OSAC 2022-S-0019 Standard Guide for Forensic Examination of Fibers

Trace Materials Subcommittee
Chemistry: Trace Evidence Scientific Area Committee
Organization of Scientific Area Committees (OSAC) for Forensic Science

OSAC Proposed Standard

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Prepared by
Trace Materials Subcommittee
Version: 1.0 - OSAC Open Comment
March 2022

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Standard Guide for Forensic Examination of Fibers

1. Scope

1.1 This document is an introduction to the examination of textile fibers in forensic casework. It is intended to assist individuals who conduct fiber analyses in their evaluation, selection, and application of tests that can be of value to their examinations. The goal is to provide a consistent approach to fiber analysis. Detailed descriptions of procedures for many of the techniques are addressed in separate documents (E2224, E2225, E2227, E2228). This document is not intended as a detailed process description or rigid scheme for the analysis and comparison of fibers, but as a guide to the strengths and limitations of each analytical technique.

1.2 *This standard is intended for use by competent forensic science practitioners with the requisite formal education, discipline-specific training (see Practice E2917), and demonstrated proficiency to perform forensic casework.*

1.3 *This guide does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[1]

D123 Terminology Relating to Textiles

D629 Standard Test Methods for Quantitative Analysis of Textiles

D4845 Terminology Relating to Wool

D4849 Standard Terminology Related to Yarns and Fibers

D7641 Guide for Textile Fibers

E620 Practice for Reporting Opinions of Scientific or Technical Experts

E1459 Guide for Physical Evidence Labeling and Related Documentation

E1492 Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Science Laboratory

E1732 Terminology Relating to Forensic Science

E2224 Guide for Forensic Analysis of Fibers by Infrared Spectroscopy

E2225 Guide for Forensic Examination of Fabrics and Cordage

E2227 Guide for Forensic Examination of Non-Reactive Dyes in Textile Fibers by Thin-Layer Chromatography

E2228 Guide for Microscopical Examination of Textile Fibers

E2917 Practice for Forensic Science Practitioner Training, Continuing Education, and Professional Development Programs

OSAC 2022-S-0029 Standard Guide for Interpretation and Reporting in Forensic Comparisons of Trace Materials

WK 78748 Practice for a Forensic Fiber Training Program

WK 78749 Guide for Microspectrophotometry in Forensic Fiber Analysis

2.2 *AATCC Standards:*[2]

AATCC Test Method 20: Qualitative Test Method 20–2013 Fiber Analysis: Qualitative

[1] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[2] Available from American Association of Textile Chemists and Colorists (AATCC), P.O. Box 12215, Research Triangle Park, NC 27709-2215, http://www.aatcc.org.

2.3 *Other Documents:*

ANAB ANSI 3125[3]

ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories[4]

SWGMAT Introduction to Forensic Fiber Examination

3. Terminology

3.1 *Definitions*— For additional terms commonly employed for fiber examinations, see E1732 and E2228. For additional terms relating to textiles and wool, see D123, D4845, and D7641.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *animal fiber, n*—any natural protein-based fiber. D7641

3.2.2 exclusionary difference, *n*—A difference in one or more characteristics between compared items that is sufficient to determine that the compared items did not originate from the same source, are not the same substance, or do not share the same composition or classification. (OSAC Preferred Term – Lexicon)

3.2.2.1 Discussion—What is sufficient depends on the performance and limitations of the method used on the material in question.

3.2.3 *generic class, n—as used with textile fibers*, a grouping having similar chemical compositions or specific chemical characteristics. D123

3.2.4 *inorganic fibers, n*—a class of fibers of natural mineral origin (for example, chrysotile asbestos) and manmade mineral origin (for example, fiberglass). E2228

3.2.5 *manufactured fiber, n*—a class name for various genera of fibers (including filaments) produced from fiber forming substances which can be (*1*) polymers synthesized from chemical compounds [synthetic fibers], (*2*) modified or transformed natural polymers [regenerated fibers], and (*3*) minerals, for example, glasses. E2228

3.2.5.1 *Discussion*—Acrylic, nylon, polyester, olefin, urethane, and polyvinyl are examples of fiber synthesized from chemical compounds. Cellulose based fibers, such as acetate and rayons, and alginate fibers are examples of modified or transformed polymers. D123

3.2.6 *natural fibers, n*—a class name for various genera of fibers (including filaments) of: (*1*) animal (that is, silk and wool); (*2*) mineral (that is, asbestos); or (*3*) vegetable origin (that is, cotton, flax, jute, and ramie). E2228

3.2.7 *synthetic fibers, n*—a class of manufactured polymeric fibers, which are synthesized from chemical compounds (for example, nylon and polyester).

