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The Evidential Value of Fibers Used in Hi-Vis Workwear

ABSTRACT

This paper investigates whether the finding of fluorescent fibers, typical of those seen in Hi-Vis workwear, have any evidential significance. This investigation was performed by combining a color block study (examining a number of samples of Hi-Vis workwear and assessing the extent to which they can be discriminated from each other), a population study (examining tapings taken from the general public to assess the extent to which Hi-Vis fibers are present on a person's clothing at random) and a target fiber study (examining tapings taken from the general public to assess whether there are any fibers present that are microscopically and chemically indistinguishable from an individual sample of Hi-Vis clothing). Two case studies are also presented involving the examination of Hi-Vis fibers. The study shows that whilst it is possible to discriminate between garments constructed from Hi-Vis fabrics, there were instances where significant numbers of samples were found to be indistinguishable from each other. On that basis the authors recommend caution in the interpretation of findings involving Hi-Vis workwear.

Keywords: Hi-Vis, Fiber, Evidential Value, Polyester

INTRODUCTION

For many years, forensic fiber researchers in Europe have been conducting studies known as 'color blocks' [1-8], where multiple sources of very specific colored fiber types have been examined to determine the types of dyes used in their manufacturing and the degree to which a traditional forensic fiber comparison processes can discriminate them. This approach, together with information from more traditional population and target fiber studies, provides very valuable information to the forensic fiber expert. This information can be used to aid case assessment, prioritize examinations and in the interpretation of fiber links in criminal cases.

Searching for textile fibers recovered from a surface of a textile is not always easy. Whether or not that search is conducted on tapings, scrapings or vacuumed debris, the search requires the examiner to be able to identify target fibers against a background of

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other fibers, most of which are likely to be irrelevant to the criminal activity under investigation. This task is further complicated by the fact that the most commonly worn colors of clothing are dark in shade, meaning that often forensic fiber examiners find themselves searching for natural and synthetic fibers that are dark against a background of similar dark fibers.

Forensic fiber examiners are also required to identify populations of fibers, from which the source may be unknown. Such populations can provide valuable intelligence regarding sources involved in contact with the garment or environments where the garment may have been stored. The identification of such traces relies entirely on the examiner to decide which fibers constitute a population and whether such fibers have any significance in the context of the case.

In our experience in casework, target fibers that stand out from the background fiber population are likeliest to be identified as a fiber population worth pursuing. This approach is open to criticism over the potential for selective bias, particularly if a fiber population is selected purely on the basis that the population is distinctive. After all, the probative value of fiber types does not depend on how easy fibers are to find.

We are aware of at least one high profile case from the UK where fibers from high-visibility ("Hi-vis") workwear played a role in securing the conviction of a serial rapist [9] and our casework experiences inform us that fluorescent fibers tend to stand out during examinations, but what value are they evidentially?

The demand for fluorescent, Hi-vis colored clothing has boomed worldwide over the last few decades. The requirement for such Hi-vis textiles to be used as part of an organization's corporate responsibility has become part of health and safety requirements worldwide, to the degree that the design and construction of such textiles is tightly regulated by governments across the globe (Europe EN471:2003, China GB20653:2006, Canada CAN/CSA Z96.1-08, CSA Z96-09, USA ANSI/ISEA 207-2006, ANSI/ISEA 107-2010, Australia/New Zealand AS/NZS 1906.4:2010, AS/NZS 4602:1999). These standards are likely to be superseded by an International Standard ISO 20471 in the near future. Europe's EN471:2003 regulation is typical of the restrictions imposed on the clothing, and whilst it does not specify precisely the types of dyes required to be used in the clothing, it does specify the color space allowable in terms of chromaticity coordinates and luminosity of the material [10].

This work seeks to inform the forensic community regarding the evidential value of fibers used in the construction of Hi-vis textiles. It comprises a color block study, a population study and target fiber study in relation to fibers that are used in the construction of Hi-vis clothing.

This study into these fiber types encompassed the following:
1. An assessment of the characteristics and discrimination of fibers used in the construction of 52 samples of Hi-vis clothing.
2. A population study of fibers, with the characteristics of Hi-vis fibers, on tapings taken from 100 garments.
3. A target fiber study of tapings taken from 100 garments for the presence of specific Hi-vis fibers from the samples examined in part 1.
4. Two case examples of Hi-vis fibers recovered during criminal fiber examinations.
Overall, this paper provides a discussion on the value of finding Hi-vis fibers as evidence in cases.

