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A Fiber Data Collection for Forensic Scientists—Collection and Examination Methods

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ABSTRACT: Methods used in U.K. forensic science laboratories to establish a large fiber data base are described including details of the recording of fiber sources, types, and colors. Such a data base provides a firm foundation for the assessment of the significance of fiber matches encountered in casework.

KEYWORDS: forensic science, fibers, matching, colors (materials)

The forensic scientist is often called on to investigate a possible connection between a suspect and a victim based on the transfer of textile fibers between them. Several techniques are available to compare single fibers, including various forms of microscopy [*1*] and infrared spectroscopy using micro lead disks [*2*] or the high pressure diamond cell.[4] Thin-layer chromatography of dyes from wool [*3*], synthetic [*4*], and cellulosic[5] fibers, as well as microspectrophotometry [*5*], may be used to compare colorants. While such techniques may show two fibers to be indistinguishable, the problem for the scientist is to establish the significance of the match. As an example, indigo dyed cotton in blue denim jeans is very common and matching fibers of this type are of low evidential value. Alternatively, regenerated protein fibers are very rare and transfer of such fibers would be extremely significant. Assessment of the significance of a match therefore depends on reliable knowledge of the frequency with which specific fiber types occur.

To obtain this information, several different lines may be followed. Where the source garment is labelled, the manufacturer can be contacted and production figures obtained. However, apart from unlabelled, untraceable garments, the possibility exists that other clothing may contain identical fibers unbeknown to a specific manufacturer or distributor. On the other hand, differences may exist between fibers used in garments produced in quantity that go unrecognized by their manufacturer.

An alternative method for obtaining frequency information is to examine the constituent fibers of numerous garments [*6*]. Such information is not available from commercial organi-

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[4]D. K. Laing and R. J. Dudley, unpublished results.

[5]J. M. Home and R. J. Dudley, personal communication.

zations: specialist textile market research information does exist,[6] but this satisfies the needs of the industry and is of limited use to the forensic scientist. Because of these problems, the U.K. Home Office Forensic Science Service made proposals for its own collection of data on fibers.

It was proposed that U.K. forensic science laboratories would collect fiber samples from clothing and textile materials submitted for examination. This would enable information such as fiber type, thickness, and cross-sectional shape to be recorded together with the major evidential feature, fiber color. The color was to be recorded using a microspectrophotometer which allows the spectra of single fibers to be measured accurately and objective numerical descriptions of color stored [7].

This paper describes the system adopted for the collection of fiber samples, the details recorded, and the procedures used to ensure objective assessment of information.

Collection of Fiber Data

Collection of Fiber Samples

Over a period of three years, scientists in U.K. forensic science laboratories have sampled fibers from casework articles, mainly from cases involving crimes of violence. The selection of articles has been random; every fifth case was chosen and representative samples removed from each fibrous item present. With the exception of sewing threads and interlinings, all constituent fibers were sampled. All samples were transferred to individual self-sealing polythene bags and a portion mounted on microscope slides using XAM neutral medium. Different types and colors of yarns present in a sample were mounted on separate slides.

It is difficult to be sure that fibers from casework garments are truly representative of those in the general fiber population. However, given the types of cases sampled and the inclusion of garments from both accused and victim, it is likely that the fibers in the collection are as representative as can practically be surveyed.

The Fiber Questionnaire

Figure 1 shows the questionnaire used for the collection of data. The information recorded is of three types:

(1) general details about the case from which the sample originated (Section 1),
(2) information about the garment or fiber source (Sections 2, 3, 4, 10, and 11), and
(3) a description of the fibers present in the item under study (Sections 5 to 9).

For each type of fiber, or for different parts of a garment, a separate questionnaire is completed. Color information is treated separately.

The General Case Details—Recorded in this section are the source laboratory, the case, exhibit and slide numbers, and the date of the alleged offence. This information allows easy identification and retrieval of the samples. In addition, knowledge of the laboratory and date of offence may enable regional and seasonal variations to be recognized.

Information About the Garment or Fiber Source—Six classes of information are recorded that relate to the garment. These are the garment type, the part of the garment, the sex of the wearer, the type of fiber mixture present, the sheddability, and the brand name of the garment.

Garments are assigned to one of the classes shown on the questionnaire. It is surprisingly difficult to classify garments into types unambiguously so the classes have been summarily defined. For example, topcoats are defined as outer garments longer than hip length, such

[6]Textile Market Studies, London, personal communication.