3.2.8 *target fibers, n*—questioned fibers that an examiner selects for further examination based on their resemblance to the known sample.

3.2.9 technical review, *n*—a qualified second party's evaluation of reports, notes, data, and other documentation to ensure there is appropriate and sufficient support for the actions, results, conclusions, opinions, and interpretations. (OSAC Preferred Term – Lexicon)

3.2.9 *textile, n*—a general term for fibers, yarn intermediates, yarns, fabrics, and products that retain all the strength, flexibility, and other typical properties of the original fiber or filaments.

3.2.10.1 *Discussion*—*General*, a structure made from any combination of natural or manufactured fibers, having either a measured staple length or a continuous filament length, that can be in the form of a woven, nonwoven, braided, plaited, knitted, entangled or twisted product and which retains its characteristic flexibility and drape. *Specific*, as applied to: *(1)* staple fibers and filaments suitable for conversion to or use as yarns, or for the preparation of nonwoven fabrics, *(2)* yarns made from natural or manufactured fibers, (3) fabrics and other manufactured products made from fibers as defined above, and form yarns, and (4) garments and other articles fabricated wholly from one or more of the above, and articles made principally from the above when the products retain the characteristic flexibility and drape of the original fabrics. D123

3.2.11 *textile fiber, n*—a generic term for the various types of matter that can be transformed into a yarn having a length, at least 100 times its diameter, and which can be used to produce a flexible structure by weaving; knitting; braiding; felting or any other means of processing.

3.2.11.1 *Discussion*—The matter transformed into a textile fiber can be either natural or manufactured. In addition to having a high ratio of length to thickness, the textile fiber also needs to have sufficient strength,

[3] Available from ANSI National Accreditation Board, 330 E. Kilbourn Ave, Suite 926, Milwaukee, WI, 53202, https://anab.ansi.org/2018-iso-iec-17025-forensic-accreditation-documents-0.

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

cohesiveness, and flexibility.

3.2.12 verification, n—provision of objective evidence that a given item fulfills specified requirements. ISO/IEC 17025 (2017)

3.2.12.1 Discussion—The process through which the analyses of a forensic examiner are compared by a second, independent examiner so that the findings of the first examiner are corroborated, or can be corrected in situations where there is a disagreement. Verifications can be open or blind. Blind verifications are more robust than open verifications.

4. Summary of Guide

4.1 The basic activities involved in a fiber examination include case assessment, the search for and collection of fibers, preparation of the sample(s) for analysis, analysis using appropriate techniques, and evaluation of results.

4.2 The analysis of evidentiary fiber samples includes the examination of physical characteristics, including color, optical properties, spectral properties, and chemical composition. The techniques described in this document provide complementary information and should be selected and employed in an order that considers sample preservation and the amount of discriminating information that can be obtained.

5. Significance and Use

5.1 Fibers are frequently encountered in casework, whether it be through the evidentiary item itself (e.g., clothing, rope), or through the processing and collection of fibers from evidentiary items. Fibers can be exchanged between individuals, between individuals and objects, and between objects.

5.2 Fibers are subjected to a variety of manufacturing processes in order to produce textile materials for application in a wide range of industries (e.g., automotive, clothing, home furnishing). Factors such as end use, current trends, and availability influence the type, color, and frequency of fibers incorporated into textiles.

5.3 Fibers exhibit a wide range of physical characteristics, including color, optical properties, spectral properties, and chemical compositions due to the manufacturing process, end use, and exposure to post-manufacturing changes (e.g. exposure to various environmental conditions, chemicals, etc.). These characteristics and properties are observed, analyzed, and compared during a fiber examination.

6. Case Assessment

6.1 In the case assessment phase, the examiner determines what samples are to be analyzed. Sample size, sample variability, sample condition, environmental effects, evidential value (e.g. are the persons of interest known to have contact prior to incident), and collection and packaging techniques are all taken into account. The examiner chooses analytical techniques, sample preparation schemes, testing sequences, and degree of sample alteration and consumption that are suitable to the specific case.

6.2 Fiber examination involves the observation and interpretation of data, therefore opportunities for bias exist (1-3). Measures to address the effects of potential bias can include:

6.2.1 Receiving adequate training to conduct fiber examinations (refer to WK78748 Practice for a Forensic Fiber Training Program), including cognitive bias and methods that can mitigate or help avoid the effects of biasing information and procedures.

6.2.2 Avoiding task-irrelevant information (e.g., suspect's confession or investigator's opinions).

6.2.3 As practicable, evaluating questioned fibers prior to known fiber samples during the examination process.

6.2.4 Employing a quality assurance program that complies with International Standards such as ISO 17025.

6.2.5 Conducting verification and technical review.

7. Evidence Handling

7.1 Follow the general requirements set forth in Practice E1492 and Guide E1459 if handling and tracking evidence.

7.2 Each laboratory develops appropriate procedures concerning sample size, collection, packaging, preservation, and order of examinations in order to prevent contamination and loss of fibers (4, 5).

