knowledge of the working practices used by forensic practitioners and investigators within other forensic disciplines
Forensic Investigator	Competent in preparing (scientific) reports in accordance with the organisation's regulations for police investigations and court proceedings
	Familiar with local court procedures
	Competent in case assessment / forensic strategy and technical review

Table 1 Key competencies for forensic practitioners involved in trace explosives investigation

characterisation techniques. Recommended techniques include high-performance liquid chromatography (HPLC), infrared (IR) spectroscopy and nuclear magnetic resonance (NMR) spectroscopy. All authenticating data must be retained according to local (accreditation) regulations.

Standard solutions, diluted to concentrations corresponding to expected casework levels, must be used in trace explosives work. Preferably, these should be multi-component standards to facilitate the identification of possible contamination. Reference standards / materials and reagents must not be used beyond the expiry date, where provided, unless it is verified that they remain fit for purpose beyond that date.

4.4 Accommodation and environmental conditions

The FSP must provide suitable accommodation that provides the optimum working environment for trace explosives investigation, ensuring work can be performed safely, the integrity of trace evidence is protected and staff can conduct their duties with maximum effect.

Many laboratories that are active in the forensic investigation of explosives deal with cases that involve both bulk and trace quantities of explosives. In such laboratories, trace explosives contamination is likely, unless proper precautions are taken. To mitigate this, effective anti-contamination procedures, covering all activities relating to entry to, and working within, the laboratory, as well as regular environmental monitoring for explosives contamination, must be in place.

Further details relating to general considerations for anti-contamination best practice (at the crime scene and within the laboratory environment) are discussed in sections 10.1 and 10.2. Reference 11 provides an example of trace investigation facilities (and related anti-contamination regimes). However, it should be recognised that the scope and scale of the laboratory requirements for conducting trace explosives investigation will be heavily influenced by economic factors.

4.5 Materials and reagents

The FSP's procedures for anti-contamination, as documented within its QMS, must be applied to materials and reagents entering a trace explosives environment. Further details relating to general considerations for the use of materials and reagents (at the crime scene and within the laboratory environment) are discussed in sections 10.1 and 10.2.

If trace explosives sampling kits are produced by the FSP, i.e. for use at explosives-related crime scenes, these must be manufactured in a suitable trace environment and be demonstrably explosives-free prior to use. [11] An appropriate quality control regime, documented as part of the FSP's operating procedures, must be observed in such cases.

5. METHODS

5.1 General approach to trace explosives investigation

The varying nature of explosives-related crime scenes may lead to the requirement for several decision making points during the overall trace explosives investigation process. As an introduction, the general phases of the trace explosives investigation process are presented in Figure 1, although it should be noted that this process may not always be sequential. The best practice in choosing the type of methods and the order of methods used during these different phases of the process are addressed in more detail in subsequent sections of this BPM.

