Scene of Crime Evidence
FIBRES
A Review: 1998 to 2001

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This report presents advances in the forensic examination of Fibres since the 12th Interpol Symposium (October 1998) (1). Over the last three years, many research subjects have been developed and important information published in scientific proceedings and professional journals. The majority of this information has been at the European Fibres Group (EFG, affiliated with the European Network of Forensic Science Institutes, or ENFSI) and the Fibres Subgroup of the Scientific Working Group for Materials (U.S.A.) meetings. Both of these active groups have on-going collaborative research projects and continue to exchange information between forensic fibre specialists.

One of the most important results of this collaboration is the EFG's Manual of Best Practice for Forensic Fibres Analysis. This Manual is based on the Guidelines for the Forensic Examination of Fibres, published by the Fibers Sub-group of SWGMAT in 1998 (revised in 1999: 2). The Manual is scheduled for distribution in September 2001. The Manual is a comprehensive set of guidelines for the analysis of fibres in forensic cases, including sections on collection, microscopy, infra-red spectroscopy, microspectrophotometry, thin-layer chromatography, dye analysis, and other methods central to the analysis of fibres. Standardisation is a critical component of forensic science, because it provides a common language for all practitioners. Additionally, it gives justification for avoiding duplication of efforts and selecting the proper exam for the available evidence. The EFG's Manual of Best Practice is a milestone of co-operation and collaboration among forensic fibre examiners and sets the pace for future efforts from other Working Groups.

The EFG also has implemented a collaborative trials programme. Annually, EGF members receive a declared fibres trial in accordance with Quality Assurances measures. The trials demonstrate that the laboratory practices and analytical techniques for forensic fibre analysis are similar in the majority of laboratories. For example, in the trial reported on in 1998 with 42 laboratories participating (6), 30 (71%) laboratories used microscopy and 28 (67%) used FTIR to achieve the correct answer; these laboratories comprised 87% of the respondents with the correct answer. The differences that exist are critical: equipment availability and the extent of fibre knowledge and training (3). In the 1998 report mentioned previously, 10 (24%) laboratories misidentified one of the trial fibres. The laboratories that misidentified the fibres used microscopy and FTIR but did *not* use a subsequent technique, such as solubility, to confirm their previous observations. The emphasis on standardisation should motivate laboratories to make the proper equipment available and kept calibrated for continued quality efforts.

The last three trials were essentially oriented on interpretation and evidential value of fibres (4; 5; 6; 7), but these clinical trials do not always reflect casework. In order to see a real application of how forensic fibre examiners interpret their results, a survey on the evidential value of fibres was conducted by the EFG. In 1998, 164 scientists (Europeans, Australians, and North Americans) participated in this survey (8; 9; 10; 11; 12), which asked participants about how they would rank the significance of fibres and fibre analysis based on the fibre type, colour, size, shape, and crime scene conditions.

The survey showed the following areas of research interest:

- **a need for more inter/intra laboratory discussion on fibre frequencies;**
- **literature and contacts within the textile trade and industry need to be widely distributed;**
- **greater investment in the training of new examiners on "evidence evaluation".**

Surveys such as this help to communicate basic information between scientists and laboratories, keeping practitioners consistent in their interpretation of fibre evidence. These topics will be the focus of future EFG efforts.

In 1999, the second edition of *The Forensic Examination of Fibres* by Robertson and Grieve was published (13). This book is a significant reference publication in the field of fibre examination. It is divided into 15 chapters, each updated and written by recognised experts in the field. All aspects of forensic fibres examination are addressed: analysis, classification, examination, microscopy, instrumental analysis, and interpretation. It is an invaluable reference for students, forensic scientists, or anyone who works with this type of evidence.

A number of papers also researched the different methods that exist for fibre collection: forceps, tapes, combing (in hair), and vacuuming (14; 15; 16). A collection study (17) involving 38 laboratories worldwide was performed. In general, taping is the collection method of choice. This study also shows that there is a need for uniformity in the adhesive choice and the size and shape of the tape. For example, Swinton (18) proposes a roller device and a single-sided adhesive tape. A few laboratories use scraping (19; 20) or brushing (21) techniques instead of taping. Belgium examiners recommend brushing for large collection rooms with linoleum or tiled floors. Regardless of the method of fibre recovery, all necessary precautions to avoid contamination must be taken (22; 23; 24; 25; 26).