MATERIALS AND METHODS

Fabric samples

Fifty-two Hi-vis fabric samples were obtained from 50 Hi-vis garments being worn by various workers in a busy business park over a period of a few weeks. Samples were taken by cutting a square of fabric out with a scalpel (to obtain a known sample) and by means of a taping of the surface (to assess the sheddability of the fabric).

In the laboratory, the 52 samples of fabric were examined using a Leica MZ16 stereomicroscope (magnification range 7.1x – 115x). A representative sample of the fibers from each fabric was removed and mounted on microscope slides in Entellan® under glass cover-slips. Table 1 provides a list of these samples.

Constituent fibers were identified using a Leica DM EP polarized light microscope (PLM) at magnifications between 100x and 400x. Information about the color, cross section, diameter and luster of the fibers was recorded and the birefringence characteristics were used to give an initial identification of the fiber type. The constituent fibers were classified according to their thickness, color and cross sectional shape.

All of the samples of the Hi-vis clothing were compared to each other by comparison microscopy. A Leica FS 4000 comparison microscope with transmitted white light (bright field) and reflected incident light (equipped with Leica narrow banded excitation filters UV (A) and Blue (I3)) was used.

Table 1. Collected fabric samples and sheddability information from Hi-vis garments

No.	Manufacturer	Garment Type	Color	Label Description	# fibers on shed tape
1	Viz Lite	Vest	Yellow	100% Polyester	1
2	Yokotex		Green	No label	4
3	JSP		Yellow	100% Polyester	0
4	Unknown			No label	1
5	Uneek			100% Polyester	2
6					6
7	Unknown			100% Polyester BSEN 471	1
8	Strada Functional			No label	N/A
9	Aggressive Safety			100% Polyester	0
10	Unknown				2
11	Wceng			100% Polyester BSEN 471:2003	0
12	Unknown			No label	1
13		Jacket		100% Polyester	3
14		Vest		No label	7
15				100% Polyester BSEN 471:2003	1
16					1
17	ARCO			100% Polyester BSEN 471:94 Dir	69
17a		Inside Mesh		100% Polyester	50
18	Unknown	Vest			50
19		T-Shirt		No label	80
20	Leo Workwear	Vest			8
21	Beartex Dimensions	Coat		100% Polyester BSEN 471:1994	6
22	Leo Workwear Retromax	Vest		100% Polyester	0
23					0
24**					2
25	ST Workwear		Orange	100% Polyester Dir 89/686/EEC	0
26	Buck and Hickman		Yellow	100% Polyester	0
27*	H Protection Work		Green		3
28	Unknown		Yellow	No label	4
29					1
30	Sainsbury's		Orange		0
31	Unknown		Yellow		2
32	UPS				3
33	Partwest	T-Shirt		100% Polyester BSEN 471:1994	51
34	Royal Mail	Vest	Orange	100% Polyester BSEN 471:2003	1
35	Unknown		Yellow	No label	4
35b		Inside Mesh			10
36	Virgin	Vest	Red		1
37					5
38					3
39	Unknown		Yellow		8
40				100% Polyester BSEN 471:2003	2
41				100% Polyester Dir 89/686/EEC	9
42		Jacket		No label	0
43		Jumper Inside			11
44		T-Shirt	Orange		0
45		Vest	Yellow		N/A
46					12
47	TP Worksafe				31
48	Unknown			100% Polyester BSEN 471:2003	4

49	Dickies	Hoody			14
50		Jacket			0
51	TP Worksafe	Vest		100% Polyester BSEN 471:2003	60

* Label states- 'Does not conform with Hi-Vis BSEN:471'
** No sample present
N/A No sheddability tape taken

Spectral characteristics of all of the identified fiber types in each of the 52 samples were analyzed using a Zeiss/TIDAS Microspectrophotometer (MSP) in the region of 380 nm – 730 nm. The spectral characteristics of the fibers were compared in order to determine the level of discrimination across the samples obtained.