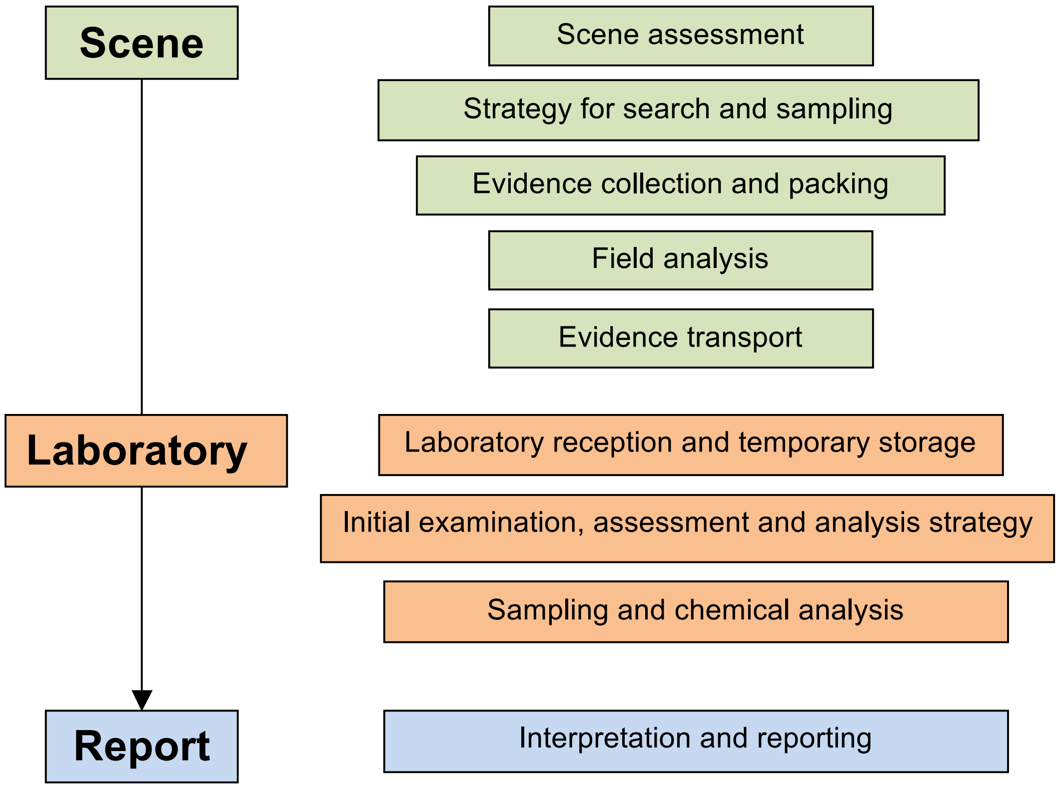

Figure 1 General approach to trace explosives investigation

5.2 Peer review

To ensure a high quality and robust forensic process, peer review must be conducted for the following phases of the process:

- ‘strategy for search and sampling’ at the scene and ‘initial examination, assessment and analysis strategy’ within the laboratory:
  Where possible for more complex explosives-related crime scenes, e.g. post-explosion, these strategies must be reviewed by another Crime Scene Attendant experienced in explosives-related crime scene work beforehand. This is very important, as they are likely to have a very high impact on the outcome of trace explosives investigation.
- analytical results obtained during chemical analysis:
  Another Forensic Analyst, experienced in trace explosives analysis, must check the analytical results for consistency, preferably by checking against acceptance criteria determined during method validation and stipulated in the analytical method.
- conclusions drawn during ‘interpretation and reporting’:
  Another Forensic Investigator with expertise in trace explosives investigation must check the conclusions for overall consistency with all findings of the investigation (from the scene to the laboratory analysis results).

6. VALIDATION AND ESTIMATION OF UNCERTAINTY OF MEASUREMENT

6.1 Validation

The objective of any analytical measurement is to obtain consistent, reliable and accurate data. Validated analytical methods play a crucial role in achieving this, since the results from method validation can be used to judge whether the method is fit for the specific purpose intended. The use of validated methods is an integral part of any good laboratory practice.

All analytical methods and processes used for trace explosives investigation must be validated according to the FSP's procedure for the management and conduct of method validation and method verification. This procedure must be designed to ensure that validation activities contain comparable features, irrespective of the approach taken for a specific method. [12 – 15]

Sample preparation for explosive residues is difficult not only because of the low concentration of explosives, but also because of the unpredictability of the background (matrix). For any kind of sample preparation an estimation of the recovery of a range of frequent matrices is recommended.

When the samples preparation only involves steps without significant selectivity effects, e.g. solid-liquid extraction, filtering and concentrating, a recovery experiment will suffice. When a clean-up step is involved in the sample preparation, e.g. liquid-liquid extraction, or solid phase extraction, selectivity might vary with different matrices, and thus validation of the sample preparation is recommended.

6.2 Estimation of measurement uncertainty

The estimation of measurement uncertainty is an explicit requirement of ISO 17025 and a critical part of the validation of any new method. Consequently, an assessment of measurement uncertainty must be included in all validation studies, according to the FSP's procedure for the management and conduct of method validation and method verification.

Typically, trace explosives analysis is qualitative and an assessment of method selectivity, e.g. matrix effects, suppression, etc. must be conducted as part of method validation. If a quantitative result is reported, it is good practice to identify all the components of uncertainty and make a reasonable estimation of its overall magnitude. [12 – 16]

7. PROFICIENCY TESTING

Proficiency tests (PT) must be used to test and assure the quality of the FSP's processes and methods for trace explosives investigation, noting that such tests are usually only within the scope of laboratory investigations.