7.2.1 Collect evidentiary items as soon as possible to mitigate the loss of fibers and other types of trace evidence.

7.2.2 Handling or transport can alter the location of a transferred fiber on a particular item of evidence (6).

7.3 Multiple kinds of evidence requiring the expertise of different disciplines can be present on a single item. This can include various types of trace materials (e.g., hairs, fibers, paint, glass, explosives), as well as fingerprints and DNA. Prior to processing an item, consider the types of evidence potentially present and the impact that fiber examinations can have on future analyses. Examiners from different sub-disciplines may confer before work is undertaken to ensure proper examination order and recovery of evidence. Unless circumstances dictate otherwise, the trace materials are collected and preserved prior to other examinations (4, 5).

7.4 Samples are collected in a manner consistent with generally-recognized and accepted sampling techniques.

8. Types of Examinations

8.1 During a fiber examination, two basic types of analysis are conducted. These analyses include fiber-type identification and fiber comparison (7-9).

8.2 Fiber-type identifications are performed to provide investigative leads and possible end-use information. The Federal Trade Commission has defined classifications to include manufactured fiber definitions (Table 1), and fibers are analyzed to determine to which generic class (e.g., cotton, polyester) they belong (10). This examination relies on analytical techniques to place the questioned fiber into a generic class. There are two broad categories of classification: natural fibers and manufactured fibers. Each can be further broken down into sub-classifications.

8.2.1 Natural fibers are obtained from plants, animals, or mineral materials.

8.2.2 Manufactured fibers can be further described as regenerated, synthetic, or mineral based on the starting materials used to form the fibers.

8.3 Fiber comparisons are conducted to determine if a questioned fiber exhibits the same physical characteristics, including color, optical properties, spectral properties, and chemical composition as fiber(s) comprising part or all of a known sample to assess whether the known sample can or cannot be included as a possible source. The same process can also be used to compare two or more questioned fibers in order to determine if they could share a common source.

8.4 The fiber types found at a crime scene or on a person of interest affects their evidential value.

8.4.1 Certain types of fibers, such as colorless cotton and indigo-dyed blue cotton (denim), are so common as to be of limited evidential value, except in rare cases (e.g., colorless cotton fibers embedded or fused on to a deployed airbag or a scrap of blue denim fabric caught on the undercarriage of a vehicle suspected to be involved in a hit-and-run).

9. Procedure

9.1 Select sample(s) representative of the observed variation (e.g., color, texture, luster) within a textile to serve as a known reference of the material. Differences could arise in measurements of fiber samples from the same garment or textile because of differences in weathering (e.g., sunlight exposure), spot staining/bleaching, or repaired areas (e.g., use of a fabric marker to cover a discolored area, application of a patch).

9.2 Techniques for the identification and comparison of fibers (13-18) are found in Table 2 (shaded boxes represent techniques which are highly recommended) and are presented in no particular order. Some techniques allow greater discrimination between apparently similar samples than others (19-27). The particular technique(s) employed by each examiner or laboratory will depend upon available equipment and the nature and extent of the fiber evidence in each specific case.

9.3 For any given fiber identification and comparison, not all the techniques listed in Table 2 are necessary. Fiber type, sample size, and condition should be considered if determining which techniques to use. Those requiring more sample preparation or consumption should be performed after less-destructive techniques. If sample size is limited, nondestructive techniques are exhausted before subjecting the sample to tests which could permanently alter or destroy the sample [e.g., Fourier-transform infrared (FTIR) spectroscopy, pyrolysis]. If an exclusionary difference is found at any point during the fiber comparison process, then no further analysis is necessary.

9.4 The analytical tests performed are left to the discretion of the examiner; however, at a minimum, a fiber examiner employs a stereomicroscope, light microscope, and a polarized light microscope for identification. In addition, the fiber examiner uses a comparison microscope and at least one other color comparison technique if performing fiber comparisons.

9.4.1 Using the comparison microscope, an examiner views fibers side-by-side at the same magnifications in visible light, and by alternative lighting, such as polarized light or fluorescence, if the equipment allows. For color comparison, an examiner employs at least one analytical test [e.g., microspectrophotometry (MSP), thin layer chromatography (TLC)] along with comparison microscopy. Fourier-transform infrared spectroscopy (or another technique which provides comparable chemical information) is strongly recommended for the characterization of manufactured fibers.