A selection of fibers was analyzed with a Thermo DXR Smart Raman Microscope using both a 532 nm and a 780 nm laser. Spectra were obtained over a range of 2000 – 200 cm^{-1}. The chemical composition of some of the fibers was determined using a Thermo Nicolet iN10 Fourier Transform Infrared (FTIR) spectrometer. Fibers were flattened using a diamond window and placed into the path of the IR beam. Spectra were obtained over a range of 4000 – 650 cm−1.

Population study – clothing

From a previous study [7], tapings had been taken from 100 every-day garments worn by several volunteers over a period of time. Tapings were taken by using low adhesive tape-lifts which were secured to clear plastic sheets. One tape-lift was used to tape the front of the garment and one to tape the back of the garment. It is accepted that some of the garments in this study may have been worn by people who shared similar environments such as workplace, home or transport.

These tapings were examined for any fibers that could have come from a Hi-vis garment (selected by color) using a Leica MZ16 stereomicroscope. Target fibers were identified, removed and mounted on microscope slides in Entellan® under glass cover-slips. Microscopic identification was performed as previously described for the 52 fabric samples.

Target fiber study – clothing

All fibers recovered from the tapings of the garments used in the population study that were identified as being visually similar to those typical of the type used in Hi-vis clothing were compared to the Hi-vis fabric samples. If fibers were found to be microscopically indistinguishable, under all of the lighting conditions, the MSP spectra of the fibers were compared.

Case Examples

Two case examples involving Hi-vis clothing are described in the context of the findings of this research.

RESULTS

Fabric samples

Sheddability of the Hi-vis garments was assessed by placing a strip of sellotape on the garments once and recording the number of constituent fibers present, as shown in Table 1. Of the areas samples 22% yielded no constituent fibers on the sheddability tape and 26% had either one or two fibers present. Thirty percent of the areas sampled yielded between three and nine fibers, 22% yielded 10 fibers or more. Seven sources yielded over 30 fibers and can be considered to be shedding fibers considerably well.

The majority of samples (83%) were yellow in color; the other colors found were red, orange or green. Without exception, the fabric samples consisted of fabric constructed using a single color.

All of the 52 fabric samples were constructed from polyester fibers (Table 2). Fifty-two percent were constructed from a single type of polyester fiber, whereas the remaining 48% consisted of a blend of more than one type of polyester fiber. Most blends consisted of two fiber types; however two fabric samples were constructed from blends of more than two fiber types.

In terms of levels of delustrant particles, 87% of the samples contained fibers that were classified as being “semi-dull”, whereas 27% contained fibers classified as “bright”. Some samples were constructed solely of “bright” fibers, whilst some formed a blend of “semi-dull” and “bright” fibers.

Owing to the small number of red, green and orange samples only the yellow samples were analyzed in further detail for the purposes of this study. The fiber types contained within the remaining 43 samples were separated morphologically, according to their thickness, cross-section and levels of delustrant particles; thus giving 69 identified fiber types. They were compared against each other under the microscope. It became evident through this exercise that comparison of the fibers under incident light fluorescence was very difficult due to the intensity of the fluorescence, rendering it difficult to discriminate between fibers of the same color and morphology. The microscopic color of the fibers was very consistent from one sample to another and did not in itself contribute much, if anything, to the discrimination of the fiber samples. The most discriminating features of these samples using comparison microscopy were morphological ones, namely: thickness, delustrant levels and cross-section.

