Best Practice Manual for the Forensic Examination of Fibres

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Best Practice Manual for the Forensic Examination of Fibres

Table of Contents

138 **Acknowledgements**

139 20 years have passed since the publication of the first version of the manual of best practice
140 (2001). In 2003 the efforts of those involved in its production were already officially recognised
141 by the ENFSI board. This was the first 'Manual of Best Practice' produced by any of the ENFSI
142 working groups and it became the template which others used to produce similar
143 documentation. After 10 years a revised version was made available online (2011) and its
144 structure was amended by splitting it up to several single guidelines. During this process also
145 the original European Fibre working group (EFG) has changed into European Textile and Hair
146 Group (ETHG). Inspired by the Fibre manual some members of the ETHG have produced a
147 first version of the Hair BP manual (2015). The present version of the Fibre BPM is based on
148 the ENFSI official template and it can be seen as a subtle merging between past and present,
149 between established knowledge and recent needs for standardisation and uniformisation in the
150 Forensic community.

151 Many individuals have contributed to the Manual of Best Practice but it is especially important
152 to acknowledge the efforts of the original sub-group chairpersons as well as those responsible
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160 the enthusiasm of these individuals this present manual would never have existed. Sadly, some
161 of the original members who were instrumental in the inception of the manual are no longer with
162 the group. The Steering Committee of the ETHG would like to thank them for their participation
163 and dedicate this latest revision to the memories of those who have passed.

1. AIMS

This Best Practice Manual (BPM) aims to provide a framework for procedures, quality principles, training processes and approaches to the forensic examination of textile fibres. 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 examination of fibres 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.

The term BPM is used to reflect the scientifically accepted practices at the time of creation. The term BPM does not imply that the practices laid out in this manual 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 Best Practice Manual (BPM) provides guidelines for the entire forensic process of fibre examination (including recovery at scenes of crime and in the laboratory), laboratory examination (identification, comparison and analysis), evidential evaluation and interpretation, and presentation of evidence. This BPM applies to criminal cases as well as to accident investigation cases (e.g., fibre plastic fusion).

It does not address other textile examinations such as textile damage analysis or textile imaging. This BPM is intended for experts in the field and assumes prior knowledge in this discipline. It is not a standard operating procedure (SOP) and addresses the requirements of the judicial systems in general terms only. Relevant SOPs and method descriptions are attached in the appendices.

This document also encompasses the requirements for systems, procedures, personnel, equipment and facilities for the forensic process of fibre examination.

3. DEFINITIONS AND TERMS

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”, and in standards such as ISO 9000, ISO 17000, 17025 and 17020 apply. Other relevant and specific definitions, which assist in the interpretation of this manual, are listed below.

Activity Level
The degree of support that can be assigned that an alleged activity is responsible for the transfer of a particular trace item (or items) between two surfaces or items. For this type of evaluation information regarding the framework of circumstances of the case is needed.

Associated items
Two or more items that have material present on them that appears to have originated from a common source.

Background trace
Trace(s) collected that appear to have no relevance to the crime.

Brushing
Surface debris collection technique using a brush; this is not recommended as a routine method for fibre recovery by the ETHG.

Case assessment
Also referred to as 'initial case assessment' or 'case pre-assessment'. It is an exercise involving the evaluation of circumstances and exhibits relating to a submitted case. Aspects to be considered are: the question being asked by the customer, the examination priorities and strategy, the potential examination outcomes and their associated evidential value in order to increase the effectiveness of said examination.

Case file
The physical (may also include electronic) documentation of an individual case containing all the relevant information required and generated, in order to produce a report for use by the court (e.g., the circumstances of the case itself, communications with submitting officer(s), details of continuity, results of the laboratory examinations and the final report itself).

Chain of custody
The total physical (and electronic) documentation detailing the continuity of the physical handling of items and samples, within a sphere of responsibility e.g., from submission to the forensic laboratory until return to the submitting agency.

Characterisation
The determination and documentation of features such as surface morphology, cross sectional shape, colour, damage and the results of instrumental analyses, which distinguish a particular fibre or population of fibres from other fibre populations. 'Identification' (see below) may be considered as part of this process.

Clippings
Collecting technique using scissors; usually of fingernails.

Collection
The physical recovery and packaging of an item/sample/sub-sample after its detection.

Collective
A group or population of fibres that appear to have a common origin due to sharing comparable characteristics.

Contamination
Introduction of material to an item which is not 'crime - related' and has been inadvertently introduced to it either at the crime scene, laboratory or during its storage and transportation.

Controlled environment
A location controlled in respect of physical environment, access and cleanliness, e.g., examination rooms in a laboratory.

Crime scene
Any location where illegal activity has taken place - may also be called "the scene".

Detection
The finding of an item/sample/character that is of evidential value.

Documentation
A written description of e.g., an item, event, circumstances on paper, drawings, diagrams or photographic images (Including those in an electronic format). For full validity documentation should be signed and dated by all concerned.

E-learning platform
Created by the European Textile and Hair Group (ETHG), this platform gives a practical demonstration of the best practices in forensic fibre examination through videos and illustrated presentations, made by experienced practitioners in the field. Access is limited outside the ETHG working group and the European forensic community.

https://e-learning.ethg.eu

Evidence
Established nature of an object or event that provides support to a hypothesis and is of interest to the court.

Evidential value
The judged, calculated, assessed or estimated supporting level that a finding provides to a hypothesis or proposition.

Evaluative reporting
Providing an opinion on the degree to which the laboratory findings in a case corroborate or refute a particular set of hypotheses or propositions placed before the court.

Evidentiary item
An item of physical evidence; an object with an established nature that provides evidential value.

Exhibit
An object under investigation which may bear evidence; =item

Identification
The classification of a particular fibre type according to its morphology and/or chemical composition. In some fibres (e.g., polyacrylonitrile) the presence of co-polymers may allow a more specific identification (i.e., a 'sub-classification'). 'Identification' may be considered as part of the process of 'characterisation'.

Item
An object under investigation which may bear evidence; =exhibit

Fibre Distribution Map
A diagram showing the areas where crime relevant fibres were recovered on a body or item. Such information can be generated using 'one to one' or 'zonal' taping and can be useful in corroborating an alleged activity responsible for the fibre transfer in question.

FTIS (Fibre Type Information System)
Created by the European Textile and Hair Group (ETHG), FTIS is a database and an information platform for the characterisation of common and rare fibre types and set up on a web-based platform with easy accessibility for the European Forensic Fibre Community. Access is limited outside the ETHG working group and the European forensic community.
https://ftis.kontrollwerk.com/

Known sample
A sample taken from a known source for comparison against recovered samples. (Also known as a 'control sample', 'reference sample', 'exemplar', 'target fibre').

Locard's Exchange Principle
A principle proposed by Edmond Locard, stating that objects in physical contact will reciprocally exchange material.

Loss
Undesired release e.g., of transferred fibres from a textile surface.

Man-made fibre
Man-made fibres can be classified into two groups, those derived from natural organic polymers such as cellulose (regenerated cellulosic fibres e.g., viscose, modal, lyocell etc.) or protein and those synthesized from organic chemicals found in coal and oil (e.g., polyester, polyamide, acrylic etc), often referred to as 'synthetic fibres'.

296 **Object**
297 An entity of variable size that itself is defined as physical evidence. From the object you may
298 recover traces that also may be defined as physical evidence.

299 **One-to-one taping**
300 A detailed collection technique involving surface debris taping, where the area of the tape
301 exactly represents the same area on the surface being taped. Any recovered material from the
302 tapes can then be associated with an exact location on the body or item, in order to construct a
303 fibre distribution map. See also 'Taping', 'Zonal Taping' and 'Fibre distribution map'.

304 **Packaging**
305 Physical covering of items and samples, providing security to the contents and preventing
306 contamination or loss.

307 **Peer review**
308 The process of checking casework notes and associated report(s) for factual errors and/ or
309 inaccuracies. Where evaluative opinions are expressed in a report, these should also be
310 reviewed to check the 'robustness' and underlying logic. These checks should be performed
311 by a suitably qualified colleague or associate.

312 **Persistence**
313 The degree to which an object retains trace evidence (e.g., fibres on a garment) relative to
314 factors such as time, handling and treatment since transfer.

315 **Picking-off**
316 Removal of fibres manually e.g., with forceps.

317 **Practitioner**
318 A person who is suitably qualified and trained to carry out one or more functions in a forensic
319 science laboratory (e.g., technician, court reporting scientist etc.).

320 **Preservation**
321 Action taken to ensure the integrity of an exhibit or trace evidence.

322 **Questioned**
323 Disputed e.g., by the prosecutor and/or the defence.

324 **Recommendation**
325 A particular action or methodology which is deemed to be desirable or best practice in a
326 particular circumstance, but not mandatory.

327 **Recovered sample**
328 Sample obtained from a crime scene or exhibit with the aim of identification or comparison with
329 known samples.

330 **Recovery**
331 The detection, collection and preservation of an item or a sample.

332 **Sample**
333 A representative part of an item or a trace removed for separate analysis; further sub-samples
334 may be removed from the sample.

335 **Scraping**
336 Removal of fibres by manually scraping an exhibit with a blunt edge; not routinely recommended
337 for fibre recovery by the ETHG.

Searching
Action to find single fibres or fibre tufts of interest in traces recovered from items or exhibits. Can be carried out visually or via microscopy.

Shedding capacity
An assessment of the transfer potential of a textile. Also called shedding potential or sheddability test.

Shaking
Removal of particulate traces by manually shaking items over a recipient medium in which the material can be collected and secured. It is often used in combination with 'Scraping' (see above). It is not recommended as a routine method of fibre recovery by the ETHG.

Source level
The degree of support that can be assigned that a particular trace item has originated from a putative source based on lab results.

Synthetic fibre
A term describing a fibre that is synthesized from organic chemicals found in coal and oil and whose polymeric/chemical structure does not occur in nature. The ETHG considers '*synthetic fibres*' to be a sub-set of 'man-made fibres'.

Taping or tape lifting
Action where clear adhesive tapes are pressed onto a surface to collect trace evidence present in surface debris. The tapes are then pressed onto a clear sheet (or folded back on themselves) to secure the material and maintain its integrity. See also 'one-to-one taping' and 'zonal taping'.

Target fibre
A fibre type in a fabric or defined from the background traces and chosen after an evidential assessment to be used in active searching for crime relevant fibres (see 'Known sample'). A fibre(s) of unknown provenance from a fibre population/collective may also be used for such purposes.

Textile imaging
A process to identify clothing from video and images for comparison purposes with questioned items of clothing.

Textile reference sample
A sample used to determine the fibre type in a textile and to be used to identify possible target fibres (see 'Known sample').

Trace
A smaller or larger physical part of a physical object (item) that can be further analysed for evidential purposes.

Traceability
The recognition of the ability/possibility to trace events in the total documentation (records and labelling) e.g., possibility to follow all the steps in handling and timing and identifying staff involved in an examination sequence.

Transfer
The phenomenon of displacement of material from one item, surface or person to another item, surface or person. Such displacement of material can occur from; one surface to another ('One-way transfer'), reciprocally ('Two-way transfer') or from one surface to another by an intermediary surface ('Secondary transfer').

Transporting
Physical transfer of items or persons from one location to another.