In accordance with ISO 17025, FSP's must operate an internal proficiency testing (IPT) system that covers all accredited procedures and methods that are used for trace explosives investigation at a minimum of once every four years. The preparation and management of IPT's must be documented within the FSP's QMS. An IPT will normally comprise the unsupervised measurement of one, or more, unknown samples and will be, as far as reasonably possible, representative of those which arise in routine trace explosives investigations. The FSP must also have a policy which states the frequency of external proficiency tests (EPT) it will participate in, where an appropriate EPT is available.

At the conclusion of any PT, the FSP should conduct a review of the test to assess performance against the expected outcomes. Such reviews are extremely valuable as a 'lessons learned' exercise, or to inform capability development, especially in the event of an unsatisfactory PT.

A list of currently available PT and collaborative exercise (CE) schemes is available from the ENFSI Secretariat. "Guidance on the conduct of proficiency tests and collaborative exercises within ENFSI" [17] provides information for the ENFSI Working Groups (EWG) on how to organise effective PT and CE's for their members.

In the field of trace explosives investigation, very few PT's are available. As such, the ENFSI Expert Working Group on Explosives collaborates with commercial PT providers to offer annual PT's for the EWG members, in accordance with ENFSI guidelines. FSP's that are involved in trace explosives investigation are strongly advised to participate in such PT's as a matter of routine.

8. INITIAL ASSESSMENT

The approach and strategy adopted in a trace explosives investigation will be very dependent upon an initial assessment of the crime scene, customer requirements, or the evidence submitted to the laboratory for analysis. Preliminary findings at the scene will influence the strategies for search and sampling of exhibits. Triage of exhibits in the laboratory will fix the final analyses strategy, e.g. by determining the sequence of analyses and which exhibits have to be analysed (see section 9).

8.1 <u>At the scene</u>

Prior to any crime scene work commencing, safety issues shall be considered in depth and a dynamic risk assessment for scene work must be implemented. It should be clear what the restrictions are in entering (parts of) the scene. An assessment of the scene for planning the search and sampling strategy must take into consideration: [18]

- the size of the explosive incident, the resources available (at the scene and in the laboratory) and scene conditions that might necessitate prioritisation or selection. Items will be selected according to their nature and potential evidential value (a re-assessment of the preliminary sampling strategy might be necessary, e.g. based on additional findings at the scene);
- assessment of the scene will be conducted within a multidisciplinary setting, considering not only forensic issues, but other factors such as safety and legal considerations. Typically, other forensic disciplines will also be involved and, consequently, the forensic investigator must liaise with these other parties during scene assessment. Implications of these considerations could include changes in standard personal protection and sampling procedures to allow for best practice of other trace recovery. Deviations from any standard operating procedure should be recorded;
- explosive traces can be present on people, or in the material found on / in, or extracted from them. These people might no longer be at the crime scene, e.g. moved to safe location, hospital;
- triage at the scene can help to avoid seizing exhibits that are not related to an explosives incident;
- for other explosive trace related scenes (non-explosion scenes), assessment is much more dependent on information from other investigators, e.g. what is the scenario, which locations are of interest for sampling, what traces are being looked for, etc. An example of this kind of information is intelligence that may have initiated the search. The use of mobile detection equipment in a nearby "field-lab", or canines, could be considered to aid the selection of relevant samples. [19]

8.2 <u>In the laboratory</u>

Prior to laboratory work commencing, safety issues must have been considered in depth. An assessment of submitted evidence for planning the sampling and analysis strategy must take into consideration:

- all measures must be taken to assure evidential integrity and transparency in the laboratory processes;

- exhibits will be analysed according to their nature and potential evidential value. Typically, the results of analyses other than trace explosives offer stronger links to the perpetrator and liaison with other experts, e.g. DNA, fingermarks or fibres, must be considered.
- assess the evidential value of each group of exhibits depending on customer requirements and reliable information available.

9. PRIORITISATION AND SEQUENCE OF EXAMINATIONS

This section focuses on the selection of items to be collected / sampled for the recovery of explosives traces, and does not consider the recovery of other traces with potentially higher evidential value.