9.4.2 A typical fiber examination workflow is shown in Figure 1. This figure represents one of several possible workflows used to identify and compare fibers and does not preclude the use of other workflows to perform fiber examinations. General descriptions of techniques employed during a fiber examination are listed in sections 9.5 through 9.8 to provide additional guidance for the selection of appropriate techniques.

9.5 *Microscopical Examinations*

9.5.1 Microscopical examinations provide information about the physical and optical properties of a fiber, allowing for the determination of general fiber type and the differentiation of fiber samples.

9.5.1.1 Low-magnification stereomicroscopy is used for the search, recognition, manipulation, and collection of apparent textile fibers. This technique also offers a limited characterization of the fiber's physical characteristics.

9.5.1.2 High-magnification light microscopy is employed to characterize the fiber's physical and microscopic characteristics (e.g., color, diameter, cross-sectional shape, pigment, voids, inclusions).

9.5.1.3 Comparison microscopy allows the examiner to view two fiber samples side-by-side while employing the same magnification and lighting conditions. Comparison using polarized light or fluorescence is performed if the equipment allows.

9.5.1.4 Polarized light microscopy (PLM), an essential part of the fiber examination process, is used to observe and measure the optical properties of a fiber. These properties are imparted during the manufacturing process and are used to determine the general fiber type (e.g., acrylic, nylon, polyester).

9.5.1.5 Fluorescence microscopy is a technique used to observe the optical properties of the fiber itself as well as those imparted to the fiber by various dyes, optical brighteners, chemical treatment/damage or contaminants.

9.5.2 Strengths of microscopical examination techniques include:

- Highly discriminating and reliable
- Generally non-destructive
- Rapid
- Requires minimal sample preparation

9.5.3 Limitations of microscopical examination techniques include:

- Physical and optical properties of fibers can be impacted by sample handling, physical damage or environmental factors
- Very dark fibers can impede the ability of these techniques to resolve physical and optical properties of fiber samples
- Potential for quenching of fiber samples when performing fluorescence microscopy

9.5.4 For more detailed information regarding microscopical examination of fibers, refer to ASTM E2228 Guide for Microscopical Examination of Textile Fibers.

9.6 Color Examinations

9.6.1 Color is highly variable among textiles. Dyes and pigments belong to numerous chemical categories with more than a dozen different application techniques (28, 29). Color is a highly discriminating characteristic due to the variety of dye productions, batch variations, and the multitude of colors available. Individual fibers can be colored before being spun into yarn, yarns can be dyed after being spun, or the fabric can be dyed after its construction as a fabric or garment (28-31). Color can also be applied to the surface of a fabric by printing. The absorption of the dye along the fiber length can vary based on the dyes, dyeing processes used, and the fiber type.

9.6.2 For color comparison, an examiner employs comparison microscopy along with another analytical technique, such as MSP or TLC. If another analytical technique is not performed, the reason is documented.

9.6.3 Microspectrophotometry is an instrumental technique that provides color measurement data for fibers using transmitted light. During fiber examinations, the absorption of visible light is measured and compared. If samples are compared and no differences are detected in the visible region, they can be further analyzed in the UV and NIR region using MSP. For more detailed information regarding MSP, refer to ASTM WK78749 Guide for Microspectrophotometry in Forensic Fiber Analysis.

9.6.3.1 Strengths of this technique:

- Provides objective color measurement data

- Generally considered to be non-destructive (note potential for photobleaching below)

9.6.3.2 Limitations of this technique include:

- Absorption can be impacted by environmental factors, sample handling or physical damage
- Very dark or very light fibers may display data of limited value in the visible region
- Certain fiber types naturally absorb in the UV region (e.g., wool, polyester), limiting data collection and interpretation
- Individual dye components may not be differentiated
- Photobleaching of fiber samples may occur

9.6.4 Thin layer chromatography is a dye analysis technique requiring the extraction of dye from the colored fiber. Different dye mixtures can produce similarly-colored fibers that may be difficult to distinguish by optical techniques such as MSP. By first extracting the dye and then separating the individual dye components, TLC provides complementary information to further discriminate between fiber colorants. For more detailed information regarding TLC, refer to ASTM E2227 Guide for Forensic Examination of Non-Reactive Dyes in Textile Fibers by Thin-Layer Chromatography.

9.6.4.1 Strengths of this technique include:

- Simple dye analysis technique
- Provides complementary information to MSP

9.6.4.2 Limitations of this technique include

- Destructive
- Limited by the small amount of dye present in a single fiber

9.7 Fourier-Transform Infrared Spectroscopy

9.7.1 Fourier-transform infrared spectroscopy is an instrumental technique that employs the use of infrared radiation to obtain information about the chemical structure of fibers in order to determine the fiber-type (e.g., nylon, polyester), sub-type (e.g., identification of acrylic fiber co-polymers), and inorganic fillers (if present). FTIR spectroscopy is typically employed following microscopical and color examination due to potential alteration of fiber morphology. For more detailed information regarding FTIR spectroscopy, refer to ASTM E2224 Guide for the Forensic Analysis of Fibers by Infrared Spectroscopy.