Table 2. Microscopic properties of fabric samples

SAMPLE	BLEND	FIBER TYPE	COLOR	LUSTRE	DIAM (µm)	CROSS-SECTION
1	NO	POLYESTER	YELLOW	SEMI	17.5	TEXTURED / TRILOBAL
2	NO	POLYESTER	GREEN	SEMI	20	ROUND
3	NO	POLYESTER	YELLOW	SEMI	15	TEXTURED / TRILOBAL
4	YES	POLYESTER	YELLOW	SEMI	15	TEXTURED / TRILOBAL
4	YES	POLYESTER	YELLOW	BRIGHT	10	ROUND
5	YES	POLYESTER	YELLOW	SEMI	17.5	TEXTURED / TRILOBAL
5	YES	POLYESTER	YELLOW	BRIGHT	12.5	ROUND
6	YES	POLYESTER	YELLOW	SEMI	17.5	TEXTURED / TRILOBAL
6	YES	POLYESTER	YELLOW	BRIGHT	12.5	ROUND
7	YES	POLYESTER	YELLOW	SEMI	12.5	TEXTURED / TRILOBAL
7	YES	POLYESTER	YELLOW	BRIGHT	10	ROUND
8	YES	POLYESTER	YELLOW	SEMI	20	ROUND
8	YES	POLYESTER	YELLOW	SEMI	15	TEXTURED / TRILOBAL
9	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND
9	YES	POLYESTER	YELLOW	SEMI	15	TEXTURED / TRILOBAL
10	YES	POLYESTER	YELLOW	SEMI	15	ROUND
10	YES	POLYESTER	YELLOW	SEMI	15	TEXTURED / TRILOBAL
10	YES	POLYESTER	YELLOW	BRIGHT	10	TEXTURED / TRILOBAL
11	YES	POLYESTER	YELLOW	SEMI	15	TEXTURED / TRILOBAL
11	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND
12	YES	POLYESTER	YELLOW	SEMI	12.5	TEXTURED / TRILOBAL
12	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND
13	NO	POLYESTER	YELLOW	SEMI	20	TEXTURED / TRILOBAL
14	YES	POLYESTER	YELLOW	SEMI	25	TEXTURED / TRILOBAL
14	YES	POLYESTER	YELLOW	SEMI	15	ROUND
15	NO	POLYESTER	YELLOW	SEMI	15	TEXTURED / TRILOBAL
16	YES	POLYESTER	YELLOW	SEMI	12.5	TEXTURED / TRILOBAL
16	YES	POLYESTER	YELLOW	SEMI	15	ROUND
17	YES	POLYESTER	YELLOW	SEMI	12.5	TEXTURED / TRILOBAL
17	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND
17A	NO	POLYESTER	YELLOW	SEMI	17.5	ROUND
18	NO	POLYESTER	YELLOW	BRIGHT	10	ROUND
19	NO	POLYESTER	YELLOW	BRIGHT	10	ROUND
20	YES	POLYESTER	YELLOW	SEMI	17.5	TEXTURED / TRILOBAL
20	YES	POLYESTER	YELLOW	SEMI	15	ROUND
21	NO	POLYESTER	YELLOW	SEMI	20	TEXTURED / TRILOBAL
22	NO	POLYESTER	YELLOW	BRIGHT	10	ROUND

SAMPLE	BLEND	FIBER TYPE	COLOR	LUSTRE	DIAM (µm)	CROSS-SECTION
23	NO	POLYESTER	YELLOW	BRIGHT	10	ROUND
25	NO	POLYESTER	RED	SEMI	17.5	TEXTURED / TRILOBAL
26	NO	POLYESTER	YELLOW	BRIGHT	10	ROUND
27	NO	POLYESTER	GREEN	SEMI	25	TEXTURED / TRILOBAL
28	NO	POLYESTER	YELLOW	SEMI	20	TEXTURED / TRILOBAL
29	YES	POLYESTER	YELLOW	SEMI	15	ROUND
29	YES	POLYESTER	YELLOW	BRIGHT	10	ROUND
30	NO	POLYESTER	RED	BRIGHT	10	ROUND
31	NO	POLYESTER	YELLOW	SEMI	17.5	TEXTURED / TRILOBAL
32	NO	POLYESTER	YELLOW	SEMI	15	TEXTURED / TRILOBAL
33	NO	POLYESTER	YELLOW	SEMI	12.5	TEXTURED / TRILOBAL
34	YES	POLYESTER	ORANGE	SEMI	15	TEXTURED / TRILOBAL
34	YES	POLYESTER	ORANGE	SEMI	17.5	ROUND
35	YES	POLYESTER	YELLOW	SEMI	20	TEXTURED / TRILOBAL
35	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND
35B	NO	POLYESTER	YELLOW	SEMI	20	TEXTURED / TRILOBAL
36	NO	POLYESTER	RED	SEMI	20	TEXTURED / TRILOBAL
37	NO	POLYESTER	RED	SEMI	20	TEXTURED / TRILOBAL
38	NO	POLYESTER	RED	SEMI	20	TEXTURED / TRILOBAL
39	YES	POLYESTER	YELLOW	SEMI	17.5	TEXTURED / TRILOBAL
39	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND
40	YES	POLYESTER	YELLOW	SEMI	17.5	TEXTURED / TRILOBAL
40	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND
41	YES	POLYESTER	YELLOW	SEMI	15	TEXTURED / TRILOBAL
41	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND
41	YES	POLYESTER	YELLOW	BRIGHT	10	ROUND
42	NO	POLYESTER	YELLOW	BRIGHT	12.5	ROUND
43	NO	POLYESTER	YELLOW	SEMI	15	ROUND
44	NO	POLYESTER	ORANGE	SEMI	22.5	TEXTURED / TRILOBAL
45	YES	POLYESTER	YELLOW	SEMI	17.5	TEXTURED / TRILOBAL
45	YES	POLYESTER	YELLOW	SEMI	20	ROUND
46	YES	POLYESTER	YELLOW	SEMI	20	TEXTURED / TRILOBAL
46	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND
47	YES	POLYESTER	YELLOW	SEMI	20	TEXTURED / TRILOBAL
47	YES	POLYESTER	YELLOW	SEMI	15	ROUND
48	YES	POLYESTER	YELLOW	SEMI	17.5	TEXTURED / TRILOBAL
48	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND
49	YES	POLYESTER	YELLOW	SEMI	15	TEXTURED / TRILOBAL
49	YES	POLYESTER	YELLOW	SEMI	22.5	TEXTURED / TRILOBAL
50	NO	POLYESTER	YELLOW	SEMI	20	TEXTURED / TRILOBAL
51	YES	POLYESTER	YELLOW	SEMI	17.5	TEXTURED / TRILOBAL
51	YES	POLYESTER	YELLOW	SEMI	17.5	ROUND