9.1 <u>Evidence selection</u>

9.1.1 At the scene

Material in the vicinity of the seat of the explosion offers the best chance of recovering explosives traces, e.g. bare metal / glassy surfaces, porous material. [18] Good sources of explosives traces can include parts of the explosive device, e.g. containment, parts of the timer, electronics, batteries, etc. Preferably, items of all sizes should be brought to the laboratory. Only when the necessary resources cannot be allocated, sampling at the scene, or reducing the size of the item should be considered.

For other explosives trace related scenes (non-explosion scenes), the recovery of explosives traces will be more dependent on the individual circumstances. Surfaces most likely to have been in contact with explosives should be prioritised, e.g. bomb-making equipment, clothing, door handles, table tops, steering wheel, etc.

9.1.2 In the laboratory

Considering the available resources in the laboratory and the customer's / jurisdictional requirements, assess if a comprehensive analysis of all exhibits is really necessary. If not, prioritise or pool samples for analysis by considering items with the highest expectation of recovering explosives traces and combining samples from a group of exhibits with common features, e.g. containment, electronics, batteries, electrical wire, isolation tape, glues, disguising material.

9.2 <u>Chemical analysis</u>

9.2.1 At the scene

Typically, chemical analyses at the crime scene, particularly a post-explosion scene, must be avoided due to safety and contamination risks. A field laboratory, with easily deployable and robust equipment could be set up, if appropriately controlled as per the requirements of this BPM. [19] Some of the techniques listed in Appendix 1 could be available as transportable instruments.

9.2.2 In the laboratory

Selecting the methods used for analysis and the order in which to apply these methods to the exhibit are determined by several considerations, including:

- integrity of the evidence (non-destructive methods are performed before semi-destructive methods and methods corroborating other forensic evidence, e.g. DNA analysis, visualisation of fingermarks, search for fibres, etc., are conducted before

sample preparation for explosives trace analysis);
- the nature of the matrix in which possible traces are present, e.g. biological or toxic matrices;
- the performance of available instrumentation for obtaining the desired results (target compounds, sensitivity, selectivity) (see Appendix 1).

Figure 2 suggests a general protocol for prioritising and sequencing chemical analysis of exhibits for explosives traces.

10. HANDLING ITEMS

10.1 <u>At the scene</u>

10.1.1 Anti-contamination precautions
Avoid bulk explosives environments prior to conducting trace work or attending a scene. Consider changing clothes and showering between consecutive scenes and use fresh gloves, fresh protective overalls, e.g. Tyvek-suit and boots, for personnel entering the scene or dealing with exhibits. Use disposable materials and / or equipment wherever possible for each sample to be acquired and take appropriate control samples, e.g. blanks and environmental. If disposable materials and / or equipment are unavailable, a suitable cleaning regime must be followed before use, e.g. multiple solvent washes or ‘flaming’.

If canine units are used at the scene, be aware of additional contamination risks, due to their uncontrolled movement within the scene. Additionally, in case bulk explosives are encountered during the search seize trace samples first and deal with the bulk material later on (assuming appropriate safety precautions have been taken).

10.1.2 Search and recovery
Extended scenes must be divided into zones to be processed independently. Prior to taking samples, it is good practice to record the original location and condition of the items in situ, e.g. via photography. In general, try to process the scene from areas with low to high concentrations of explosives residues. In post-explosion scenes, potentially relevant parts of the explosive device could be hidden from sight. The help of special equipment, e.g. sieves, magnets, cherry pickers, could help in recovering those items.

10.1.3 Evidence collection and packaging
Where sampling takes place in an area known to be heavily contaminated with explosives, or the exhibits are suspected of containing high concentrations of explosives residues, measures must be taken to prevent subsequent contamination of the trace explosives laboratory (for suggested procedures see Appendix 2).