9.7.2 Strengths of this technique:

- Provides chemical structure and fiber-type information
- Requires minimal sample preparation

9.7.3 Limitations of this technique include:

- Sample preparation can alter the physical characteristics of the analyzed portion of the fiber
- The presence of surface contaminants can interfere with spectral interpretation

9.8 Additional techniques

9.8.1 Capillary Electrophoresis (CE) is a chromatographic technique used to analyze very small amounts of dye from colored fibers (32).

9.8.1.1 Strengths of this technique include:

- Provides complementary information to MSP
- More efficient than TLC

9.8.1.2 Limitation of this technique:

- Destructive

9.8.2 Pyrolysis (Py) is an instrumental technique in which fibers are thermally decomposed, followed by analysis using either gas chromatography (Py-GC), mass spectrometry (Py-MS) or a combination of both (Py-GC-MS) to identify the fiber-type and sub-type (33).

9.8.2.1 Strength of this technique:

- Provides fiber-type and sub-type information

9.8.2.2 Limitation of this technique:

- Destructive

9.8.3 Raman spectroscopy is an instrumental technique that uses a monochromatic source (i.e., a laser emitting a wavelength in the ultraviolet, visible or near-infrared spectral range) to produce an inelastic light scattering effect which provides information primarily about fiber dyes, pigments, and the polymer, delustrants, and fillers (34).

9.8.3.1 Strengths of this technique include:

- Provides complementary information to FTIR
- Requires minimal sample preparation

9.8.3.2 Limitation of this technique:

- Analysis can be hindered by background fluorescence or thermal degradation of the sample

9.8.4 High performance liquid chromatography (HPLC) is a chromatographic technique used to analyze dyes extracted from short lengths of colored fibers. High performance liquid chromatography employs a micro-extraction process that is effective for a wide range of fiber types, dye types, and dye mixtures (35).

9.8.4.1 Strengths of this technique include:

- Provides quantitative data
- Offers better resolution of dyes than TLC
- Effective for a wide range of fiber types, dye types and dye mixtures
- Provides complementary information to further discriminate between fiber colorants

9.8.4.2 Limitations of this technique include:

- Destructive
- Separation of various dye types on a single chromatographic system can be difficult

9.8.5 Elemental analysis techniques such as scanning electron microscopy/energy dispersive X-ray spectroscopy (SEM-EDX) and X-ray fluorescence (XRF) can provide information about the elemental composition of fibers (36).

9.8.5.1 Strengths of these techniques include:

- Provide information about inorganic components imparted to a fiber through the manufacturing process, additives/finishing agents, and environmental contaminants
- SEM-EDX and XRF are complementary techniques; however, XRF is more sensitive to higher atomic weight elements

9.8.5.2 Limitations of these techniques include that:

- X-ray production for SEM-EDX is dependent on beam energy, composition and density of the sample, and energy of the X-rays
- Sample preparation (if carbon coated and placed on carbon-taped stub) can hinder analysis of samples afterward
- XRF is less sensitive to lower atomic weight elements

9.8.6 Techniques such as cross-sectioning, melting point and solubility can be used to obtain information about the physical characteristics and chemical properties of a manufactured fiber (37, 38). It is important to consider the sequence of analysis when incorporating these destructive techniques into a fiber examination.

9.8.6.1 Strength of these techniques:

- Provide information about a manufactured fiber's physical and chemical properties

9.8.6.2 Limitation of these techniques:

- Destructive

9.8.7 Additional techniques specific to natural fibers include the drying twist test, ashing, and staining. Cross-sectioning can also be used to obtain additional information about a natural fiber’s cross-sectional shape and type. As with previously-mentioned techniques, consideration is given to the amount of sample available, and the destructive nature of the techniques employed.

10. Results

10.1 In a fiber case, the examiner analyzes the evidence, interprets the data and observations, and reports an opinion of the findings.

10.2 The comparative analysis of two or more fibers involves the evaluation of physical characteristics, including color, optical properties, spectral properties, and chemical composition.

10.2.1 If one or more exclusionary differences are recognized between compared fibers based on the measured or observed characteristics, the fibers are distinguishable. In fiber comparisons, this is described as an exclusion or elimination: two or more fibers are excluded as having originated from the same source based on the sample provided (39).