MSP analysis of the yellow samples showed that the sample set consisted of three different types of spectra. Thirty-four of the samples produced spectra consisting of a doublet (maximum at approx. 440 nm and a shoulder at 460 nm, Figure 1), these were indistinguishable from each other. Three of the samples produced spectra consisting of a single band with a symmetrical shape (single maximum at approx. 447 nm, Figure 2), these were indistinguishable from each other. Five of the samples produced spectra with a single band with an asymmetrical shape (single maximum at approx. 442 nm, Figure 3) these were indistinguishable from each other. Only one sample contained multiple fiber types whose MSP spectra differed within the sample (sample 46).

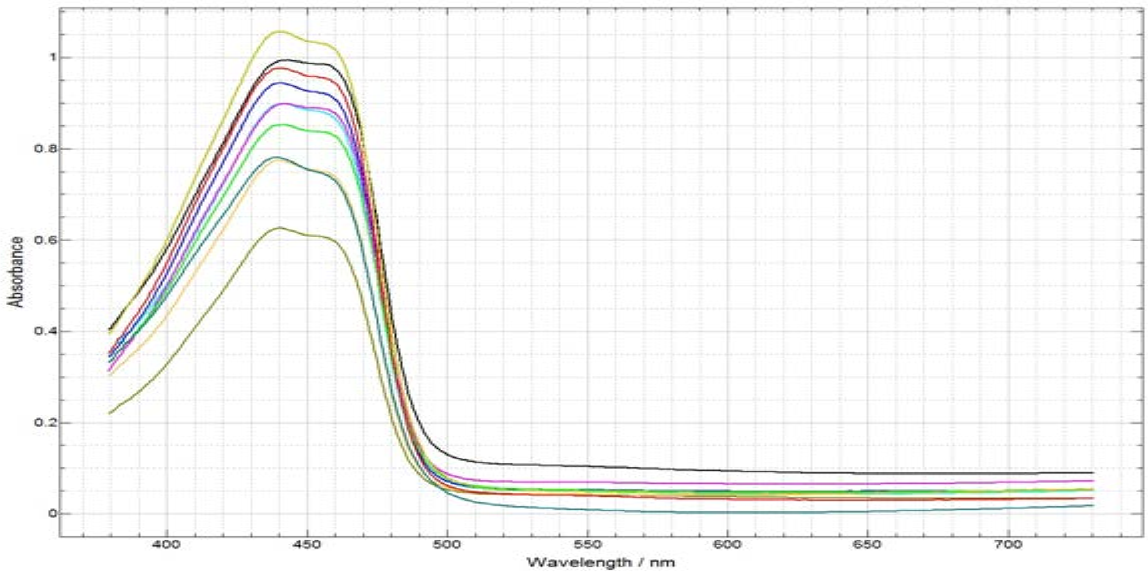

Figure 1 Spectra from several samples showing a 'doublet'