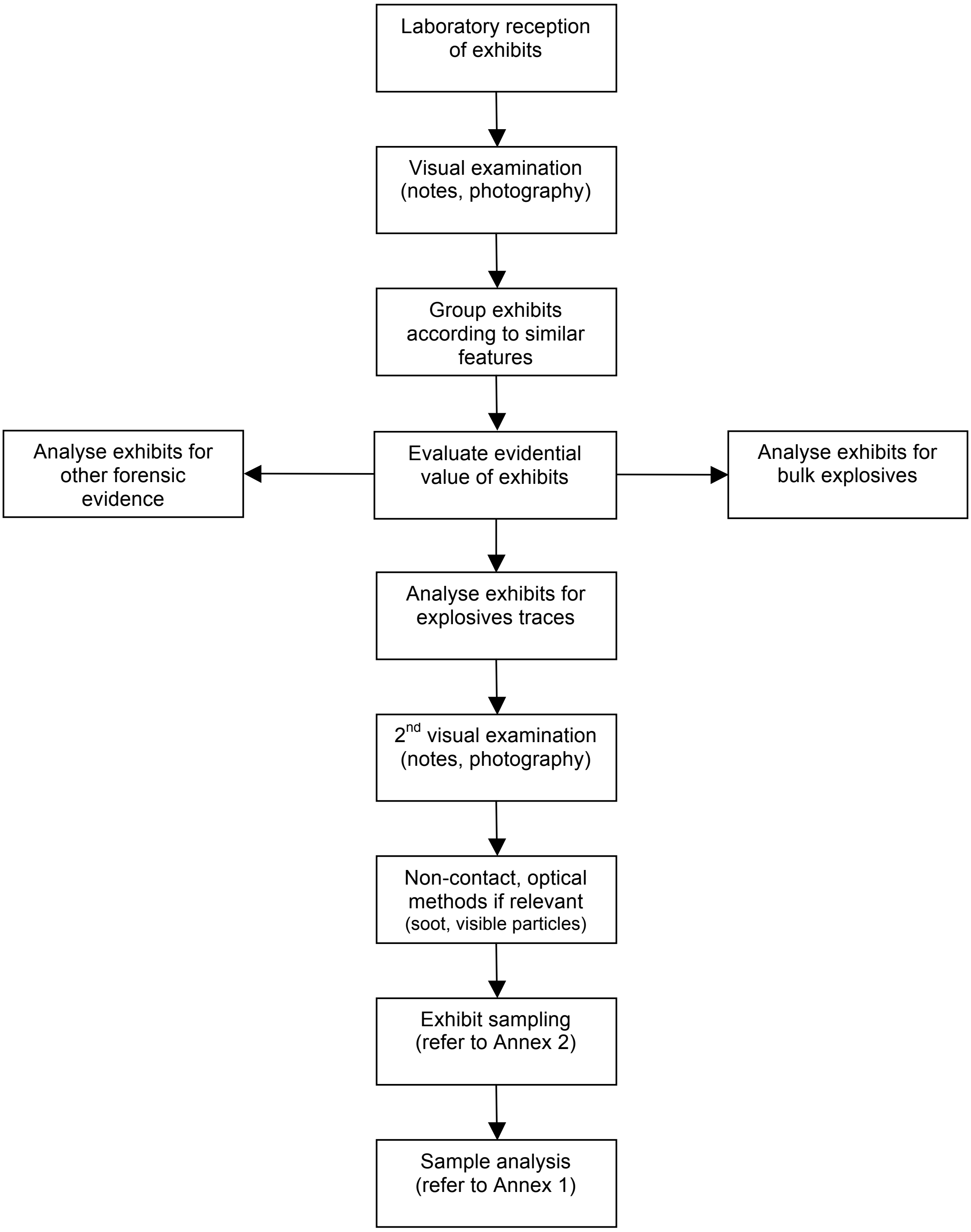

Figure 2 General protocol for prioritising and sequencing chemical analysis of exhibits for explosives traces

Preferably, pack exhibits using appropriate packing material that will not compromise their integrity or the evidential value (for suggested packing materials see Appendix 2). For relatively small post-explosion scenes, it is preferable for all items to be packed individually. For larger, or more complicated post-explosion scenes, reasonable grouping and packaging of evidence is preferable.

10.1.4 Labelling and documentation
Typically, explosive trace evidence does not have any other specific requirements other than good forensic practice for evidential integrity.

10.1.5 Transport
Transport of exhibits containing trace explosives requires neither special equipment, nor special means of transportation. However, to preserve evidential integrity, transportation together with exhibits containing bulk explosives or by agencies involved in working with bulk explosives may cause contamination and must therefore be avoided.