10.2.2 If no exclusionary differences are recognized between compared fibers based on the measured or observed characteristics, the fibers cannot be distinguished by these techniques. In fiber comparisons, this is described as an association of evidence based on class characteristics, indicating the possibility that the fibers originated from the same source. Since different fiber sources can share class characteristics, this opinion does not indicate that the fibers came from a specific source.

10.3 Refer to the Standard Guide for Interpretation and Reporting in Forensic Comparisons of Trace Materials.

11. Evaluation of the Results

11.1 When a specific item, such as fabric from a person of interest or a crime scene, is included as a possible source of a questioned fiber, or if two or more questioned fibers could share a common source, the evidential value is dependent upon many factors.

11.1.1 Source factors

11.1.1.1 Fiber type.

11.1.1.2 Intra-source variability (e.g. trunk liner, patchwork garment).

11.1.1.3 Fiber characteristics.

11.1.1.4 Condition of a specific source (e.g., shirt recovered from a hit-and-run victim exhibiting damage).

11.1.1.5 Presence of contaminants, damage, or other acquired characteristics (e.g., the questioned fiber exhibits characteristics of heat exposure and the victim clothing is burned or singed).

11.1.2 Activity or case-related factors (e.g., transfer and persistence [6, 40-47], efficiency of recovery [4,5])

11.1.2.1 Location, quantity, and acquired characteristics of the recovered fibers (e.g., fibers embedded in a deployed airbag, fibers embedded in blood on a weapon).

11.1.2.2 Number and types of fibers associated to single or multiple sources (e.g., multiple black polyester fibers associated to a shirt, multiple blue cotton fibers and multiple blue polyester fibers associated to a single shirt, apparent cross transfer of fibers between two shirts).

Note 1: As the number of associated questioned fibers increases, so too does the support for recent and direct contact occurring with the known fiber source. The converse is not necessarily true, however, and even one fiber association can have evidential value. Finding no fiber associations does not necessarily mean that no contact occurred.

11.1.2.3 Nature of contact.

Note 2: The type of physical contact between two sources can influence the number of fibers transferred and the value placed on their discovery. Brief contact is less likely to transfer multiple fibers than extended and more forceful contact.

11.1.2.4 Composition, construction and condition of a textile.

Note 3: Tightly-woven or tightly-knit fabrics shed fewer fibers than loosely-knit or loosely-woven fabrics. Likewise, fabrics composed of filament fibers shed less than fabrics composed of staple fibers. Newer fabrics can have an abundance of loosely-adhering fibers on the surface of the fabric, while worn fabrics can have damaged areas that easily shed fibers. Damage to a fabric caused during physical contact can greatly increase the potential of fiber transfer.

11.1.2.5 Environmental factors (e.g., fading, discoloration, singeing).

11.2 The ability to discriminate between similar types and colors of recovered fibers is important when assessing the significance of an association (19, 20, 23, 24).

11.3 If information about the relevant fiber population is available (e.g., published discrimination studies, product manufacturing and distribution information), the significance of the features recorded during the examination can be evaluated (48, 49).

11.4 The analytical scheme an examiner employs directly impacts the ability to discriminate between fibers and, ultimately, the significance of findings. If an analytical scheme is not inclusive of the assessment of the physical characteristics, including color, optical properties, spectral properties, and chemical composition when applicable, then a qualifying statement is necessary.

11.5 Background information regarding the potential sources involved, possible prior contact, and the environment where questioned fibers were recovered affects the significance of the association. When practicable, and as laboratory practices allow, avoid task-irrelevant information (50, 51).

12. Documentation

12.1 Contemporaneously record all observations made during case assessment and examination. Ensure the examination notes accurately reflect all observations, the evidence analyzed, the techniques employed, and all results. Notes should be sufficient to allow an independent analyst to understand and evaluate all the work performed, analyze and interpret the data, and reach independent opinions.

12.2 Case notes include acquired instrumental data that was used to reach a finding.

12.3 Verifications and technical reviews are performed and documented as per laboratory standard operating procedures and quality assurance guidelines.

12.4 Reports are written in accordance with ASTM standards (E620) and include the results of the analysis, an interpretation of the results, and qualifying statements that further describe the strengths and limitations of the analysis.

12.5 All documentation conforms to accreditation guidelines as appropriate (e.g., ISO/IEC 17025 [4, 52]), as well as the laboratory's standard operating procedures and quality assurance guidelines.

13. Keywords

Forensic science, fiber, fiber comparison, instrumental analysis.