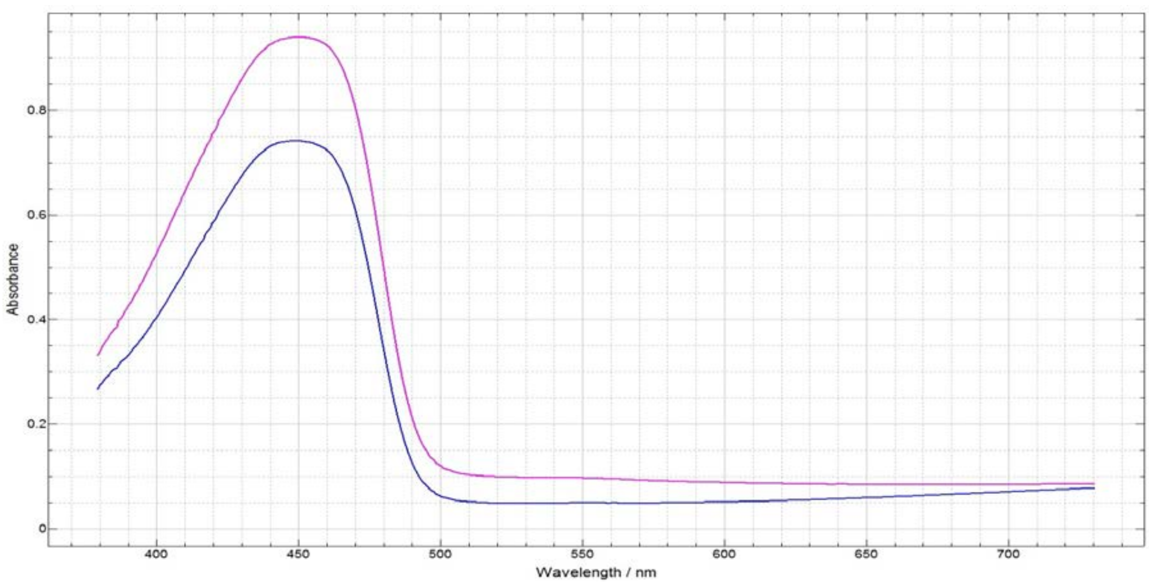

Figure 2 Spectra from two samples showing a "symmetrical" curve

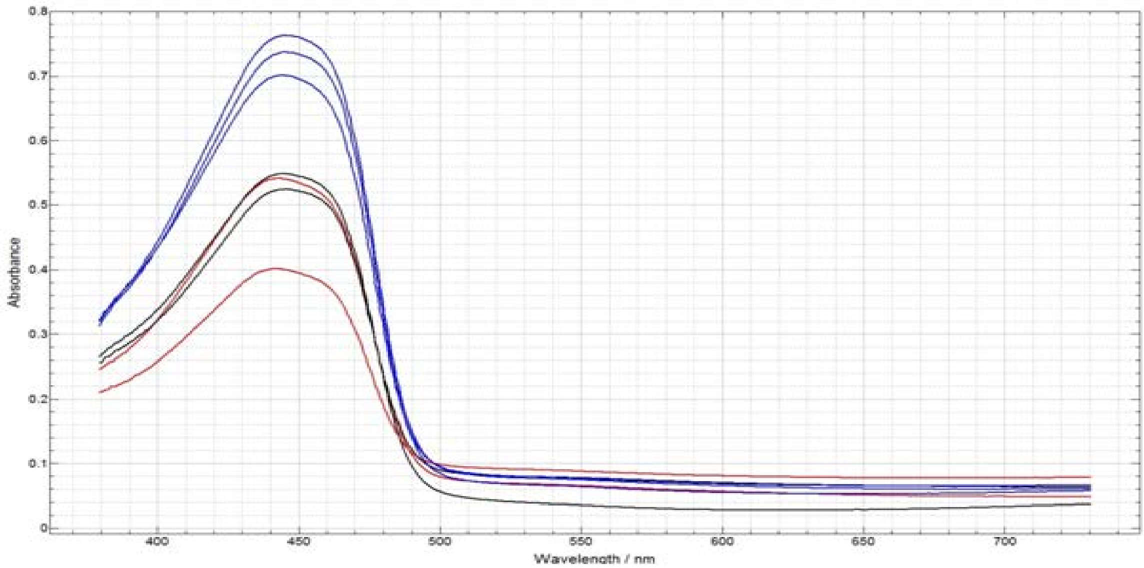

Figure 3 Spectra from several samples showing an "assymetrical" curve

When the findings from comparison microscopy and MSP were combined, the samples could be sub-classified into eight separate groups which contained fibers that were indistinguishable from each other, and 11 individual samples that were distinguishable from all others (Table 3).

Table 3. Distinguishable fiber groups after both comparison microscopy and MSP spectroscopy

Semi-Dull (≤15µm)

Round		Textured	
Group	No. of Samples	Group	No. of Samples
A (D)	4	**B** (D)	6
Unique	3	**C** (S)	2
		D (D)	5
		Unique	1

Semi-Dull (>15µm)

Round		Textured	
Group	No. of Samples	Group	No. of Samples
E (D)	13	**F** (D)	14
Unique	1	**G** (As)	2
		Unique	5

Bright

Group	No. of Samples
H (D)	12
Unique	1

NOTE: (D) Doublet in the MSP spectrum
(As) Asymmetrical band in the MSP spectrum
(S) Symmetrical band in the MSP spectrum

Raman analysis of the fiber samples did not yield much in the way of useful spectral data of the dye. Using 532 nm laser excitation most of the samples fluoresced so much that no spectral data was obtained, on only a few samples were some bands observed and these arose from the polyethylene terephthalate (PET) polymeric constituent of the fibers. At 780 nm there was significantly less fluorescence however only bands arising from PET were observed.

Population study – clothing

Thirty-eight of the 100 every-day garments contained fibers on their surfaces considered to be likely to have arisen from "Hi-vis" sources. Sixty-five fibers were recovered from these garments (Table 4). Most were either yellow (42%) or orange (45%), with the remainder (14%) being green. One recovered yellow fiber was lost prior to identification and therefore was not included in subsequent calculations. Thirty-three percent of the fibers were polyester, 27% were wool, 19% were cotton and the remainder consisted mainly of acrylic and cellulosic fibers.