10.2 <u>In the laboratory</u>
Specific procedures used for laboratory recovery of explosives traces must be documented within the FSP's QMS.

10.2.1 Anti-contamination precautions
If possible, use separated laboratory areas and different personnel (same personnel after thorough decontamination only) for bulk and trace explosives work. Ideally, only work on one case in an assigned laboratory space. Clean the relevant work areas and laboratory equipment in the assigned laboratory space before entering evidence from a new case. Cover work spaces with a disposable work surface before putting exhibits on them. Controls must be taken from relevant surfaces, e.g. benches, personnel, tools, etc., before commencing work on the evidence;

Whenever possible, use disposable equipment for the work to be performed. Other equipment must be thoroughly rinsed with suitable solvents and "flamed" if possible. When samples are taken from exhibits, relevant blanks of sampling materials, e.g. swabs, solvents, etc. must be taken.

10.2.2 Labelling and documentation
Typically, explosive trace evidence does not have any other specific requirements other than good forensic practice for evidential integrity.

10.2.3 Storage conditions
Due to the nature of explosive traces, e.g. instability, volatility, ideally exhibits must be processed as soon as possible after collection. If this is not possible, and storage is expected to last for an extended period of time, exhibits potentially containing explosive traces must be kept refrigerated and in the dark (where possible) until they can be processed. Samples containing water and organic material that will be stored for longer periods must be kept frozen to prevent growth of bacteria and fungi, which could interfere with subsequent analysis.
Samples (extract solutions) must be stored under refrigerated conditions before analysis and disposed of according to the laboratory procedures. Processed materials (sampled items) could be handled as any other evidence materials;

10.2.4 Sample processing
Samples will be processed according to their nature, their evidential value and the resources available in the lab. Further detail of specific sample processing procedures can be found in Appendix 2.

11. RECONSTRUCTION OF EVENTS

Trace explosives analysis is suitable for the identification of the explosive substance(s), or reaction products, present in a specific sample. It is neither possible to determine the specific original chemical composition of an explosive, nor to construct the original physical device from these results, since to do so other parameters must be determined. Physical reconstruction of any explosive device or parts of an explosive device (at the scene or in the laboratory), or determining the size of the original explosive charge, are beyond the scope of this BPM.

However, an examination of the physical nature of fragments, e.g. size, morphology, sooting / flashing, recovered from the original device can assist in the determination of whether, or not, there was a low-order or high-order explosion. For further details, see reference 18.

The only direct conclusion that may be drawn from the identification of explosives traces on a piece of evidence should be the presence or absence of identified explosive related substances.

12. EVALUATION AND INTERPRETATION

As discussed in section 11, it is generally accepted that the exact composition of the original explosive cannot be deduced from post-explosion trace explosives analysis results.

12.1 <u>Discriminating power</u>

In some literature, discriminating power is also referred to as 'specificity'. The specificity of the analytical methods for trace explosives analysis varies widely, as indicated in Appendix 1. It is good practice to know the specificity of the methods used in forensic casework, e.g. through method validation, by referring to accepted regulations / decisions [2], peer review of relevant literature, or by 'spiking' with known analytes to assess matrix effects; and it must be transparent in the evaluation and interpretation phase of the investigation what consequences this specificity has for the conclusions reached.

In trace explosives analysis, there is currently no consensus on the manner of expressing the degree of uncertainty when considering the identification of a chemical compound, other than to distinguish between screening methods and confirmatory methods. An example of how to express a higher degree of uncertainty (screening methods) is the phrase 'there are indications for the presence of compound x'. An example of how to express a lower degree of uncertainty (confirmatory methods) is 'compound x was identified'.

12.2 <u>Contextual information</u>

In cases where no contextual information is provided, the results of the trace explosives analysis are reported without further interpretation; only as presence or absence of the compound, e.g. 'traces of TNT are identified on item x', or 'no explosives were identified'. However, in most jurisdictions the expert has the responsibility to evaluate the significance of the analytical results and must interpret these in the context of the case. Examples of context information that is important for the evaluation and interpretation of the analytical results are:

- known activities in the area of sampling before the incident that may provide an alternative interpretation for the findings;
- procedures followed in sampling, e.g. personnel involved, sampling materials used, sampled materials, anti-contamination measures taken;
- time between sampling, storage and analysis;

[2] An example of such a 'decision' is the 2002/657/EC European Commission Decision

- questions from the customer, e.g. confirm the presence of a certain analyte as opposed to screening for traces of all possible explosives.