Vacuuming
A technique for collection by the use of a vacuum cleaner and special filters. This is not recommended by the ETHG as a routine fibre recovery method, however, there may be circumstances where taping is ineffective and this method could be considered (e.g., surface heavily soiled with particulate debris). Where this method is employed, the apparatus and filters must be scrupulously cleaned and be free of potential contaminants.

Zonal taping
A method of tape lifting where the body or item being taped is divided into distinct areas or 'zones'. Each zone is systematically taped so that any recovered material can be associated with a particular zone in order to construct a fibre distribution map. Whilst a fibre distribution map generated by this method is less detailed than 'one-to-one' taping, it is much less time consuming both at the scene and in the laboratory. Usually, zonal taping generates sufficient information. A combination of both methods may also be used.

4. RESOURCES

4.1. Personnel

For the purposes of this BPM the term 'practitioner' is used for any trained and competent individual undertaking any stage of textile fibres examination, including recovery and examination, evidential evaluation and interpretation, and presentation of evidence.

Skill levels for different tasks are listed in 4.1.1 - 4.1.4. In different organisations individuals can cover one or all of the tasks listed, for example most organisations have court reporting practitioners and non-court reporting practitioners.

Practitioner competence should be regularly assessed by proficiency tests and/or collaborative exercises. Organisations should maintain a record of the education and job-specific training, assessment and ongoing competency of their practitioners.

4.1.1. Recovery and reference sampling

For those practitioners recovering fibres at crime scenes and from items in the laboratory, and practitioners taking reference samples, the following skills are necessary:

- Familiarity with relevant health and safety issues
- Appropriate knowledge of textile fibres
- Awareness of contamination risks
- Awareness of other trace materials
- Competence in trace evidence techniques in accordance with the requirements at the examining laboratory (e.g., method of recovery, packaging, documentation)

4.1.2. Sample preparation

For those practitioners preparing samples in the laboratory for further testing (e.g., mounting) the following skills are necessary:

- Familiarity with relevant health and safety issues
- Appropriate knowledge of textile fibres
- Awareness of contamination risks
- Awareness of other trace materials
- Familiarity with the relevant laboratory protocols

4.1.3. Examination and microscopy

For those practitioners examining samples in the laboratory the following skills are necessary:

- Familiarity with relevant health and safety issues
- Awareness of contamination risks
- Awareness of other trace materials
- Competence in operating relevant instruments and equipment
- Competence in fibres examination and comparison
- Familiarity with the relevant literature

4.1.4. Evaluation, interpretation and reporting of examinations and microscopy

For those practitioners evaluating, interpreting and reporting the results of textile fibre examinations the following skills are necessary:

- Competence in assessing case requirements, devising and directing examination strategies and evaluating examination outcomes
- Competence in examination and comparison of textile fibres
- Understanding of the relevance of other trace materials
- Knowledge of contamination risks
- Knowledge of methodology and relevant instruments and equipment
- Knowledge of the relevant literature
- Competence in preparing and presenting evidence (written or verbal) for the relevant jurisdiction

Note: This BPM has been written primarily from the viewpoint of forensic laboratory personnel, but it is accepted that in some organisation's other individuals, including Police Officers, Crime Scene Technicians, Medico-legal Experts, and Medical Examiners, may play a role in recovery of textile fibres. These practitioners must have the relevant education and training listed in 4.1.

4.2. Equipment

4.2.1. At the crime scene

Recovery techniques on the crime scene should be focused on a systematic collection as fibre traces can be invisible to the naked eye. The widely used method for the collection of fibre traces at the crime scene is by means of transparent adhesive tapes. The collection technique should allow an easy search of the collected traces in the laboratory as well as a safe long-term storage (refer to Section 8.1 for equipment and materials).

4.2.2. In the laboratory

In order to achieve the highest discriminating power, it is important to use a combination of different methods that can differentiate fibres from each other. Many techniques involve different forms of microscopy. The nature and extent of the fibre examinations required, and also access to different equipment in the organisation, will dictate which types of analyses are used.

The equipment for the techniques used for fibre identification/comparison should be applicable to the smallest sample sizes, be highly discriminating and, where possible, be non-destructive. The equipment of the methods detailed below fulfil these criteria and are currently available to forensic fibre practitioners. The equipment should be used in accordance with the recommendations in the methods and appendices in this Manual (refer to Section 5).

4.2.3. Microscopy

Low power microscopy

- Objectives and eyepieces, range of magnification up to approximately 100X.
- Accessories for polarization and fluorescence (optional).

High power microscopy

- Can be standalone microscopes or comparison microscopes with different applications such as stated below.

Brightfield microscopy

- Objectives and eyepieces, range of magnification approximately 40X to at least 400X.
- Ocular micrometer scale or validated computer software.

Polarising microscopy

- Often an application to a brightfield/comparison microscope, see equipment above.
- A rotating stage.
- Analyser, polariser and a slot for compensators or lambda plate.
- Eyepiece cross-hair graticule when birefringence is calculated (optional).

Fluorescence microscopy

- Often an application to a brightfield/comparison microscope, see equipment above.
- A selection of broadband excitation filters covering the range from ultra-violet to violet, blue and green.

Miscellaneous techniques

- For interference microscopy, cross sectioning, solubility, melting point determination and scanning electron microscopy, see Appendix 1, Microscopy of Textile Fibres.

4.2.4. Microspectrophotometry

- A microscope suited for purpose.
- A magnification range / resolution suited for purpose.
    - Used in the visual range; apochromatic fluorite objectives.
    - Used in the UV and visual range; special lens objectives made from quartz.
- Photometer devices.
    - For scanning microspectrophotometers; a light source, a monochromator and a photomultiplier.
    - For multichannel microspectrophotometers (MCS); a light source, a polychromator and a diode array detector (DAD) or a charge-coupled device (CCD).
- An appropriate computer system and software for the generation, visualisation and comparison of MSP-spectra.

For more information, see Appendix 2, Microspectrophotometry of Textile Fibres.

4.2.5. Infrared spectroscopy

- A microscope suited for purpose.
- A magnification range / resolution suited for purpose.
- A detector.
    - Utilised with a microscope, e.g., mercury cadmium telluride (MCT) detectors.

- Utilised on the FTIR main bench, e.g., deuterated triglycine sulphate (DTGS) detectors.
- Different applications/sampling devices such as ATR, diamond anvil cell, golden gate etc.
- An appropriate computer system and software for the generation, visualisation and comparison of IR-spectra.

For more information, see Appendix 3, Infrared Spectroscopy of Textile Fibres.

4.2.6. Raman spectroscopy

- A microscope suited for purpose.
- A magnification range / resolution suited for purpose.
- A dispersive spectrometer using a grating-based dispersive unit and a charge-coupled device (CCD) detector.
- Lasers, preferably more than one, for example 514 or 532 nm (green) and 785 nm (NIR).
- Rejection filters suitable for the laser wavelengths used.
- An appropriate computer system and software for the generation, visualisation and comparison of Raman-spectra.

For more information, see Appendix 4, Raman Spectroscopy of Textile Fibres.

4.2.7. Other techniques

For other techniques such as thin layer chromatography (TLC) or High Performance Liquid Chromatography (HPLC), Pyrolysis Gas Chromatography (PyGC or PyGCMS) or pyrolysis/mass spectrometry (PyMS), see Appendix 5, Chromatographic Techniques and Appendix 6, Other Analytical Techniques.

4.3. Equipment maintenance and performance checks

Any maintenance, problems, calibration and performance checks must be documented and dated.

4.3.1. Maintenance

An equipment record should be maintained that records the manufacturer, model, serial number, software and firmware version, the date of acquisition, the date placed in service and the location for each piece of equipment used in the examination and comparison of fibres.

The practitioner should be familiar with and follow the manufacturer’s operating manual and maintenance recommendations for each piece of equipment used for the examination. These should be readily available, together with any repair and/or general maintenance documents.

Any technical maintenance or recalibration should be executed by a suitably qualified and accredited engineer.

4.3.2. Performance and calibration checks

All equipment must be correctly set up as detailed in the manufacturer‘s instructions and all users must be fully trained in their operation.

It is recommended that the performance of the equipment is checked against appropriate working standards every time it is used. The checks against appropriate standards should also be performed if anything is changed in the optical paths of any equipment.

Only equipment that is operating properly should be employed in casework, and then only within the limits of its performance check.

4.4. Reference materials

4.4.1. Textile fibre collections

Laboratories should hold some form of reference collections of known synthetic fibres, natural fibres and animal fibres to assist in fibre identification.

Where possible the collections should be authenticated and traceable. It is advisable that the laboratory puts into place appropriate control measures to ensure that the integrity of any authenticated samples is maintained.

If the collections are not authenticated or traceable, they should be used with caution and referred to for guidance and indication purposes only. Those collections could potentially be authenticated by cross-analysis between several forensic laboratories.

4.4.2. Calibration and working standards

All working standards should be calibrated by an accredited agency.

4.4.3. Microscopy

Calibrated stage micrometer: A slide with a linear scale of known dimensional divisions, against which the 'working standard' ocular micrometer/eyepiece graticule/validated software programme can be compared.

Optical balance fibre reference slides for comparison microscopy (e.g., brightfield and fluorescence): Paired slides with a uniformly coloured sample of fibres typically cut in half and mounted on slides.

Polarisation identification slides: Slides with cross-checked synthetic fibres.

For miscellaneous techniques such as interference microscopy, cross-sectioning, solubility, melting point determination and scanning electron microscopy, see Appendix 1, Microscopy of Textile Fibres.

4.4.4. Microspectrophotometry

Certified holmium and/or didymium filter: Wavelength accuracy check.

Certified absorption filters/ neutral density filters: Absorption accuracy check.

4.4.5. Infrared (IR) spectroscopy

Certified polystyrene or indene: Wavelength accuracy check.

4.4.6. Raman spectroscopy

Raman shift standard, for example certified polystyrene or silicon: Wavelength accuracy check.

4.4.7. Other techniques

For chromatographic techniques such as Thin Layer Chromatography (TLC) or High Performance Liquid Chromatography (HPLC), Pyrolysis Gas Chromatography (PyGC or PyGCMS) or pyrolysis/mass spectrometry (PyMS), see Appendix 5, Chromatographic Techniques and Appendix 6, Other Analytical Techniques.

4.5. Facilities and environmental conditions

4.5.1. At the crime scene

The environmental conditions vary considerably for every crime scene (see Section 8.1).

4.5.2. In the laboratory

Laboratories used for the examination of items for fibres should be designed for efficient and effective working (see Section 8.2). Particular consideration should be given to the need for avoidance of contamination (see Section 8.1.1).

To minimise the chance of contamination, some consideration should be given to the following:

- Laboratories, equipment and sampling materials used for the examination and comparison of fibres should be cleaned thoroughly before and after use.
- Laboratories should provide a minimum of two purpose designed search rooms with limited access, for searching items. This allows for physical separation of associated items from different sources, such as suspects, victims and the scene. If different examiners and/or rooms cannot be used for associated items, there must be a clear, documented time gap and evidence of relevant decontamination procedures between searches.
- In situations where evidence types other than fibres may be of potential significance the laboratories should provide accommodation to allow for the effective recovery of the different evidence types.