FIBRE QUESTIONNAIRE

1. GENERAL SECTION

A. Laboratory

Aldermaston	HC	Belfast	BF
Birmingham	WM	Chepstow	WW
Chorley	NW	CRE	CR
Huntingdon	EM	MPL	ML
Strathclyde	GL	Wetherby	NN

B. Case Number [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]

C. Exhibit Number [ ][ ][ ][ ][ ]

D. Slide Number(s) [ ] [ ] [ ] [ ] [ ]

E. Date of Offence [ ][ ]/[ ][ ]/[ ][ ]

2. SOURCE OF FIBRE

A. Garment Type

Topcoat	01	Tights	10
Jacket	02	Glove	11
Trousers	03	Hat	12
Shirt	04	Carpet-Car	13
Jumper	05	Carpet-house	14
Dress	06	S.Furnishing	15
Underwear	07	Bedding	16
Neckwear	08	Rope	17
Sock	09	Other	18

If "other", specify source: [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]

B. Part of Garment

Lining	01	Outer fabric	02
Trim	03		

3. SEX OF WEARER

Male [M] Female [F]
Unknown/Not Applicable [U]

4. FIBRE MIXTURES

Shoddy	S	Complex mix	C
Print	P	Not S,C, or P	N
Can't decide/Don't know			U

5. FIBRE TYPE

Wool	01	Cotton	08
Animal	02	Vegetable	09
Viscose	03	Acetate	10
Triacetate	04	Polyamide	11
Polyester	05	Acrylic	12
Modacrylic	06	Polyolefin	13
Other	07		

If "other" or "animal" specify type: [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]

6. SUBDIVISION OF FIBRE TYPE

A. Vegetable fibres

Corchorus (Jute)	01	Agave (Sisal)	04
Cannabis (Hemp)	02	Musa (Manila)	05
Cocos (Coir)	03	Linum (Flax)	06
Unknown/Not Determined			07

B. Polyamides

Nylon 6	01	Nylon 6 6	04
Nylon 6 10	02	Nylon 11	05
Qiana	03	Aromatic	06
Unknown/Not Determined			07

C. Acrylics

Type 1	01	Type 5	05
Type 2	02	Type 6	06
Type 3	03	Type 7	07
Type 4	04	Type 8	08
Unknown/Not Determined			09

D. Polyolefins

Polyethylene	01	Polypropylene	02
Other Olefins and Mixtures			03
Unknown/Not Determined			04

7. CROSS-SECTIONAL SHAPE

Round	01	Bean etc.	04
Flat	02	R.Multilobal	05
Irregular	03	Other shapes	06
Unknown/Not Determined			07

If "Regular Multilobal", give number of lobes (3–9 only): [ ]

8. DELUSTRANT

Present [P] Absent [A]

9. FIBRE DIAMETER

Maximum [ ][ ][ ] microns
Minimum [ ][ ] microns

10. SHEDDABILITY

High [H] Medium [M]
Low [L]
Attach Sheddability Tape Here:

11. BRAND NAME

Insert Brand Name: [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]

NOTES:

Completed by ____________ Date ______
Checked by ______________ Date ______

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FIG. 1—*The fiber questionnaire.*

as raincoats and overcoats. Items not categorized are recorded as "other" and specified in the space provided.

The part of the garment from which the sample originated is classified as either "lining," "trim," or "outer fabric." This division is designed to specify fiber sources more accurately. For example, the synthetic fur trim on many topcoats contains modacrylic fibers, yet these form a small proportion of the fibers used in topcoats as a whole. By specifying the part of the garment from which these fibers originated, a true picture of their use emerges.

The sex of the garment wearer is recorded as "male," "female," or "unknown/not applicable." The latter is used with items such as carpets and bedding which are not articles of dress.

The type of fiber mixture in the garment is recorded mainly as a guide for later color measurement, the categories being shown on the questionnaire. Garments made from random mixtures of different fiber types or colors are defined as "shoddy." In this category, no information on fiber type and color can be recorded as individual fibers are unrepresentative of the garment as a whole. "Complex mixtures" are those which contain many different fiber types or colors but, unlike shoddy, in a definite, though complicated, mix. They are separately identified as special care is required to obtain a representative mounted sample. Printed fabrics are classified separately as colors may be produced by overprinting; special care is then required to select uniformly colored fibers for measurement.

Sheddability is assessed using high tack adhesive tape. A piece is smoothed onto the relevant part of the item and the garment classified according to the number of constituent fibers adhering to the tape.

Brand names present on garment labels are recorded on the questionnaire as they may be useful in deducing the type of clothing worn by an unknown assailant from fibers transferred to a victim. In addition, information on specific manufacturers may be obtained.

The Description of the Fibers Present in the Item—Apart from their color, up to five categories of information are recorded about constituent fibers. These are fiber type and subtype, cross-sectional shape, the presence or absence of delustrant, and fiber thickness.

The different fiber types are distinguished mainly by microscopy. However, modacrylic and acrylic fibers can be confused, so infrared spectroscopy and scanning electron microscopy/microprobe analysis[7] are recommended for discrimination. Fiber types not specified are recorded as "other" and detailed on the questionnaire. Animal species are also recorded in this section.