The above considerations also mean that when new information comes to light, re-evaluation / interpretation of the results might be required.

12.3 Relevant databases

Typically, no databases are used in the field of explosives trace analysis. The use of databases during the evaluation and interpretation of analytical results is mainly relevant when the analytical results will be used to infer more than just the identity of the explosive, such as its use in previous cases, the characteristics of the explosive identified, etc. However, this is outside the scope of this BPM.

12.4 Background considerations

Several studies show that organic high explosives are not usually present in the ‘normal’ environment (with the exception of specific areas such as explosives training grounds, areas in the vicinity of explosives manufacturing, handling and storage, or conflict areas), while traces of ions present in inorganic explosives are prevalent at varying levels in the environment.

When available, relevant knowledge of background levels of analytes must be used during interpretation of the analytical results to support the evidential value of the presence of these analytes. [20 – 23]

13. PRESENTATION OF EVIDENCE

The overriding duty of those providing expert testimony is to the court and to the administration of justice. As such, evidence must be provided with honesty, integrity, objectivity and impartiality. Evidence can be presented to the court either orally or in writing. Presentation of evidence must clearly state the results of any evaluation and interpretation of the examination.

Written reports must 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 and must clearly state the results of any evaluation and interpretation of the examination.

Where an evaluation and interpretation of the scientific findings is included in the report it is recommended that the background circumstances of the case on which the evaluation and interpretation is based on, as understood by the scientist at the time of writing the report, are stated clearly. It is also recommended that, should the circumstances of the case change, e.g. by new information coming to light, a comment stating that a re-evaluation of the scientific findings may be required.

Where the oral presentation of the scientific findings is required, for example in court, it is recommended that the expert witness receives appropriate court training, either in-house or by a suitable external trainer. Expert witnesses must resist responding to questions that take them outside their field of expertise, unless specifically directed by the court, and even then a declaration as to the limitations of their expertise should be made.

References 24 and 25 provide further specific information relating to the presentation of explosives casework evidence.

14. HEALTH AND SAFETY

Prior to any crime scene work commencing, safety issues shall be considered, e.g. structurally damaged buildings, bio-hazard by broken wastewater pipes, hazards by asbestos, gas, spilled inflammable liquids, live electrical wiring, secondary devices and live explosives, and a dynamic risk assessment during scene work shall be implemented. [18]

For trace explosives laboratory work, there are no additional health and safety risks above those for general working in a laboratory, covered by the FSP's risk assessment and health and safety policy.

15. REFERENCES

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16. AMENDMENTS AGAINST PREVIOUS VERSION

Not applicable (first version)

APPENDIX 1 TECHNIQUES FOR DETECTING TRACE EXPLOSIVES

This Appendix lists currently available techniques for the detection and identification of explosive traces. This list is not intended to be exhaustive, and it should be noted that most of these techniques are in constant development and new techniques are being developed continuously.

Indications are given of the type of analytes and typical limits of detection (LOD) for the specific techniques. However, these specifications will depend to some degree on the specific sample preparation/introduction method, specific application and combination of these techniques. Some of the techniques would typically be applied in the context of bulk explosives analysis, but could also be applied in the context of trace analysis as well.

Sample introduction	**Targets**	**Typical techniques**
Pure (e.g. on a slide, stub, swab)	All	Microscopy, XRD, XRF, FT-IR, Raman
In solution	Soluble in solvent used	LC, IC, TLC, CE
Head-space	Volatile	GC

Separation technique	**Targets**	**Typical detection technique**
Thin Layer Chromatography (TLC)	All	UV-vis absorption or fluorescence
Ion-chromatography (IC)	Inorganics, sugars	Conductivity, amperometry or mass spectrometry
Liquid chromatography (LC)	Organics	UV-vis absorption, fluorescence or mass spectrometry
Gas Chromatography (GC)	Organics with higher vapour pressures	Mass spectrometry or thermal energy analyser
Capillary Electrophoresis (CE)	Inorganics	UV-vis absorption or fluorescence