Regarding environmental conditions and accommodation needed for specific equipment, the manufacturer's operating manual and maintenance recommendations for each piece of equipment should be followed.

4.6. Materials and reagents

4.6.1. At the crime scene

Materials used in recovery/sampling fibres at the crime scene can include the use of clear adhesive tape and backing, forceps and scissors.

The choice of personal protective equipment (PPE) such as protective coats, disposal gloves and facemasks will be determined by the aims of the examiner and just as importantly, the hazard assessment of the scene itself (see Sections 8.1.1 and 14.1). For the purposes of anti-contamination, it is recommended that a protective overall, disposal gloves and facemasks should be worn as a minimum.

4.6.2. In the laboratory

All materials and chemicals used for the examination and comparison of fibres should be of suitable quality and demonstrated to be fit for purpose.

All chemicals and reagents, whether manufactured internally or obtained from external suppliers, should be labelled with their identity, concentration (if appropriate), date of preparation or receipt, date of opening, date of expiry and any special storage or safety requirements, if applicable, to comply with laboratory policy and/or appropriate regulations. The identity of the individual preparing reagents produced in the laboratory should also be recorded together with records of the preparation procedures.

Materials used in recovery and/or examination of fibres at the laboratory can include the following:

- forceps (preferable smooth, non-serrated tips)
- clear adhesive tape and backing
- glass microscope slides and cover slips
- mounting media and solvents
- ruler/measure marked in mm increments (this need not be calibrated as measurements are rarely critical).

Many suitable mounting media are available for preparing temporary and permanent fibre mounts, and the selection of an appropriate mounting medium will be influenced by the particular microscope technique used, see relevant appendices. Solvent-based mounting media may affect the morphology or dyeing of certain type of fibres especially considering long-term storage (reference fibre collection).

The choice of personal protective equipment (PPE) such as protective coats, disposal gloves and facemasks will be determined by the aims of the examiner and the hazards associated with a particular exhibit (e.g., body fluid contamination) (see Sections 8.2.1 and 14.2).

5. METHODS

Before any examination is carried out, a case examination strategy should be defined as described in Section 9, Initial Assessment. Prior to any analyses using a dedicated technique, the relevant performance checks should be carried out as described in Section 4.2, Equipment. It is paramount that maintenance on a regular basis is also valuable for the proper functioning of the equipment. Moreover, a validation of the methods used is also highly recommended according to criteria developed in Section 6.1, Validation.

The following techniques are currently available to forensic fibre practitioners. They should be carried out in accordance with the recommendations in the Appendices to this Manual. The techniques used for fibre identification/comparison should, where possible, be non-destructive, applicable to the smallest sample sizes, and be highly discriminating. The methods detailed below generally fulfil these criteria.

For comparison purposes it is desirable to use appropriate techniques for colour comparison and fibre polymer and chemical composition determination. Fibre comparison should be made between questioned and reference fibres or between questioned fibres that potentially originate from the same source. This is usually carried out using low and high power microscopy, colour comparison techniques (e.g., Microspectrophotometry) and chemical composition analytical methods (e.g., FTIR). The use of microscopic techniques may be sufficient for elimination purposes in some cases when the differences are obvious.

5.1. Examination techniques

Macroscopic and low power stereomicroscopic examinations are useful for recovering fibres from tapings/samples or directly on pieces of evidence. Recovery and sampling are further described in Section 8, Handling items.

This is an important preliminary step for determining whether a questioned item is a textile fibre or not and for observing fibre characteristics, such as colour, shape and texture.

Low power microscopic examination can also be used to define the type of fibre (e.g., natural versus man-made) and the colour (i.e., a colour block description such as red/orange, blue/violet, grey/black, etc.). It is not suitable for accurate identification of fibre type and objective description of fibre colour.

Based on the previous steps, low power microscopy can also be used for assessing which questioned fibres are suitable or not for further comparison. Where there is doubt, those questioned fibres should be included in the subsequent comparison sequence.

5.2. Microscopy of textile fibres

Microscopic examinations are employed in forensic fibre characterisation, identification, and comparison. Several types of light microscopes may be used, and the nature and extent of the fibre evidence will dictate which techniques are selected and performed.

A side-by-side, point-by-point microscopic comparison of morphological features provides a fundamental discriminating method for determining if two or more fibres are distinguishable or not.

The use of microscopic techniques may be sufficient for elimination purposes when the differences are obvious, however, where an elimination is uncertain, further tests may be required.

For questioned and reference comparisons with the use of high power microscopy, a fibre or multiple fibres may be mounted on a uniquely labelled glass microscope slide, with an appropriate cover slip, and the same mounting medium must be used for both questioned and reference fibres. Each mounted fibre must be clearly visible and correctly labelled.

Before use, microscopes must be correctly set up as detailed in the manufacturer‘s instructions and all users fully trained in their operation and adjustment. Any microscope used to measure dimensions should be calibrated.

More theoretical, technical and practical aspects are detailed in the Appendix 1, Microscopy of Textile Fibres. Sample preparation is briefly mentioned in Section 8.2, In the laboratory and further described in the Appendix.

5.2.1. Brightfield microscopy

Brightfield microscopy is the basic technique used for observation of morphological characteristics in all fibre types. Physical characteristics of man-made, natural and inorganic fibres are detailed in the Appendix, Microscopy of Textile Fibres, the FTIS database and scientific literature.

Comparison using only one microscope has the advantage that both the questioned and reference samples are viewed under exactly the same physical and optical conditions.

However, examination using a single microscope requires extremely meticulous work routine with exact recording of all steps taken (e.g., including photographs of the fibres being examined so that questioned and reference fibres can be clearly differentiated).

5.2.2. Comparison microscopy

Comparison microscopy is used for simultaneous viewing of questioned and reference fibres, enabling comparisons of the morphological characteristics and colour of fibres to be made. However, the colour comparison is subjective, so additional complementary techniques are recommended (Microspectrophotometry, Raman spectroscopy).

The use of a comparison microscope has the advantage that the questioned fibres can be easily compared with a wide range of fibres from the reference material, thus taking into account variation that may occur within it (e.g., in fibre diameter; depth of dyeing). The questioned and reference fibres are examined with separate light beams, and depending on the microscope, there may be one or two light sources. Both microscopes must be balanced so that the background appears the same. The visual responses from two fibres known to have originated

from the same source, and mounted on separate microscope slides, must be the same colour, brightness, and clarity; a balanced neutral background colour is optimal.

5.2.3. Polarising microscopy

Polarising microscopy is used for determination/measurement of optical characteristics, (e.g., sign of elongation and birefringence) leading to preliminary identification of the generic type of man-made fibres. Optical characteristics are detailed in the Appendix 1, Microscopy of Textile Fibres. Polarising microscopy cannot be used to identify exact chemical composition of fibres, but the presumptive polymer type can be determined.

5.2.4. Fluorescence microscopy

Fluorescence microscopy is used for examining/comparing materials applied in the dyeing and finishing of textile fibres. It is always recommended to use this technique, if Microspectrophotometry is used only in the visible range.

Fluorescence may arise from fibres themselves or from dyes and other additives, such as washing powder and optical brighteners. Fibres should be mounted in a non-fluorescent medium, and examination using various combinations of excitation and barrier filters is desirable (mostly used: UV, Violet, Blue, Green). At each excitation wavelength, the colour and intensity or absence of fluorescence emission should be noted. Care should be employed to ensure that questioned fibres are not excluded because of fluorescence caused by contaminants, or the effects of localised conditions, that is not exhibited by the reference fibres. It is also possible to measure emission fluorescence spectra.

Samples should not be exposed to UV excitation for too long under a high magnification as this could result in a change in fluorescence, peak intensity and colour of the fibre, possibly due to the bleaching effects.

5.2.5. Miscellaneous techniques

Other techniques, such as interference microscopy, cross sectioning, solubility, melting point determination and scanning electron microscopy, which may yield additional physical and analytical information on examined fibres, are detailed in the Appendix 1, Microscopy of Textile Fibres.

5.3. Microspectrophotometry

Microspectrophotometry (MSP) provides an objective means of colour comparison. It may be used in the visible range (MSP-Vis), or in the UV and visible range (MSP UV-Vis), the latter normally requiring the use of non-UV absorbing materials (e.g., quartz) and temporary preparation of the sample.

This technique has been tried and tested by forensic fibre experts with the undoubted conclusion that, when performed on a modern instrument, it is highly discriminating. What is of particular importance to an operator is a clear understanding of the capabilities of the instrument. However, it is just as important to be able to recognise its limitations and to use other discriminating techniques when necessary. Obvious examples where other techniques should be considered include heavily dyed fibres that produce bland, featureless spectra and very pale coloured fibres with nondescriptive spectra.

The aim of the operator is to demonstrate, by using the instrument to its full effect, the full range of variation of dye intensity and colour measurement artefacts present in the reference sample prior to analysing the questioned fibres.

Man-made fibres, as opposed to natural fibres, usually demonstrate little intra-sample variation in terms of their absorption or transmission of light. However, it should be remembered that fibres are not plane objects so their characteristics (cross-sectional shape, texturisation, levels of delustrant etc) will all have an effect on the result. When selecting measuring areas these factors should be taken into account and the choice made carefully and consistently.

Samples should not be exposed to UV excitation for too long in a high magnification as this could result in a change in fluorescence, peak intensity and colour of the fibre, possibly due to the bleaching effects.

More theoretical, technical and practical aspects are detailed in the Appendix 2, Microspectrophotometry of Textile Fibres. Sample preparation is briefly mentioned in Section 8.2 In the laboratory and further described in the Appendix.

5.4. Infrared spectroscopy

Fourier Transform Infrared (FTIR) microspectroscopy allows accurate identification of fibre polymers from very small samples. Fibre identification is made by comparison of the fibre spectrum with laboratory reference spectra (as well as authenticated spectral data gathered within forensic networks) or by following guidelines for the interpretation of spectra. Infrared spectral libraries made commercially available may also be used.

Successful identification of fibre polymers by IR spectra depends on experience and familiarity with fibre reference spectra. The spectra must be acquired and examined carefully. The effects of pressure, diffraction, scattering, artefacts, noise, interference, fibre flatness and instability of the detector should be recognised when present in the spectrum. The % transmission (no less than approximately 70% is recommended) and baseline drift should be considered when interpreting the spectra as these will affect any library searches.

There is some potential for obtaining additional compositional information (fibre generic class and subclass) by using infrared spectroscopy in addition to polarizing light microscopy, PLM. Because of the large number of sub-generic classes, forensic examination of fibres containing e.g., polyacrylonitrile is likely to benefit significantly from infrared spectral analysis. The spectral information due to the presence of dye(s) is usually low but may also be used, e.g., in acrylic fibres, for comparison purposes. The extent to which infrared spectral comparison is indicated cannot be generalized and will vary with specific sample and case evaluations.

The generic class of man-made textile fibres and the sub-generic class of synthetic manufactured fibres may be identified. Sub-generic classes of e.g., polyester, polyamide, acrylic and modacrylic fibres can be discriminated by IR spectroscopy. It may be desirable to confirm the identification by other methods such as PLM or melting point determination.