Table 1 Federal Trade Commission Rules and Regulations Under the Textile Products Identification Act, 16 CFT Part 303 Pursuant to the provisions of Section 7 of the Act, the following generic names for manufactured fibers, together with their respective definitions, are hereby established (10):

Fiber Name	Definition
Acetate	A manufactured fiber in which the fiber-forming substance is cellulose acetate. Where not less than 92% of the hydroxyl groups are acetylated, the term triacetate may be used as a generic description of the fiber.
Acrylic	A manufactured fiber in which the fiber-forming substance is any long chain synthetic polymer composed of at least 85% by weight of acrylonitrile units.
Anidex	A manufactured fiber in which the fiber-forming substance is any long chain synthetic polymer composed of at least 50% by weight of one or more esters of a monohydric alcohol and acrylic acid.
Aramid	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings.
Azlon	A manufactured fiber in which the fiber-forming substance is composed of any regenerated naturally occurring proteins.
Elastoester	A manufactured fiber in which the fiber-forming substance is a long chain synthetic polymer composed of at least 50% by weight of aliphatic polyether and at least 35% by weight of polyester, as defined in 303.7(c).
Fluoropolymer	A manufactured fiber containing at least 95% of a long chain polymer synthesized from aliphatic fluorocarbon monomers.
Glass	A manufactured fiber in which the fiber-forming substance is glass.
Lyocel	A manufactured fiber composed of precipitated cellulose and produced by a solvent extrusion process where no chemical intermediates are formed.
Melamine	A manufactured fiber in which the fiber-forming substance is a synthetic polymer composed of at least 50% by weight of a cross-linked melamine polymer.
Metallic	A manufactured fiber composed of metal, plastic-coated metal, metal-coated plastic, or a core completely covered by metal.
Modacrylic	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of less than 85% but at least 35% by weight of acrylonitrile units.
Nylon	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polyamide in which less than 85% of the amide linkages are attached directly to two aromatic rings.

Nytril	A manufactured fiber containing at least 85% of a long chain polymer of vinylidene dinitrile where the vinylidene dinitrile content is no less than every other unit in the polymer chain.
Novoloid	A manufactured fiber containing at least 85% by weight of a cross-linked novolac.
Olefin	A manufactured fiber in which the fiber-forming substance is any long chain synthetic polymer composed of at least 85% by weight of ethylene, propylene, or other olefin units.
PBI	A manufactured fiber in which the fiber-forming substance is a long chain aromatic polymer having reoccurring imidazole groups as an integral part of the polymer chain.
PLA	A manufactured fiber in which the fiber-forming substance is composed of at least 85% by weight of lactic acid ester units derived from naturally occurring sugars.
Polyester	A manufactured fiber in which the fiber-forming substance is any long chain synthetic polymer composed of at least 85% by weight of an ester of a substituted aromatic carboxylic acid, including but not restricted to substituted terephthalate units and para substituted hydroxy-benzoate units. Where the fiber formed by the interaction of two or more chemically distinct polymers (of which none exceeds 85% by weight), and contains ester groups as the dominant functional unit (at least 85% by weight of the total polymer content of the fiber), and which, if stretched at least 100%, durably and rapidly reverts substantially to its unstretched length when the tension is removed, the term elasterell-p may be used as a generic description of the fiber.
Rayon	A manufactured fiber composed of regenerated cellulose, as well as manufactured fibers composed of regenerated cellulose in which substituents have replaced not more than 15% of the hydrogens of the hydroxyl groups. Where the fiber is composed of cellulose precipitated from an organic solution in which no substitution of the hydroxyl groups takes place and no chemical intermediates are formed, the term lyocell may be used as a generic description of the fiber.
Rubber	A manufactured fiber in which the fiber-forming substance is comprised of a natural or synthetic rubber, including the following categories: (1) A manufactured fiber in which the fiber-forming substance is a hydrocarbon such as natural rubber, polyisoprene, polybutadiene, copolymers of dienes and hydrocarbons, or amorphous (noncrystalline) polyolefins. (2) A manufactured fiber in which the fiber-forming substance is a copolymer of acrylonitrile and a diene (such as butadiene) composed of not more than 50% but at least 10% by weight of acrylonitrile units. The term lastrile may be used as a generic description for fibers falling within this category. (3) A manufactured fiber in which the fiber-forming substance is a polychloroprene or a copolymer of chloroprene in which at least 35% by weight of the fiber-forming substance is composed of chloroprene units.
Saran	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 80% by weight of vinylidene chloride units.
Spandex	A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85% of a segmented polyurethane.
Sulfar	A manufactured fiber in which the fiber-forming substance is a long chain synthetic polysulfide in which at least 85% of the sulfide linkages are attached directly to two aromatic rings.

Vinal	A manufactured fiber in which the fiber-forming substance is any long chain synthetic polymer composed of at least 50% by weight of vinyl alcohol units and in which the total of the vinyl alcohol units and any one or more of the various acetal units is at least 85% by weight of the fiber.
Vinyon	A manufactured fiber in which the fiber-forming substance is any long chain synthetic polymer composed of at least 85% by weight of vinyl chloride units.