The vegetable, polyamide, acrylic, and polyolefin classes are further subdivided on the questionnaire according to either species (vegetable fibers), monomer composition (polyamide and polyolefin fibers), or dye receptive additive (acrylic fibers). For vegetable fibers, the division is made on the basis of microscopic examination of the whole mount and cross section [*1*]. Subdivision of polyamides, acrylics, and polyolefins is made by infrared spectroscopy.[7] This has the advantage that it also confirms the identification of generic class. However, the use of melting point determination [*8*] is acceptable to identify polyamide and polyolefin types [*1*].

For all synthetic fibers, the cross-sectional shape and presence or absence of delustrant is recorded. The cross-sectional shape is normally determined by microscopic inspection of the whole mount. However, in case of doubt, a cross section is required using a method such as the plate system [*1*]. Assignment to specific categories is made with the aid of photomicrographs of whole mounts and sections prepared using authentic specimens. The description of delustrant is limited to just two categories as no simple method could be devised for grading delustrant levels in individual fibers. For the purposes of this collection, where pigment grains were present as a result of mass coloration, the fibers were considered delustred.

For all synthetic, wool, and animal fibers (but not cotton or vegetable fibers), a measure of fiber thickness is required. The method adopted was to select randomly, in the whole mount, ten fibers of the type required and then to measure their thicknesses with a calibrated eyepiece graticule. From these ten readings, the maximum and minimum values were abstracted and recorded.

Measurement of the Color of Single Fibers

The instrumentation used for the color coding of single fibers and the derivation of a suitable color notation have been described [*7*]. Briefly, the NanoSpec 10S microspectrophotom-

[7]D. K. Laing and J. M. Home, unpublished results.

eter is used to obtain visible spectra from individual fibers in a sample. From such spectra, numerical color values based on the CIE (Commission Internationale de l'Eclairage) system of color notation can be derived. By interfacing the microspectrophotometer to a PET microcomputer system through an analogue to digital converter, the color calculations are performed without intervention by the operator.

Measurement of Fiber Colors—Organization and Hardware—The measurement of fiber colors is performed by a contractor using the microspectrophotometer and computer facilities previously described together with a set of computer programs and suitable calibrants. On each questionnaire, a list is made of all the different fiber colors present. Instructions for measurement are placed alongside these color designations; black and colorless fibers are not measured. (In this context, a black fiber is one that is so optically dense that no color is discernible. Conversely, a colorless fiber has no recognizable color under the microscope, even though the cloth itself may be colored.) The annotated questionnaires and mounted samples are forwarded to the contractor for color measurement.

Measurement of Fiber Colors—Methodology and Data Storage—A single computer program is used by the contractor to measure fiber color and handle data storage. In operation, the program first requests the transcription of data from the questionnaire and checks it for consistency. Next, the absorbance spectrum of a calibrant, which consists of a small, thin, tabular piece of colored glass mounted on a slide, is measured. This spectrum is compared with standard values held within the program and correction factors calculated. All subsequent spectra are corrected according to these factors. Replicate determinations of the spectra of fibers are then obtained to enable variation within the sample to be assessed. Wool, cotton, animal, and vegetable fibers require ten determinations, all other fiber types only five. Fewer replicates are undertaken for synthetic fibers as spectra are, in general, very reproducible. The fibers measured are selected at random. After each spectrum is obtained, color values are calculated automatically within the program. When the required number of determinations has been completed, a routine within the program checks the color values for consistency, any deviant values being redetermined. On completion, all the information is stored on floppy disks. The information on these disks is transferred to a Prime 550 computer for incorporation into the data collection and its associated search routines.

General Discussion

All the information recorded can be measured objectively. It might be thought that other attributes used regularly in comparing casework fibers such as the fluorescence colors of fibers when illuminated with blue, violet, or ultraviolet light could be included in this data collection. Although this would seem a simple matter, the objective assessment of fluorescence colors is very difficult. Just as visible colors are impossible to code with certainty without a microspectrophotometer, so fluorescence colors require a similar objective method. Information from techniques such as thin-layer chromatography could also be included in the data base if spot colors and positions could be standardized and quantified.

Storage of color information as complementary chromaticity coordinates rather than as visible spectra is preferred, as there is a considerable saving in computer memory and search time. While spectra provide more information on the appearance of colored fibers than color codes, this is offset by the practical considerations of storing and searching a large data base.

Suitable programming has been implemented so that information about the frequency of occurrence of any combination of fiber characteristics can be obtained. The fiber data base, which currently stands at 10 000 fibers, is now accessible on-line to caseworkers.

Acknowledgments

The collection of data on fibers followed discussions within the Inter Laboratory Advisory Committee (Fibres) of the U.K. Home Office Forensic Science Service and much of the methodology arose as a result of these deliberations. Fiber samples are collected by opera-

tional forensic science laboratories within the United Kingdom and without their cooperation the compilation of a fiber data base would have been impossible.

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