Natural fibres may also be analysed by IR spectroscopy; however, other than assisting with classification of the fibres, little additional compositional information is provided over that yielded by light microscopy. Dyes may be detectable in these fibres by subtraction of the undyed fibre. It may be desirable to confirm the identification by other characteristics such as morphological features or Herzog test.

More theoretical, technical and practical aspects are detailed in the Appendix 3, Infrared Spectroscopy of Textile Fibres. Sample preparation is briefly mentioned in Section 8.2 In the laboratory and further described in the Appendix.

5.5. Raman spectroscopy

Raman spectroscopy is, among other techniques (such as MSP, TLC and FTIR), a possible method for analysing and characterizing dyed (or pigmented) fibres. At the moment it is not widely used as a routine technique for fibre identification and comparison, because most of the

forensic laboratories can rely on information provided by the conventionally used techniques (microscopy, MSP and FTIR). Raman spectroscopy allows the in-situ analysis of single fibres and offers the advantage of being almost non-destructive.

At present the dedicated literature is incomplete regarding the potential and limitations of this method. The added value of Raman spectroscopy is still under debate and is highly dependent on the fibre type and colour. Raman analyses are mostly carried out in a comparative way between reference and questioned samples. The technique provides an additional and complementary means of colour comparison.

The dyes (or pigments) signal is usually dominant in the Raman spectrum and may partially or totally hide the information from the fibre substrate (generic class, sub-class). Pigments are usually easily detected in fibres and can be identified using a spectral database. The spectral response of a dye varies depending on the dye itself and its concentration in the fibre. Dye identification may be complicated due to the large number of dyes present on the market, the use of their multi-component mixtures and also because different dyes can provide similar Raman response.

For man-made fibres Raman spectroscopy can also be used to identify fibre generic classes and in some cases sub-classes. Fibre substrate identification can be made by comparison with laboratory reference spectra. The analytical information provided is usually equivalent or sometimes less detailed than when using FTIR.

More theoretical, technical and practical aspects are detailed in the Appendix 4, Raman Spectroscopy of Textile Fibres. Sample preparation is briefly mentioned in Section 8.2 In the laboratory and further described in the Appendix.

5.6. Other techniques

There are other analytical methods, which can be applied to fibre examinations. A number of these techniques are currently being developed and may prove to be useful in examination and comparison of single fibres. Some of the techniques included here involve the use of hazardous chemicals, and the possible safety hazards or precautions associated with their application should be taken into account. It is the responsibility of the user of these documents to establish appropriate safety and health practices, and to determine the applicability of regulatory limitations prior to use.

5.6.1. Chromatographic techniques

Chromatographic methods, especially in combination with mass spectrometry, are characterized by high sensitivity and very good identification parameters. Metameric coloration of fibres can be detected using UV/visible Microspectrophotometry, but if this technique is restricted to the visible range only, differences in dye components may remain undetected. Further differentiation may be possible with the use of additional chromatographic techniques, as thin layer chromatography (TLC) or High Performance Liquid Chromatography (HPLC). Pyrolysis Gas Chromatography, with or without mass spectrometry (PyGC or PyGCMS) or pyrolysis/mass spectrometry (PyMS) can be used to identify the generic type of an unknown fibre and in some/many cases may identify sub-classes within a generic class.

5.6.1.1. Thin layer chromatography (TLC)

TLC is an inexpensive, simple, well-documented technique that can be used to complement the use of Microspectrophotometry in comparisons of fibre colorants. The application of TLC may serve to discriminate between fibres, or it may confirm their similarity. Since the technique involves classification of the dye and visualisation of mixture components, it may provide very useful information in intelligence led investigations involving industrial enquiries. However, in

the era of Green Chemistry, this method is losing importance and popularity. TLC method has some disadvantages as a large amount of sample is required for pale colours (e.g., yellow), the quantification is not accurate, and due to the variation of retention factor between TLC runs there is difficulty in making a spectral database of dyes.

More theoretical, technical and practical aspects concerned with the classification and TLC of textile fibre dyes are detailed in the Appendix 5, Chromatographic Techniques.

5.6.1.2. High performance liquid chromatography

An alternative for TLC is high performance liquid chromatography (HPLC), a fast and sensitive technique which can be applied for analysis of dyes in forensic science. HPLC systems have been developed to analyse a small number of dyes, a dye mixture and its components, a particular dye class, and a combination of dye classes. However, there are many dye classes used to colour fibres, and it is difficult to separate them on a single chromatographic system. More theoretical, technical and practical aspects are detailed in the Appendix 5, Chromatographic Techniques.

5.6.1.3. Pyrolysis-GC(MS) and pyrolysis-MS

Some laboratories conduct pyrolysis gas chromatography with or without mass spectrometry (PyGC or PyGCMS) or pyrolysis/mass spectrometry (PyMS) as a method for forensic fibre examination. More theoretical, technical and practical aspects are detailed in the Appendix 5, Chromatographic Techniques. The information contained in it are concerned with the pyrolysis of single fibres and fibres from bulk material, classification of the generic class of polymer, and interpretation of the resulting pyrograms and mass spectra. The protocols and equipment mentioned in this document are not meant to be totally inclusive or exclusive.

5.6.2. Other selected techniques

Brief details of numerous other less well-known methods, which are sometimes mentioned in connection with forensic fibre examination, as fibre density measurement, solubility tests, thermal methods, methods for elemental determination and miscellaneous techniques, are described in the Appendix 6, Other Analytical Techniques. They are available but are not routinely used due to problems associated with sample size and/or interpretation of the results. Some of them are methods using costly research grade equipment but may occasionally be useful for specific purposes.

5.7. Overview of the instrumental methods

Table 1 is intended to give the reader an overview of the instrumental methods available for fibre examination and comparison. Some of these methods are already well-known and used routinely and others may be used to collect extra information when trying to identify or compare fibre samples. In practice it is not possible to use all the methods listed below but the reader is now aware of their existence and properties.

Some additional information is provided for each method so the reader can make her/his own opinion about the usefulness and relevance of the technique in her/his analytical procedure or particular casework. Depending on instruments available in her/his own laboratory the reader could choose to combine several techniques in order to collect valuable information about fibre type, colour and characteristics.

When choosing an instrumental method, some properties may be taken into account:

(A) The method is non-destructive;

(B) The method is applicable to single fibres, as well as short fibres;

(C) The method is known to be discriminatory;

(D) Sample preparation is minimal (in situ measurement is possible);
(E) The method is fast;
(F) The method is well documented (in literature or by the end-user).

Table 1: Overview of instrumental methods

Instrumental methods	(A)	(B)	(C)	(D)	(E)	(F)	Analytical information (* = sometimes)
Optical microscopy							
Brightfield microscopy (BF)	++	++	++	++	++	++	Morphology
Polarising microscopy (PLM)	++	++	+	++	++	++	Fibre generic class, dichroism
Fluorescence microscopy (FLUO)	++	++	+	++	++	++	Fluorescence properties (dyes and finishes)
Birefringence	++	++	+	++	+	++	Fibre polymer orientation
Darkfield microscopy (DF)	++	++	-	++	++	-	Presence of pigments/delustrant
Interference microscopy	++	++	-	++	++	-	Fibre classes
Comparison microscopy	++	++	++	++	++	+	Morphology, polarisation and fluorescence
Microspectrophotometry (MSP)							
Visible range (MSP-Vis)	++	++	++	++	++	++	Absorption spectrum (colour)
UV visible range (MSP-UV)	++	++	++	+	++	++	Absorption spectrum (dyes and finishes)
Fluorescence (MSP-FLUO)	++	++	+	++	++	+	Fluorescence spectrum (dyes and finishes)
Linear dichroism (MSP-PPL)	++	++	+	++	++	++	Linear dichroism (LD) spectrum
Vibrational spectroscopy							
Raman	++	++	++	++	++	+	Fibre generic class (and subclass*), dyes/pigments*
FT-IR	+	++	+	+	++	+	Fibre generic class and subclass
Chromatography techniques							
TLC	-	+	++	-	-	+	Number of dye components (+ behaviour)
HPLC	-	++	++	-	+	-	Number and ID* of dye components
Pyr-GC/MS	-	++	++	+	+	-	Fibre class, dye composition
Elemental composition							
SEM/EDX	++	++	++	+	++	+	Elemental composition; detailed morphology
ICP/MS	-		++	+	++	-	Elemental composition
Other methods							
Hot stage microscopy	+	+	+	+	+	+	Range of melting point
Solubility tests	+	+	-	+	++	-	Fibre subclass
Microtomy	+	+	-	+	-	+	Cross-sectional pattern
Microchemical tests	+	+	+	+	+	-	Fibre chemical class
IR/MS	-	-	+	+	-	-	Isotope ratio

(A) Nature of the method: (++) non-destructive; (+) partly destructive, a short segment of the fibre is used; (-) destructive.
(B) Applicability on single fibres: (++) always; (+) sometimes; (-) never.
(C) Discrimination power (based on scientific literature): (++) high; (+) medium; (-) weak.
(D) Sample preparation: (++) none/minimal; (+) limited; (-) hard preparation step.
(E) Rapidness: (++) very fast; (+) normal; (-) slow.
(F) Appropriate methods: (++) routinely used; (+) sometimes used; (-) rarely used.

5.8. Peer review

Peer review is part of a laboratory's quality management system and includes technical, critical and the evaluation of evidence.

The outcome of a fibre examination should be reviewed prior to the issuing of any report detailing the findings and/or any associated interpretation of microscopic or instrumental analysis.

This process takes the form of a review of technical findings and critical findings during which a second competent practitioner:

- reviews the documented results
- carries out an independent examination of the fibre samples when necessary
- reviews any evidence evaluation and opinion

The reviewing process should be traced in the case and may be outlined in the report. A standard check sheet may be an option for ensuring that all relevant issues have been covered. The laboratory should have a procedure in place to address and resolve any differences in opinion between two practitioners.

Other specific requirements during the examination process of textile fibres may be applicable depending on some legal jurisdictions, international standards or institution-specific requirements.

5.8.1. Review of the technical findings

In fibre examination cases, 'technical findings' are considered those findings not related to opinion, such as, the observation and documentation of any macroscopic and microscopic characteristics of the questioned and/or reference fibres. These may also include the results of other analytical measurements or findings. Except spectral data, some characteristics (e.g., colour) may be described differently between two practitioners, but it is paramount that each practitioner remains consistent when describing the same characteristics among various samples.

The technical review can be made based on detailed photographs, microscopic images and display of spectral data or other findings using tables and/or charts.

When necessary, the second practitioner may examine the fibre samples again or collect additional raw data for identification or comparison purposes.

5.8.2. Review of the critical findings

In fibre examination cases, 'critical findings' are considered those findings which are based on interpretation or opinion. For example:

- the identification of the fibre generic class or sub-class
- the comparison of microscopic characteristics
- the comparison spectral data
- the initial location of questioned fibres, where significant evidential value will be attached to where the fibres were recovered (for example, fibres located on the edge of a knife blade or on the neck of a strangulated victim).

Most of these interpretative steps will help in reporting an opinion on whether or not questioned and reference fibres are indistinguishable or, in case of questioned fibres comparison, could have originated from the same source. A second opinion can be given by a practitioner with technical competencies on the techniques used for comparison/ identification purposes.