German laboratories have taken the taping technique to a further level: 1:1 taping (22; 27; 28; 29). In this method, one area of taping exactly represents the same area on the surface from which the fibres have been removed. This procedure is used only where the exact position of the fibres is in question because of the enormous increase in work making and searching the tapings. Analysis time is also increased simply because more fibres are recovered and must be examined. The search time might be reduced by the use of automatic fibre finder systems.

Five fibre finder systems exist today, but their use is not common (7; 30; 31; 32; 33). These systems are:

- **Fiber Finder (Cox Analytical Systems AB),**
- **Maxcan (Cox Analytical Systems AB),**
- **Fx5 Forensic Fibre Finder (Foster and Freeman),**
- **Q550fifi (Leica Vertieb GmbH), and**
- **Lucia Fibre Finder (Laboratory Imaging s.r.o.).**

Although the systems differ in their conception, they all operate under similar principles. A reference sample of the target fibres is prepared. Reference spectra of these fibres are collected to define the target colour range. The colour definition is optimised to produce the most efficient search routine. Next, the tapings are searched for fibres with colours that fall within the limits of the reference target sample. Finally, the results are reviewed by an analyst for accuracy and completeness. Wiggins et al (33) tested the Fx5 fiber finder and Kolar (31) tested the Lucia. These systems and software have considerable potential that has not yet been fully realised in routine casework. Because they have a direct bearing on the how the fibre evidence is collected, and because evidence collection can vary from agency to agency, changes to laboratory protocols to adopt these systems will be slow.

Protocols for fibre identification and comparison are well-established (34) and depend on a number of factors, principal among these are the available equipment, the experience of the fibre examiner, and the nature and amount of the fibres to be examined. Microscopy (35) is still the essential core of these protocols. Physical and optical characteristics of fibres are highly useful for identifying fibre polymer class; if this cannot be determined, the microscopic characteristics alone could discriminate between fibres (36; 37).

Poly(trimethylene) terephtalate PTT) is a type of polyester that, until recently, was too expensive to mass produce. PTT is now being made in large amounts and applied to a variety of textiles, especially carpeting. PTT has optical characteristics that are different from those traditionally associated with PET but is spectroscopically distinct from other types of polyester (38; 39). New fibre types like PTT underscore the need for a variety of tests, each of which elicits independent information from the fibre.

Infrared spectroscopy (40; 41) and especially FTIR spectroscopy is another well-established technique in analytical and forensic chemistry. FTIR microscopy is one of the methods of choice for the identification of synthetic fibres due to its selectivity, sensitivity and simplicity. It is not only useful to identify the polymer type but also the sub-class. For example, it can differentiate between the many varieties of modacrylic and acrylic fibres (36). Small sample (0.5 mm or less) analysis is possible by using a Diamond Cell to flatten fibres. Attenuated Total Reflectance (ATR) is used in surface-coated fibres analysis, such as those found in many stain-resistant carpets. Contamination, such as physiological fluids, does not mask the characteristic peaks of the fibre type (42). However, in fibre identification, peak intensity and possibly peak frequencies necessitates careful interpretation when comparing ATR spectra and transmission spectra; an ATR library of fibre standards should be created by the forensic laboratory.

Friedrich and Zahn (43) propose infrared emission spectroscopy to study fibres samples that do not have a well-defined sample geometry or are not suitable for transmission spectroscopy. Cho et al. (44; 45) propose polarised IR microspectrometry for comparison and classification of polyester fibres samples by discriminant analysis of dichroïc spectra using a zinc selenide wire grid polarizer.

Another vibrational spectroscopy technique is Raman microspectroscopy. This technique is currently little used in the forensic examination of fibres because of sample fluorescence and heating. However, because no sample preparation is required and extremely small samples (around 1 µm) may be examined, Raman holds much promise as an analytical tool. Raman and infrared microspectroscopy are complementary for polymeric identification of single fibres (46). Liu et al. (47; 48) demonstrate the FT-Raman potential in identification and discrimination between naturally coloured and white cotton cellulose fibres. Because of the potential of this technique, Raman is now one of the research subjects of the EFG.