Detection Technique	**Target Analytes**	**Specificity**	**Typical LOD**
Visual microscopy	All	Low	µg
UV / Vis absorption	All	Medium	ng – µg
Fluorescence	Fluorescent organics and inorganics	Low – medium	ng – µg
Spot test / chemical colour test (Nessler-test etc.)	Several relevant targets: e.g. nitrates, chlorates, peroxides, sulphur, sugars,	Low – medium	µg / ml
Immunoassay	Organics	Medium	ng
Ion mobility spectrometry (IMS)	Organics	Medium – high	pg – ng
Mass spectrometry (MS)	All (depending on ionisation used)	Medium (unit mass resolution) High (high resolution)	pg – ng
Scanning Electron Microscopy / Energy Dispersive Spectroscopy (SEM/EDS)	Elements, Z >(3)10	High (elements)	pg
X-ray diffraction (XRD)	Crystalline organics and inorganics	High (pure compounds) Medium (for mixtures)	mg
Fourier Transform – Infra Red (FT-IR) (ATR and microscopic)	Infrared active organics and inorganics	High (pure compounds) Medium (mixtures)	mg µg (ATR)
Raman (including Surface Enhanced (SERS)	Raman active organics and inorganics	High (pure compounds) Medium (mixtures)	µg ng (SERS
(µ-)X-ray fluorescence (XRF)	Elements, Z>10	High (elements)	µg
Inductively coupled plasma mass spectrometry or optical emission spectrometry (ICP-MS / OES)	Elements, Z>7 (ICP-MS)	High (elements)	ng
Thermal Energy Analyser (TEA)	Nitro-containing compounds	High	pg
Electron Capture Detector (ECD)	Organics	Low	pg
Conductivity	Inorganics, sugars	Low	ng
Amperometry	Sugars	Low	ng

APPENDIX 2 SUGGESTED PACKAGING, SAMPLING AND SAMPLE PROCESSING

At the scene:

- define a strategy for search and sampling considering the circumstances and the resources available;
- select locations for sampling and select exhibits according to the considerations given in section 10.1;
- as a general rule, exhibits should be submitted to the laboratory in their original form. If this is not possible, consider the following sampling options:
  - where an exhibit cannot be removed from the scene and has a non-porous surface, swabbing is the preferred sampling technique. For exhibits with porous surfaces, scraping or vacuum sampling is preferred;
- exhibits, or samples, taken at the scene should be sealed (air-tight) in packaging materials that are disposable and impermeable to explosives. Such materials include:
  - nylon bag
  - fluoropolymer bag
  - aluminium clad multi-layer bag
  - metal can
  - glass jar/bottle

Note: use of polyethylene bags should be avoided, due to their permeability for organic materials. If this is unavoidable, they must not have physical contact with other exhibits and shall be replaced as soon as possible.

- care should be taken when packaging exhibits that are likely to penetrate the standard packing material, e.g. sharp items;
- where there are insufficient resources available, use a single packing for a group of similar items;
- liquids, suspected of containing explosives traces, shall be sampled in bottles (do not use sampling bags); glass (for suspected organic traces) and plastic (for suspected inorganic traces);
- swabs will be treated as solid exhibits;
- in cases where exhibits are suspected of containing high concentrations, or visible quantities of explosives material, samples should be specially labelled to raise the laboratory's awareness and extra packaging should be considered.

In the laboratory:

The general sampling and analyses strategy is described in section 10 and Figure 2.

- preferred sampling techniques for non-porous surfaces are swabbing and solvent wash/extraction;
- preferred sampling techniques for porous surfaces are solvent extraction, vacuuming, scraping, headspace (for volatile explosives), or solid-phase micro extraction (SPME);
- the selection of the solvent will be determined by the trace explosives expected, the analysis methods to be applied and the nature of the exhibits, e.g. MeOH, MeOH/H_2O, EtOH/H_2O;
- additional sample processing steps may be considered, such as ultra-sonication, centrifuging, filtering, or solid-phase extraction (SPE) / pre-concentration techniques, to prepare samples for instrumental analysis.

Best Practice Manual for the Forensic Recovery, Identification and Analysis of Explosives Traces

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