The relative rarity of the fibre type (source level) or the location and the number of questioned fibres (activity level) can lead to evidence evaluation (see Section 12, Evaluation and interpretation). In this particular case the technical competences are not mandatory to be able to give a second opinion, but the reviewer has to be educated with this kind of evaluative reasoning and with relevant literature.

6. VALIDATION AND ESTIMATION OF UNCERTAINTY OF MEASUREMENT

6.1. Validation

For the general requirements of validation, the reader is referred to the ENFSI document "Guidelines for the Single Laboratory Validation of Instrumental and Human Based Methods in Forensic Science".

Validation should focus on the process of characterisation and comparison of textile fibres and does not normally extend to evaluating the significance of fibre comparison results.

Fibre characterisation is based upon well-established scientific principles supported by scientific literature extending back over a few decades. Fibre characterisation is soundly based on scientific peer-reviewed methodology in forensic examination of textile fibres.

Fibre characterisation is based on a combination of morphological details (human based method), colour measurement (instrumental method) and determination of chemical composition (instrumental methods) using established analytical techniques (see Section 5, Methods).

The FTIS database of the ETHG working group can be used for finding trusted information on morphology (microscopic images, morphological and optical properties) and chemical composition (infrared spectra), as well as for other additional properties (thermal behaviour, solubility tests).

Forensic comparison of fibres has been used and scientifically accepted worldwide for many decades. The literature dealing with fibre characteristics and the reliability of forensic fibre comparison is extensive. The comparison is based on the observation of similarities as well as differences in morphological details and in analytical data (i.e., the presence or absence of discriminant details in (UV)Vis, infrared and/or Raman spectra).

The quality of fibre comparisons depends both on the instrumental performance and on the judgment and experience of the practitioner, which may be achieved by scientific education, training and continued professional development.

Fibre characterisation and comparison are a combination of instrumental and human-based methods of examination. Therefore, validation and verification should comprise a thorough testing of all instrumental methods used and, on the other hand, practitioners demonstrating competence by showing that they can provide consistent, reproducible and valid results that are compatible with the results of other competent practitioners (see Sections 4, Resources and 7, Quality Assurance). The latter can be achieved by testing and comparing several practitioners within the same laboratory and/or by taking part in PT/CE tests.

Validation should be done and documented in compliance with the laboratory quality management system of the institution. This applies for the methods described in Section 5, Methods.

6.2. Estimation of uncertainty of measurement

Uncertainties of measurement in fibre examinations can firstly relate to those arising from the use of instruments, equipment and reagents. Secondly, as a human-based method, practitioner competence forms the basis of reliable and reproducible results. In addition, fibre examinations are often reliant on adequate sampling and the nature and variation of fibre samples.

6.2.1. Instrumentation / equipment / reagents

Uncertainties of measurement attributable to instrumental techniques can be minimised by servicing and maintenance of the equipment according to the manufacturer's specifications. In addition, regular performance and calibration checks should be performed.

Uncertainties may arise with various techniques, but other complementary techniques could be used to compensate the known limitations. In any case using several complementary techniques is always desirable for minimizing uncertainty. Table 2 provides a troubleshooting guide for the most conventional techniques used in fibre examination.

Table 2: Troubleshooting guide for conventional fibre examination techniques

Technique	Limitation(s)	Additional techniques
Microscopy	Observation of morphological details (e.g., longitudinal view, cross-section, polarisation colours, wool scale pattern) with deeply coloured fibres	Cross-sectioning, spectroscopy for polymer identification, scale casting or SEM for scale pattern
MSP	Poor quality spectra with very pale (faint absorption) and deeply coloured fibres (saturation of spectral details)	Raman spectroscopy, chromatographic techniques
IR	Identification of natural fibres with a very similar cellulosic composition	Microscopy (morphological details), Herzog test, cross-sectioning, staining tests e.g., Billinghams test
Raman	Absence of response (due to extensive fluorescence emission); limited detection of single dye or dyes in mixtures	Multiple Raman laser sources (to try to bypass fluorescence); MSP, chromatographic techniques
Chromatographic techniques	Analysis of single fibres	MSP

Uncertainties of measurements attributable to reagents (e.g., mounting media, solvents for extraction) can be minimised by the selection of reagents of appropriate quality and/or refractive index. Failure to carry out these steps can have an impact on the practitioner's ability to visualise and recognise key characteristics / features.

Macroscopic measurements, such as fibre length, are rarely critical and are typically used as direct comparison. Therefore any uncertainty of measurement is unlikely to be of significance.

Uncertainties will increase when comparing questioned fibres to fibre collectives instead of comparing to known fibres originating from the same textile source material.

6.2.2. Practitioner competence

As a human-based method, the reliability and reproducibility of results of fibre examinations are highly reliant upon practitioner competence. Well-trained and competent practitioners participating in regular proficiency testing and collaborative exercises pose minimal risk of error and uncertainty.

The e-Learning platform of the ETHG working group can be used as a guidance for educating and training individuals with trusted best practices.

Practitioner competence extends in some cases to reporting (see Section 12, Evaluation and Interpretation).

6.2.3. Fibre samples

Each of the following has an impact on the ability of the practitioner to attribute a fibre to a source with any degree of certainty:

- Non representative reference sampling (e.g. surface fibres vs core fibre, warp and weft yarns)
- Highly variable fibre samples (e.g. labels with high content of ‘other (re-use) fibres’)
- Fibre samples with limited or non-distinguishable characteristics / features (typically undyed fibres and especially the natural ones)
- No authenticated source material (comparison to fibre collectives)
- Irregular fibre population (single trace, damaged traces, traces contaminated with body fluids, small sample sizes...).

7. QUALITY ASSURANCE

7.1. Proficiency testing / collaborative exercises

Proficiency tests (PTs) and collaborative exercises (CEs) should be used to test and assure the quality of identification and comparison of fibres.

Proficiency tests and collaborative exercises could form a part of the maintenance of a practitioner's competence. A list of currently available PT/CE schemes as composed by the QCC is available at the ENFSI Secretariat.

"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 and collaborative exercises for their members.

Proficiency tests in fibre examination are usually set annually by the ENFSI Textile and Hair Group (ETHG). Such tests typically involve:

- Fibre identification
- Fibre comparison
- Identification of the fibre origin
- Description of findings (conclusion)

In addition, these may be supplemented by tests provided by collaborations of laboratories or within an organisation.

The performance in proficiency testing and collaborative exercises must be reviewed by the organisations in a timely manner and any anomalous results should be investigated and addressed with appropriate corrective actions according to the institute's quality management system.

7.2. Quality controls (QC)

It is essential to carry out calibration and performance checks for instrumental analysis. All calibration and performance checks must be documented and dated.

For further information please see appendices of methods. In the following subchapters calibration adjustments are carried out during an instruments servicing by a qualified engineer, which is usually conducted at defined intervals. Regular performance checks as outlined below should be completed prior to an instrument´s use.

Hard copies of the instrumental results of recovered fibre and known fibre should be printed and placed in the case file. The practitioners involved should sign and date the printout. This verification process can also be completed electronically.

7.2.1. Microscopy

Before use, microscopes must be correctly set up as detailed in the manufacturer‘s instructions and all users fully trained in their operation and adjustment. In particular, bright field microscopes should always be adjusted for Köhler illumination and a comparison microscope must additionally always be balanced using paired slides of fibres from the same source. Any microscope used to measure dimensions should have its eyepiece graticule accurately checked at least annually (or if any part of the microscope is changed) using a slide micrometer. Instruments used to establish refractive index, birefringence or melting point should be checked to ensure that the expected results are obtained from known materials.

For miscellaneous techniques such as interference microscopy, cross-sectioning, solubility, melting point determination and scanning electron microscopy, see Appendix 1, Microscopy of Textile Fibres.

7.2.2. Microspectrophotometry

Microspectrophotometers (MSP) and microscopes interlinked with spectrometers should be checked regularly. This ensures that the instrument is operating to expected standards.

Before any form of calibration is undertaken the system must demonstrate absolute consistency in the optical path so results are comparable. The microscope should be set up for Köhler illumination; normal operating parameters should be defined, and the lamp allowed to warm up and stabilise according to manufacturers' instructions.

Demonstration of the accuracy of wavelength and absorbance are important and if colorimetry is used as a comparative feature, then that too should be standardised using traceable commercial standards.

Wavelength accuracy over the visible range can be checked with the aid of holmium and/ or didymium filters. As the exact position of the absorption bands vary from batch to batch it is important that the filter is authenticated and traceable to original data from the manufacturer. Resolution can also be checked routinely using these filters.

Demonstration of standardisation of absorbance is also important especially if undertaking colorimetry. It also acts as a check on linearity, it is important that these standards are authenticated and traceable to original data from the manufacturer. Absorption filters will normally be placed in the sample plane, but if they are not, a blank slide, plus mountant and cover slip must be placed in the sample plane to assist with Köhler illumination.

Consistency may be monitored using the lamp energy and 100% transmittance line. This is acquired by measuring an area without the analyte; because there is no absorbing substance in the optical path, the transmittance at all wavelength steps should be 100% +/- 1 %. It can also be used to indicate aberrant behaviour of the lamp especially with the xenon lamp.

Calibration limits of each standard are supplied with authenticated samples direct from the manufacturer.

It is suggested that the calibration checks are performed and recorded for reference regularly or adjusted accordingly to frequency of use.

If your laboratory is using an MSP or MCS on a daily basis it is suggested that you should undertake at least one calibration checks regularly to demonstrate reproducibility. During operation the operator may run the 100% line and/ or a background scan for each cover slip. Necessary adjustments can be made to demonstrate instrument consistency.

7.2.3. Infrared spectroscopy

An infrared spectrometer with a microscope (or camera) attachment is recommended. All infrared spectrometers should be quality controlled regularly.

It is essential that instrument performance and calibration is monitored routinely according to the manufacturers' recommendations. It is recommended that the energy of the detector is checked through the object and the microscope before use. Instrument performance records may be maintained on hard copy and/or computer disk. These should include calibration and alignment checks, maintenance records, wavelength checks (e.g., polystyrene spectra), and should be signed and dated. Examples of the performance evaluation method for FTIR include:

- System throughput to check for optimal performance i.e., both the microscope and interferometer are properly aligned, and the S/N is comparable to normal manufacturer recommendations.
- The interferogram size, position (800-1200cm^{-1}) and shape are examined to ensure that there is maximum signal, and a stable, smooth signal, as per the manufacturers' recommendations. The sampling mode, the sample type, and the instrument alignment affect the peak height.
- Single-beam spectrum of the background should be examined to ensure that there are no interfering absorbances from the surface where the background spectrum is acquired, the water and carbon dioxide absorbances are minimised i.e., the instrument has stabilised.
- The spectral shape and the noise should be examined.
- S/N checks by recording the 100% line, in absorbance, at the 2000 – 2600 cm^{-1} region i.e., where no interfering absorbing atmospheric bands occur in the spectrum. S/N = 100/max-min at this area or P-P S/N = 1/max-min (peak to peak).
- 100% transmittance (T) line. Ideally an IR spectrum should be composed of a collection of smooth curves emanating from a flat baseline, at 100% transmission (or zero absorbance). If the IR beam travels through more than 10-15µm thickness of fibre, then 0% transmission will be obtained in some regions of the spectrum.
- Peaks may be offset because of lack of frequency calibration. Since infra-red spectroscopy is mainly used for structure determination it is important that frequencies are accurate and reproducible. Drifting of wavelength occurs in dispersive instruments. This is not a factor in the FTIR because the laser provides a continual internal accuracy alignment.
- By measuring a thin organic film on polished metal plates, or by using a flattened microfibre to identify the spatial adjustment of the system.
- Polystyrene or Indene are used for wavelength accuracy as they produce an elaborate many-featured spectrum. Interference fringes may distort polystyrene spectra.