Table 2 **Techniques for the identification and comparison of fibers. Shaded boxes represent techniques which are highly recommended.**

Physical Characterization	Optical Properties	Microchemical Analysis	Color/Dye/Pigment Analysis	Instrumental Analysis
Stereomicroscopy	PLM	Solubility	Comparison Microscopy	FTIR (Manufactured Fibers)
Light Microscopy/ Comparison Microscopy	Light Microscopy/ Comparison Microscopy	Staining (Natural Fibers)	MSP, TLC or a combination of both	SEM-EDX/XRF
SEM	Fluorescence Microscopy		CE	PyGC/PyGCMS
Melting Point			Raman	Raman
Physical Test (Dry Twist, Ashing, etc.)			HPLC	

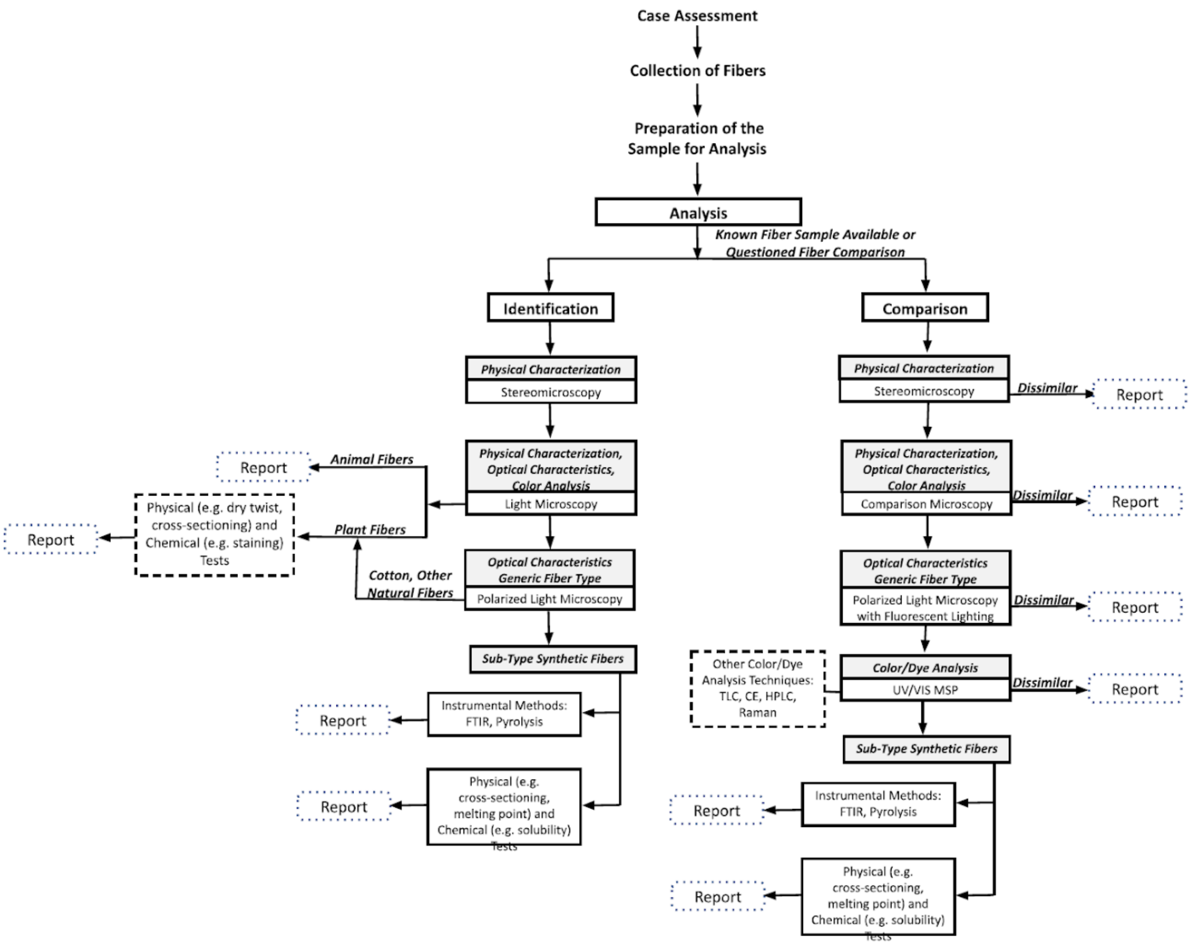

Figure 1. Visual representation of a typical workflow used to identify and compare fibers. This does not preclude the use of other workflows to perform forensic fiber examinations.

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