The largest number of such fibers found on any garment was four. Eighty-two percent of the garments where "Hi-vis" fibers were found contained one or two fibers only.

Target fiber study – clothing

All of the fibers recovered from the clothing were compared to the samples of Hi-Vis garments. None of the fibers recovered from the clothing were indistinguishable from any of the 52 samples of "Hi-vis" clothing.

Case examples

Case 1 – Offenders stole a construction vehicle (JCB) and used it to extract a cash machine (ATM) from the wall of a bank. Tapings were submitted for examination. Two fibers were found on the tapings from the JCB that were considered likely to have come from yellow Hi-vis clothing. One of these fibers was found to be microscopically and chemically indistinguishable to fibers used in the construction of several Hi-vis garments sampled in this study.

Case 2 – A cyclist was involved in a hit-and-run with a vehicle. The cyclist's jacket was Hi-vis (a light waterproof material) and was found to be constructed from a yellow nylon exterior and a yellow polyester mesh interior. A vehicle was examined several weeks later and fibers were recovered from the hood and roof. Three Hi-vis yellow polyester fibers were found on the outside of the vehicle, however, all three fibers differed in cross-section from those used in the construction of the inside mesh of the cyclist's jacket. No fibers were found that could have come from the yellow nylon material that comprised the outer shell of the cyclist's jacket.