Where used, the microscope should be set for Köhler illumination each day before use if used in transmittance.

7.2.4. Raman spectroscopy

Raman spectrometers and microscopes interlinked with spectrometers should be calibrated regularly. This ensures that the instrument is operating to expected standards.

It is essential that instrument performance and calibration are evaluated routinely according to manufacturers' recommendations. Instrument performance records should be maintained and should be signed and dated. Examples of the performance check method for Raman include:

Raman shift calibration check: As small changes in true Raman shift can be scientifically informative, it is very important to proceed to a Raman shift calibration check. In order to determine the Raman shift, both the frequency of the laser and the Raman scattering should be known. Usually, visible lasers are very stable, but the frequency of diode laser is less accurate and may even vary with the time.

Frequency calibration with absolute frequency standards: In this case, the atomic emission lines of gases are used (neon, argon or mercury lamps). The atomic source is placed near the sample position. The laser must correspond to zero Raman shift. The plasma lines from the laser itself can also be used if the bandpass filter is removed. This calibration is usually done by the manufacturer.

Frequency calibration with Raman shift standards: Raman shift standards does not depend on accurate knowledge of the laser frequency provided it is constant. The ASTM committee collected and tabulated the results for a set of 8 standards [ASTM E 1840-96, 1998]. ASTM Raman shift standards are available with a standard deviation of < 1cm^{-1}. These shifts were determined with 514 and 1064 nm lasers. Changes in observed frequencies are possible at other wavelengths due to resonance effect. The instrument response has to be controlled by checking the magnitude of the Raman signal under identical analytical conditions. For example, the intensity of the silicon band at 520 cm^{-1} (silicon is used to set the Raman shift in dispersive instruments) permits the detection of instrumental changes. Amongst the different substances proposed, polystyrene is also suitable for forensic application. It is in solid form, stable and nontoxic. It shows Raman shifts between 620 and 2904 cm^{-1}.

7.2.5. Other techniques

For other techniques such as Thin Layer Chromatography (TLC) or High Performance Liquid Chromatography (HPLC), Pyrolysis Gas Chromatography (PyGC or PyGCMS) or pyrolysis/mass spectrometry themselves (PyMS), see Appendix, Chromatographic techniques.

7.3. Data collection for control, monitoring and trend analysis peer review

Data collection should be documented according to the regulatory requirements and quality assurance system of each laboratory.

If applicable, it is recommended to carry out trend analysis relating to the results of performance checks in order to perform risk assessment and preventive measures.

Any irregularity observed during maintenance, performance checks or calibration should be monitored. It is advisable to perform root-cause-analysis if applicable.

7.3.1. MSP data processing

Commercially available MSPs have incorporated the requirements of operational settings, data control, processing and recording with the support of a system processor. As such they all carry their own software routines to cope with the tasks. In addition, there are further software routines available for use with these systems.

Through the science of colour coding (colorimetry) it is also possible to numerically determine and specify colours. However, modern computer software allows spectral searching and comparison.

7.3.2. MSP databases

Some laboratories now accrue the data: some in the form of spectra, others include physical characteristics and manufacturers details as well. Modern software packages offer the capabilities to store the information in blocks of colour. As long as these databases are kept up to date and used in conjunction with other information (e.g., peer review, literature, practitioner experience) they can offer valuable information both in terms of evidential value and as an intelligence aid. To use a database effectively a considerable amount of data is required.

7.3.3. IR spectra

It is recommended that spectra of the known fibres are saved to a hard disk or a CD, as per laboratory procedures. It is generally useful to save all data on disk just after it is generated and prior to any modification. If any data manipulation has been carried out the raw data must be saved, and the data manipulation carried out on a copy of the spectrum. Data that is damaged during subsequent processing can then be restored from the saved files. Any manipulation carried out, e.g., baseline correction is carried out in absorbance and should be noted on the

hard copy of the spectrum. The saved spectra can be retrieved and compared with pre-stored library spectra at a later date.

7.3.4. Use of IR libraries

Reference (IR) spectra are essential for the identification of the fibre composition. These can be in the form of literature references or a spectral library. Do not attempt to identify spectra by Trade name, but only by chemical composition.

A computer-assisted search can be used to provide valuable information. In addition to indicating the identity of the fibre the library search may compute a probability of match based on band position and intensity. This can be an approximate technique due to noise, environmental conditions, varying peak heights etc. The results of a database search should be treated with caution as the database may not contain all the variations in fibre polymer structures.

An in-house spectral library built from a collection of authenticated specimens representing the generic types and sub types is recommended. This should be created using the same technique and instrument used within the laboratory for the unknown fibre.

Any problems due to sample preparation, instrument etc. are overcome by comparison of spectra prepared in house on the laboratory IR spectrometer. For more information, refer to Appendix 3, Infrared Spectroscopy of Textile Fibres

8. HANDLING ITEMS

8.1. At the crime scene

The following recommendations apply to the examination of fibres relating to a crime scene, as well as fibres relating to victim(s), suspect(s) and other person(s) relevant to the case.

8.1.1. Avoidance of contamination

The accessibility to the crime scene, to other relevant areas and to corpses should be restricted and any access to these by individuals should be documented.

Items from different sources must be physically separated from one another after seizure to reduce the potential for contamination, e.g., clothing and other articles from the scene, suspect(s) and of the victim(s) must be kept separate from one another. Seized items from different incident related individuals should be packed by different personnel if possible.

Any situation that could cause contamination or otherwise compromise the trace evidence examinations should be documented and communicated.

In order to protect fibre traces or their substrates from loss and/or biological, chemical, or physical contaminants, personal protective equipment (PPE) such as protective coats, disposal gloves and facemasks should be worn by the practitioner and respective attendees at the scene. The choice of PPE will be determined by the aims of the examiner.

PPE should not only protect fibres but also personnel from possible generic hazards that may apply to any crime scene, for example risks associated with exposure to body fluids, trip hazards, etc. (refer to Section 14.1, Health and Safety / At the crime scene).

The area for examination at the crime scene may require protection against environmental conditions and other disturbing factors, e.g., tents to protect against adverse weather, crowds of onlookers, etc.

Items at a crime scene which bear visible but easily lost traces, or items that are impractical to transport, should be appropriately documented, and the traces collected by an appropriate technique.

To prevent the loss of evidence, consideration should be given to the recovery of fibres at the scene by an appropriate method (refer to Section 8.1.2, Search and recovery). Alternatively, items can be removed from the scene and fibres recovered later in the laboratory. If this is the case, these items should be packaged immediately in an appropriate manner (refer to Section 8.1.4, Preservation and packaging).

Steps should be taken to avoid post-incident contamination between the scene(s),

victim(s) and suspect(s), e.g., by the use of different personnel or PPE. In addition,

suspects or other incident related individuals should be transported in different police cars.

8.1.2. Search and recovery

Items at a crime scene which bear visible but easily lost traces, or items that are impractical to transport, should be appropriately documented, and the traces collected by an appropriate technique.

Depending on the circumstances, here are some general guidelines pertinent to securing fibre evidence at a crime scene with deceased victims:

- 1:1 Taping or Zonal Taping should be carried out on the bodies and/or clothes of the victim(s) at the crime scene providing they are undisturbed (e.g., a deposition site may not be appropriate). This will assist in providing an exact record of the original location and density of transferred fibre traces. Wet bodies or bodies covered with fresh blood may affect the efficiency of the tape lifting recovery and a subsequent taping may be required after a drying step.
- Removal of clothes from the body at the scene, and immediate packaging of the clothing to preserve trace evidence. These items should be packed in separate bags and transported to the laboratory as soon as possible.
- Bodies should be removed immediately only if circumstances do not first permit inspection and evidence recovery, e.g., due to imminent danger, extreme hindrance to traffic, no possibility of working without being overlooked by persons who are not involved (crowds of onlookers).
- The body must always be transported in such a way as to preserve any potential evidence. A new body bag must always be used. When no fibre recovery on the body was possible at the scene, the inside of the body bag or any appropriate containers (paper sacks, etc.) should be taped.
- (Naked) wet bodies should be transported to the relevant facility in order to dry for fibre recovery.

Small or manageable items at a crime scene which bear visible, firmly attached traces or which are expected to bear invisible significant fibre traces, should be documented, packaged and sealed individually for transport to a laboratory for examination.

Items and traces should be kept secure, in a sealed package, protected from loss, damage and contamination, until the item is examined in the laboratory.

Quality control samples, that can be used to satisfactorily verify a contaminant-free recovery environment, may be taken.

Depending on the case circumstances standard procedures regarding fibre recovery at scenes cannot always be followed. However, it is important to recover as many fibres as possible and

any non-standard methods (e.g., for damp items, heavily contaminated items) employed should be documented together with the reasons for the use of the non-standard methods.

8.1.3. Target fibre selection

Known samples of fibres from a specific source, with which it would be helpful to establish that the offender(s) and/or victim(s) and other person(s) relevant to the case may have come into contact, should be recovered. These should include all component fibre types and colours (including faded and unfaded areas, worn and less worn areas, etc.). Tufts of fibres or an excised piece of material is preferred to tapings.

In absence of a reference garment, questioned single fibres of an unknown provenance, recovered on different surfaces, can also be analysed in order to do a trace comparison.

"Background" fibres may also be obtained from areas with which the offender is not thought to have had contact, but to help establish whether any 'collectives' of fibres found on a victim could have originated from the victim's own environment or they could relate to textiles worn by the suspect. The background fibre population at the crime scene is also helpful in identifying if there are textiles in the area that would be an obvious source of questioned fibres (bright colour/good shedding potential) which could have been transferred to the offender.

8.1.4. Preservation and packaging

The method of preservation and packaging of fibres and items to be examined for fibres will vary. Packaging must prevent loss, deterioration or contamination of the fibres.

Minute or loose trace evidence must be secured under tape, on microscope slides or be placed in small clean containers such as small paper folds, petri dishes, tubes etc. Large items, such as whole garments, should preferably be sealed individually in clean, unused packaging.

Wet recovered items should be air dried as soon as possible, without exposure to heat or sunlight, in a secured area in a manner that will prevent loss or contamination of the fibres.

8.1.5. Labelling and documentation

The techniques used for detection, collection, and preservation of the items should be recorded together with the location from which the items are removed.

The labelling of any items recovered should follow the local jurisdiction guidelines.

The minimum details that should be recorded and be directly and unequivocally attributed to each package are:

- The location of the scene, from where or from whom, the item was seized
- The date (and time, when appropriate) the item or trace was recovered
- The name of the person recovering the item or trace
- A short description of the recovered item or trace, plus appropriate remarks about any special observations/circumstances that may apply
- A unique identifying mark for each item or trace, e.g., case number and item number
- The position of relevant items (e.g., documented by notes, sketches, measurements and/or photographs, 3D scan)

8.1.6. Transport

There are no particular problems or risks associated with the transportation of fibre samples provided that they have been packaged appropriately as to avoid any risk of contamination or tampering.