Pyrolysis gas chromatography (49) also has potential for the identification of fibre additives. Morrisson and Archibald (50) compared different flax qualities and proved that the quality depends on the concentration of alcohol and phenolinic derivatives. These characteristics may help in distinguishing otherwise similar fibres.

Besides the morphology of fibres and the polymeric composition, colour is another crucial characteristic that dominates forensic fibre comparisons. A recent instrumental development has been the introduction of photodiodearray spectrophotometers (PDA). The fibre is illuminated by white light and all spectral regions are scanned simultaneously. The signal is then sorted out by the solid-state detector and displayed as a spectrum. The time needed to obtain a single spectrum has been reduced to under a second, with the advantage that a very large number of fibres can be scanned extremely rapidly. A PDA mounted on a Leica DMRXP microscope with polarised light and fluorescence capabilities provides a nearly complete station for fibre examinations. Microspectrophotometry (MSP) is quick and non-destructive and its discriminating power is high. This power increases with an instrument capable of measuring spectra in the ultra-violet and visible ranges (240-760 nm) (51; 52; 53; 54).

Thin layer chromatography (55; 56) is still used in fibre dye comparisons even thought it is destructive. Because TLC has additional discrimination possibilities, it should not be neglected by the fibre examiner, especially if no colour measurement besides simple visual examination is used.

White (57; 58) utilised Surface Enhanced Resonance Raman Scattering Spectroscopy (SERRS) on reactive dyed cotton fibres. Further refinement of the technique and its applications to other classes of fibre dyes are currently being studied. Other methods in this vein are capillary electrophoresis (59) and sample induced isotachophoresis and micellar electrokinetic capillary chromatography (60).

Textile damage has been another area of fibre examination research. The second edition of the *Atlas of fibre fracture and damage to textiles* (61) is the standard reference in this area. Over 30 years of the authors' experiences are presented, making this update an invaluable resource for the novice and expert alike. Other publications (62; 63; 64) of textile damage casework show the importance of microscopic and macroscopic examinations damage determination or biodegradation (65). A comprehensive review of the subject can be found in Robertson and Grieve's book (66).

New techniques of analysis and comparison of fibres and dyes continue to be published and existing methods are being refined. The combination of existing methods provides a reliable scheme of analysis but research into novel applications must continue. Areas of research for the future continue to be discrimination of otherwise similar samples, limits of detection, industrial inquiries to determine source and distribution of textiles, significance and interpretation methods, and the exploration of novel methodology. With the Manual of Best Practice soon available, fibre examiners throughout Europe and the rest of the world will have a standard, firm basis from which to explore new branches of research. International co-operation between agencies and laboratories has been well established, primarily through the EFG and the Fibres Subgroup of SWGMAT, and this yields new potentials for communication and information exchange.

The essential topics of these last years have been fibre frequency (67; 68; 69; 70; 71) and fibre transfer and persistence (72; 73; 74; 75; 76). These are the central questions pertaining to evidential value. While many fibre examiners agree on how to analyse fibres, not all agree on what the results mean or how to report them. Publications (77; 78; 79; 80; 81; 82; 83; 84; 85; 86) and workshops (14; 87) have been devoted to the Bayesian approach. The Bayesian approach has been vigorously debated in the literature and at meetings. Because of its subjective nature and complexity, the Bayesian approach is, at present, has not been adopted by the majority of experts around the world (11; 12). Legal and scientific issues remain unresolved on this topic; each laboratory and analyst must decide for themselves at this point. A need of databases for frequencies and population information of fibres, such the German clothing databse (69; 70; 71), could assist in this regard. Real data collected from actual samples could improve objectivity and assist in the interpretation of fibre results.

Overall, the past few years have seen an increasingly wide sphere of research and improvement in the methodology of fibre analysis. The variety of methods that can be successfully applied is growing and data continue to be generated that assist in the examination and interpretation of fibres found in criminal cases. The international co-operation between the EFG and the SWGMAT are an investment in the continuity and intensification of quality fibre analysis in forensic science.

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