8.2. In the laboratory

8.2.1. Anti-contamination precautions

The accessibility to examination areas should be controlled and documented.

Items should preferably be searched in purpose designed rooms with restricted access and air filtration.

Every effort must be made to use different rooms to search items from different scenes or people and these rooms should be physically located some distance from each other. Ideally, different examiners should examine items from victim(s) and from suspect(s). When this is not possible, there must be a clear, documented time gap and evidence of decontamination between searches.

Once the fibres are recovered, secured and labelled the risk of inter-sample contamination is minimised. To demonstrate the integrity of the examination, notes should include details of item packaging and the examination undertaken, together with the examination date, time and location.

Any situation that could cause contamination or otherwise compromise the trace evidence examination should be documented and communicated.

In order to protect fibre traces or their substrates from loss and/or biological, chemical, or physical contaminants, personal protective equipment (PPE) such as protective coats, disposal gloves and facemasks should be worn by the practitioner. The choice of PPE will be determined by the examination strategy.

PPE should not only protect fibres but also personnel from possible generic hazards that may apply to any fibre examination, for example risks associated with exposure to body fluids, etc. (refer to Section 14.2, Health and Safety).

Equipment used for collection and/or storage of evidence, e.g., adhesive tapes, acetate sheets, forceps and scissors, should be maintained in a manner so as to avoid contamination, either between items or between different cases.

If it is deemed necessary, clean any packaging of exhibits immediately prior to opening to prevent any contamination. Measures should be taken as to avoid contamination between the item and the outside of the packaging of the items, e.g., by opening the packaging of the items close to, but not on, the examining bench and changing to a fresh pair of gloves before moving the item to the bench, or by cleaning the outside of the packaging before opening it to prevent any contamination.

Laboratories, examination areas and equipment should be cleaned according to laboratory anti-contamination protocols before and after examinations are carried out.

8.2.2. Search and recovery

Examination areas should have adequate lighting.

Fibres may be recovered in the laboratory by taping and picking off the fibres or fibre tufts individually with forceps, respectively.

Clear adhesive tape is usually used to recover transferred fibres. The width and degree of adhesiveness of the tape should be varied according to the nature of the surface being taped. After collection of the fibres, it is recommended that the tapes should be placed sticky side down on a transparent carrier (e.g., an acetate sheet) and clearly labelled with the unique identifying

mark and their place of origin. Alternatively, the tapes may be sealed by folding them over on their own sticky surface.

Combing could also be used as an alternative to taping for removal of fibres from head hair. A new fine-toothed comb should be used, and the hair should be combed over a large sheet of paper. Alternatively, a sterile gauze could be inserted in the teeth of the comb as a carrier for collecting fibres.

Vacuuming (by use of a vacuum cleaner and special filters) or shaking could also be applied as an alternative to taping for fibre recovery in exceptional circumstances. However, these methods are not recommended by the ETHG as routine methods for fibre recovery.

Depending on the case circumstances standard procedures regarding fibre recovery in the laboratory cannot always be followed. However, it is important to recover as many fibres as possible and any non-standard methods (e.g., for damp items, heavily contaminated items) employed should be documented together with the reasons for the use of the non-standard method.

Quality control samples, that can be used to satisfactorily verify a contaminant-free recovery environment (as far as is practically possible), should be taken.

8.2.3. Reference samples

Reference samples of fibres comprising fabrics from known sources (e.g., clothing, carpets, upholstery, bedding or other textile fabrics present in a particular environment), with which it may be helpful to establish that relevant offender(s) /victim(s) / other person(s) may have come into contact, should be recovered. These should include all component fibre types and colours (including faded and unfaded areas, worn and less worn areas, etc.). Tufts of fibres or an excised piece of material is preferred to tapings. If tapings are to be used as reference samples from the known source, care must be taken in order to avoid any confusion with background fibres from other sources.

In addition, a taping should be made to assess the shedding potential of the items sampled. These should be taken from a representative area, including any areas of obvious damage and/ or wear.

In absence of a reference garment, questioned single fibres of an unknown provenance, recovered on different surfaces can also be analysed in order to carry out a trace comparison.

8.2.4. Storage

Any items recovered from the scene, victim(s), suspect(s) or others should be stored in a manner which prevents loss, deterioration, or contamination, e.g., tape lifts should be secured in clean, unused containers or packaging. Ideally, fibres should be stored in a dry and dark environment.

A record of movement including storage should be held.

9. INITIAL ASSESSMENT

The significance and evidential value of fibre evidence as associative evidence relies heavily on the correct detection, collection and preservation of this evidence and the appropriate sequence of examination both at the scene and in the laboratory (refer to Section 10. Prioritisation and Sequence of Examinations). Furthermore, the success of fibre examinations and interpreting the evidential value of fibre evidence (refer to Section 12, Evaluation and Interpretation) is strongly dependent on the case assessment and the forensic examination strategy, devised by the relevant personnel involved.

Prior to starting any examinations, the requirements of the customer must be clearly defined and documented. Detailed information about the alleged circumstances of the case is usually necessary to initially assess any potential limitations in the examinations proposed and their effect on the perceived outcome. This is particularly important when evaluative reporting on activity level is involved.

Factors to be considered when establishing the customer's requirement include:

- What area(s) and level of expertise is required
- Whether the laboratory has the capacity, suitable resources, facilities and equipment available to perform the necessary examinations
- Whether there is any time or other constraints that might affect the overall examination strategy, for example, where other evidence types are involved in the examination sequence
- Whether the request put forward by the customer can be executed
- If the request includes a proposition, it should be assessed whether the proposition can be tested
- If yes, at least one alternative proposition favourable to the defence should be framed
- In relation to fibre evidence specifically, here are some general guidelines pertinent to case assessment:
- What is suspected or known to have occurred before, during and after the incident
- What persons (or objects or garments) are involved
- The sequence of events and the time frames involved, including those associated with the recovery of items submitted for examination
- If an article has been worn for a considerable length of time subsequent to the offence, a fibre examination for fibres transferred to the recipient may not be of value, but the shedding capacity of the item should still be considered
- Particular garments or areas of garments can be prioritized depending on the circumstances of the case
- Prioritise those fibres and garments likely to be of the most value.

Considering fibre recovery, the following guide should be used when deciding which garments should be taped, and which items are appropriate as potential sources of questioned fibres:

- Garments that shed low numbers of fibres are easily taped but are poor as potential sources of questioned fibres.
- The more contrast there is between questioned fibres and reference fibres from the garment itself, the more easily target fibres can be discriminated (e.g., brightly coloured, coarse).
- Fibres, which fluoresce strongly under ultraviolet light are good, target fibres, particularly if the garment being taped does not fluoresce or fluoresces to a lesser extent.
- The less common the fibre type, the better it is as a target fibre.
- If a garment is damaged it may be a good source of transferred fibres, even when the sheddability of the overall garment is poor.
- Pay special attention to important areas of the garment as indicated by the circumstances of the case, e.g., the seat of a pair of trousers may be targeted if the person was believed to have been sitting on a car seat cover.
- If possible, it is always preferable to establish two-way contact or association.
- In addition to garments, other non-textile objects may also have to be examined for fibres, e.g., car parts in hit and run pedestrian accidents, window ledges in break and enter cases, etc. Bulky objects may need to be taped at the crime scene; however, it is

preferable that items which can be easily transported without loss of evidence be taped within the laboratory, under controlled conditions.

In instances where more than one scientific discipline is involved and/or different evidence types need to be considered, a coordinated examination strategy will determine the actions to be taken and the most appropriate methods to be used for the search and recovery of fibres. This may involve a joint examination by practitioners from different disciplines.

The general principles and practices to prevent and control contamination and loss of evidence are applicable to both crime scene and laboratory.

When seizing, recovering, storing, transporting and examining items/samples/sub-samples from a scene, or when seizing clothing or textiles belonging to individuals potentially involved in the crime, care must be taken to prevent contamination and loss of trace materials. The investigator (police officers, forensic examiners etc.) should assess the situation carefully before acting and then take decisions on how to manage the actual case. This will often involve discussion with other experts and the officer in charge of the case.

Factors to be considered when assessing the potential risk of contamination by establishing whether:

- There was any opportunity for the transfer of fibres between the individuals, items and/or surfaces involved prior to the incident or the fibre recovery respectively
- There was any opportunity for fibre transfer between the individual(s), items and/or surfaces involved following the incident or the fibre recovery respectively
- The items relating to the individual(s), and/or items involved were properly handled during recovery and packaged appropriately
- There was any opportunity for secondary transfer to individuals, items and/or surfaces involved, such as contact with other individuals and/or seating.

Factors to be considered when assessing the chance of recovery of fibre evidence:

- The opportunity for fibre transfer between textile items will depend on the area of contact, the duration of the contact and the pressure involved in the contact. It will also depend on the construction and nature of the surface of the textiles or other items involved.
- Transferred fibres are quickly lost or redistributed after the initial transfer. The rate of loss will depend on the nature of the recipient surface and the conditions to which it is subjected. Trials have shown that up to 80% of transferred fibres may be lost within the first two hours after contact. However, the original number of fibres transferred can run into thousands, so it is possible that large numbers of fibres will still remain after this interval.

The retention of transferred fibres is also heavily influenced by the nature and duration of the post contact activity of the recipient. Where possible, information concerning this should be obtained. As well as useful for forming initial expectations of recovery, this may have subsequent importance in assessing the relevance of any fibre evidence.

The situation is largely better when considering fibre traces on a static dead body, however outdoor conditions could also affect the number of traces transferred and retained.

- Certain types of textiles, with smooth non-porous surfaces, have very limited capacity for donating or retaining fibres.

Factors to be considered when assessing the relevance of fibre evidence:

- Textiles are mass-produced articles. It is normally not possible to state that specific recovered fibres originated from a particular textile source to the exclusion of all others. Textiles are seldom unique, and the possibility of the specific recovered fibres having

originated from another item made with the same material can never be ruled out completely.

- Nevertheless, fibres, especially man-made ones, exhibit a very high degree of variety and the matching of recovered fibres in a case can provide strong evidence.
- The combination of several characteristics of fibres such as colour, fibre type, alteration/bleaching etc. can improve the individuality of fibres and therefore increase the evidential value.
- However, some fibre types (e.g., colourless cotton and indigo ~~or sulphur black~~ dyed cotton) are so widely distributed that in most circumstances they will be of no evidential value. In addition, colourless fibres are not normally included in transfer examinations due to the difficulty in recovering them and their relative lack of comparative features. In special cases, e.g., traffic accidents involving fibre-plastic fusions, even these common types/colourless fibres may assume special significance due to case circumstances.
- In order to be able to assess the potential significance of any findings, it is necessary to have information on:
    - The distribution and frequency of occurrence of the different types of questioned fibres/fabrics involved in the case
    - Transfer and persistence studies in relation to the types of questioned fibres/fabrics involved in the case

When evaluative reporting is used the practitioner should assess the evidential value of the anticipated findings considering what is expected to find if the proposition or its alternative were correct or not (based on the relevance, the potential significance, the chance of recovery, transfer and persistence of the fibre evidence).

All of the issues regarding the evidential value of fibre evidence are discussed further in Section 12, Evaluation and Interpretation.

10. PRIORITISATION AND SEQUENCE OF EXAMINATIONS

The prioritisation and sequence of examinations is determined by the customer's requirement and the overall forensic examination strategy (refer to Section 9, Initial Assessment). Personnel should be aware that various types of evidence will be present during the processing of a crime scene or the examination of items submitted to the laboratory. Some types of evidence may be more significant to a particular case and therefore should be given higher priority. The situation has to be considered carefully before any examination takes place. All potential forensic opportunities should be considered, and the appropriate experts should be consulted.

Consideration should be given to the following before commencing any recovery and examinations of fibres:

- The urgency and priority of the customer's need for information
- Other types of forensic evidence, and the associated examinations, which may have to be carried out on the same items
- Which items have the potential to provide the best evidence
- Which items offer the best choice of questioned fibres, in terms of evidential value, colour and sheddability

It is usually preferable to start by searching for the best choice of questioned fibres on the items where the finding of questioned fibres may have the most evidential significance (e.g., underclothes in a rape case).

To minimise the possibility of contamination it is preferable to examine all items relating to one individual or scene before commencing with items relating to others.

In general, the examination protocol might be as follows:

- Recovery of visible material, such as tuft of fibres, hairs, glass, etc., adhering loosely to the item
- Recovery of any potential fibre evidence not visible to the naked eye. In some instances, a low power microscopical search of the item may be relevant (e.g., fibres on knives, under fingernails etc.). This method decreases any potential contamination and loss of unforeseen evidence
- Fibre analysis and comparison using the agreed methodology (refer to Section 5, Methods)

Considering the potential value of the information from each technique we refer to Section 5, Methods.

11. RECONSTRUCTION OF EVENTS

In some cases, it might be necessary to carry out experimentation to evaluate the findings. This might take the form of a simulation or reconstruction exercise designed to mimic the proposed causative actions. For example, tests to replicate heat-damaged fibres in cases of suspected arson, crush-damaged fibres in cases of assault.

Such tests should be designed so as to answer the issues raised during the examination process, or by the client. Any experiments or tests carried out should be well documented, including any assumptions made and limitations of the tests. Before carrying out destructive testing in reconstruction experiments it is advisable to consider the use of replicate samples. Where replicates are used (e.g., weapons) they should closely reflect the form and condition of the original item.

When carrying out any experimentation, it is preferable not to alter the original evidence (depending on the legal jurisdiction). Where it is altered by experimentation, this has to be clearly documented and appropriate permission should be sought.

The detection of Fibre Plastic Fusions and associated plastic coating marks may also be used to determine, with a great deal of confidence, who was driving a motor vehicle at the time of a collision.

12. EVALUATION AND INTERPRETATION

Evaluation and interpretation of the findings should reflect the issues identified in the initial pre-assessment of the case and should address the specific requirements of the investigation within the specific framework of circumstances of the case itself (refer to Section 9, Initial Assessment). This is particularly important where a logical evaluative approach (such as a Bayesian framework) is employed in this process.

Case pre-assessment should provide a means of determining expectations concerning potential examination outcomes given the allegations of the prosecution and defence. The actual outcome of the examination can therefore be evaluated in this context and mitigate the potential for cognitive bias (see below).

The significance of the laboratory findings in a specific fibre case can essentially be considered in two distinct parts.

At the most fundamental level, this considers the results of the analysis and comparison of a fibre(s) considered to be related to a crime, with a putative source and the ‘confidence’ that can be attributed to any ‘match’ obtained. In a Bayesian framework (see below), this is referred to as a “source level” proposition.

Factors important in this evaluation include (but are not limited to), the relative 'rarity' of the fibres in question, the number of tests employed and the discriminating power of the analytical sequence.

In addition, peer reviewed published studies such as: fibre population studies, colour block studies, target fibre studies, as well as the practitioners own experience, must also be considered in this type of evaluation. Where a database is consulted in this process, caution should be employed when considering generated fibre frequency data – particularly where a limited or unrepresentative dataset is used and should (unless there are compelling reasons to do so) not be used as the sole means of information.

This most fundamental evaluation aids the practitioner in assisting the legal system in considering the question of how likely is it that the fibres in question are 'crime related' as opposed to be chance ('adventitious') matches.

In many legal systems there is a requirement to assist in addressing the question of how 'crime related' fibres became transferred to a particular garment or surface.

In adversarial legal systems (such as in the UK ~~and USA~~) it is common for the practitioner to be asked to assist in determining how likely it is that an activity alleged by the prosecution could account for the presence of such fibres, compared to an alternative activity alleged by the defence. In a Bayesian framework (see below), this is referred to as an "activity level" proposition.

Where this is a requirement of a particular legal system (adversarial or inquisitorial), examples of factors important in this type of evaluation include (but are not limited to): the relative rarity of the fibres, background, the nature and type of the donor and recipient surfaces, the ease with which they retain or shed fibres, the type, nature and duration of contact as well as post contact/ crime activity.

There are numerous peer reviewed published transfer and persistence studies providing data concerning the transfer and persistence of fibres on various substrates, and these can and should be used in order to inform such an evaluation. In addition, the practitioner's own casework experience is also invaluable in forming an opinion in this respect.

Where a very specific activity is alleged to be responsible for the presence of crime related fibres, it is, wherever possible and practical, desirable to carry out an experimental reconstruction of the alleged activity to inform the practitioners opinion.

Where possible, and where the legal system permits, interpretation and evaluation of the findings should be carried out using a logical evaluative reasoning approach.

ENFSI recommends using a Bayesian framework to provide a verbal scale of support for a particular event, based upon the calculation of a likelihood ratio. Guidance for the use of this framework this is set out the published document "Guideline for Evaluative Reporting in Forensic Science".

This framework essentially provides a robust and impartial methodology for the practitioner to evaluate how likely the findings are in a given case, given the prosecution version of events compared to those proposed by the defence.

It is beyond the scope of this document to provide examples of its use in practice, however, there are numerous published papers and texts on the application of this method.

Whatever level or method of evaluation is employed by the practitioner, it is incumbent on them to ensure that any report provided for use by their legal system, should be written in a form which offers maximum transparency and justification regarding this evaluation (e.g., what tests

have been performed, literature or other experimental data has been referred to, what propositions/ versions of events have been considered?) in a balanced and impartial manner.

'Confirmation bias' occurs when the practitioner sees what they expect to see, and this becomes particularly apparent where the findings are relatively ambiguous. Non-case relevant information e.g. police opinions, awareness of any particularly emotive aspects of a case ('contextual bias'), or knowledge of the opinion of any earlier examination by a colleague, can all influence the interpretation. The effects of such cognitive bias have been widely reported, but it should be stressed it has never been demonstrated or quantified in fibre examinations. Since all forensic examinations are context sensitive, it is vital that case relevant information is used in the evaluative process and that this is documented in the notes. The use of a documented case pre-assessment and a transparent, balanced and robust, peer reviewed evidence evaluation are effective methods of countering allegations of cognitive bias in fibre casework.

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 should be provided with honesty, integrity, objectivity and impartiality.

Evidence can be presented to the court either orally or in writing. Only information which is supported by the examinations carried out should be presented. The presentation of evidence should clearly state the results of any evaluation and interpretation of the examination.

After issuing their report, the practitioner may review and alter their opinion based on new information given to them.

13.1. Presentation of written evidence

The practitioner's findings and opinion are normally provided in written form, as a statement of evidence or an analytical, investigative or evaluative report. These can be used by the investigator, the prosecutor, the defence or the court. Depending on the customer’s requirements, either a shortened or a complete report can be issued.

Written reports should include all the relevant information in a clear, concise, structured and unambiguous manner, as required by the relevant legal process for the country of jurisdiction, as well as the guidelines of the institute. Where possible, reports should clearly state the results of any evaluation and interpretation of the examination, and written reports must be peer reviewed.

13.2. Presentation of oral evidence

At Court, the practitioner should only respond to matters arising from their report, or those matters raised in Court, which fall within their area of expertise. Expert witnesses should resist responding to questions that will 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.

14. HEALTH AND SAFETY

The relevant national health and safety regulations must be complied with.

14.1. At the crime scene

There are no specific hazards associated with the recovery of fibres at the crime scene.

Generic hazards that apply to any crime scene, for example risks associated with exposure to body fluids, trip hazards, etc., will always need to be considered and may be documented as part of the formal risk assessment process prior to scene entry. Control measures should be put in place to either remove the risk or minimise it to an acceptable safe working level.

No specific protective clothing is necessary for trace evidence recovery at crime scenes, and the usual anti-contamination clothing is adequate.

14.2. In the laboratory

Generic hazards that apply to any laboratory examination, for example risks associated with exposure to body fluids, etc., will always need to be considered. Control measures should be put in place to either remove the risk or minimise it to an acceptable safe working level.

No specific protective clothing is necessary for fibre recovery or examination at the laboratory, and the usual laboratory anti-contamination clothing (as dictated by local laboratory procedure) is adequate.

Appropriate safety equipment such as 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.

Risks in the examination process at the laboratory include:

- Microscopic examination and comparison of fibres can be a lengthy process, during which time the operator may be seated for prolonged periods at the microscope. There is a risk of eye strain and postural discomfort, which should be alleviated by frequent breaks from the examination process.
- The laboratory may consider the need for a documented risk assessment of the workplace environment, to ensure that laboratory lighting is adequate and seating position is optimised, with seating providing the appropriate lumbar support and set at the appropriate height relative to the laboratory bench and microscope etc.
- Exposure to chemicals can also be an issue. Solvents may be used by some laboratories to remove fibres from tape lifts, whilst some laboratories may utilise solvent-based mountants for mounting fibres on microscope slides. The risks associated with the various chemicals, solvents and mountants used will vary.

The laboratory should undertake and document a risk assessment of the hazards associated with the use of any chemicals, solvents or mountants, in a specific activity and identify the precautions to be taken during their use in that activity to mitigate the risks. Some chemicals, solvents and mountants may have to be used in a fume hood or while wearing a suitable protective mask and safety spectacles. In some instances, certain personnel should avoid any exposure to the particular chemical. For example, xylene-based mountants may pose a risk to unborn children and exposure of pregnant female staff to these chemicals must be avoided.

All chemicals, biohazards and supplies should be stored and disposed of according to the appropriate government regulations and laboratory policy.

- Firearms could also be an issue when recovering fibres. Therefore, caution should be taken when handling guns. If needed, firearm experts should be consulted before handling guns and assist when recovering fibres.

14.3. At court

There are no specific safety risks associated with fibre evidence where the materials may be brought into the public domain, such as Courts.

However, if the fibres are known to present a biohazard, for example, it is contaminated with body fluids, it should be appropriately packaged and clearly labelled to indicate the biohazard risk.

15. REFERENCES

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16. AMENDMENTS AGAINST PREVIOUS VERSION

Not applicable.

17. TABLE OF APPENDICES

Appendices provide additional information on methodology and analytical techniques. This information was already part of the previous guidelines [3]. For recent advances in the field the reader is intended to refer to dedicated literature or to references [9-10 & 14].