Table 4. Hi-Vis fibers found on the surfaces of clothing

Garment Number and Description	# of Fibers	Microscopic Color			Microscopic Identification					
		Yellow	Green	Orange	Polyester	Wool	Cellulosic	Acrylic	Cotton	Other
2 - Blue Top	2	2	-	-	1	-	-	-	1	-
6 - Blue T-Shirt & Trousers	2	2	-	-	2	-	-	-	-	-
11 - Blue & White T-Shirt & Denims	1	-	-	1	-	-	1	-	-	-
12 - Blue Jeans	2	-	2	-	-	-	-	-	2	-
13 - Blue Jeans	4	1	2	1	-	-	-	-	4	-
15 - Grey Hooded Top	1	1	-	-	-	-	1	-	-	-
16 - White, Red & Green T-Shirt	1	-	-	1	-	-	-	1	-	-
21 - White T-Shirt	2	1	-	1	-	1	1	-	-	-
22 - White Blue Striped T-Shirt	3	2	-	1	2	-	-	1	-	-
23 - Blue T-Shirt	2	2	-	-	1	-	-	-	1	-
25 - Grey & Black Top	3	2	1	-	2	-	-	-	-	1
26 - Black T-Shirt	1	1	-	-	1	-	-	-	-	-
28 - Brown T-Shirt	1	1	-	-	1	-	-	-	-	-
32 - Beige/Yellow T-Shirt	3	-	-	3	3	-	-	-	-	-
38 - Grey Rugby Shirt	1	1	-	-	-	-	1	-	-	-
40 - Black Trousers	4	1	-	3	-	4	-	-	-	-
42 - White Shirt	1	1	-	-	-	-	-	-	1	-
44 - Beige Top	2	1	-	1	1	-	-	-	1	-
45 - Blue T-Shirt	2	-	1	1	1	1	-	-	-	-
46 - Blue & Grey Jacket	1	-	-	1	-	-	-	-	1	-
48 - Black Fleece Jacket	2	-	-	2	1	-	-	1	-	-
53 - Green Top	3	-	-	3	-	2	-	-	-	1
55 - Black Top	2	-	-	2	2	-	-	-	-	-
59 - Yellow T-Shirt	1	1	-	-	-	1	-	-	-	-
62 - Pink T-Shirt	1	-	1	-	-	1	-	-	-	-
63 - Green top	1	-	-	1	-	-	-	1	-	-
64 - Grey Cardigan	1	1	-	-	1	-	-	-	-	-
66 - Blue Skirt	1	-	1	-	-	-	-	-	-	1
73 - Blue Dress	1	1	-	-	-	-	1	-	-	-
74 - White Shirt & Black Trousers	1	-	-	1	-	1	-	-	-	-
76 - Blue Jeans	1	1	-	-	-	-	1	-	-	-
77 - Black Blazer	1	-	-	1	-	1	-	-	-	-
78 - Teal Jumper	1	-	-	1	-	1	-	-	-	-
82 - Grey Top	2	1	-	1	-	1	-	1	-	-
87 - Blue Jeans	1*	1	-	-	-	-	-	-	-	1
90 - Navy Polo Shirt	1	1	-	-	-	1	-	-	-	-
94 - Blue Jumper	1	1	-	-	-	1	-	-	-	-
95 - Blue Jumper	4	-	1	3	2	1	-	-	1	-
Total	65	27	9	29	21	17	6	5	12	4

* Fiber lost prior to identification.

DISCUSSION AND CONCLUSIONS

The construction of Hi-vis clothing used for textiles is subject to very strict regulation and this, the authors believe, has led to a very high degree of uniformity between samples, far higher than would be expected from the general textile market. In relation to the most commonly occurring colored sample, yellow, the microscopic comparison was mainly found to be of value when samples were compared based on the morphological characteristics of the fibers, namely their thickness, cross-section and levels of delustrant particles. Comparison using incident light fluorescence was less effective than expected, in general the samples fluoresced very brightly within a narrow range of color. MSP analysis offered additional discrimination of samples, but not to the degree observed in other studies for other types of colored fibers. When considered together the combination of comparison microscopy and MSP (visible range) only managed to separate a small sample set of randomly chosen clothing into a small number of groups, some of which were densely populated by samples indistinguishable from each other. Raman and FTIR analysis did not assist in discriminating any further. We can conclude from this study that when compared to normal colored clothing and textiles, yellow Hi-vis garments are generally poorly discriminated from each other using traditional methods.

Eight percent of the every-day garments chosen at random were found to contain yellow polyester fibers on their surfaces. Where such fibers were found, the highest number recorded was two. It is therefore reasonable to expect fiber examiners to encounter these fibers as part of their general case working experiences, although only a small number of fibers. We believe that the reason that so few fibers are encountered so infrequently on clothing is that 48% of Hi-vis sources did not tend to shed fibers well (i.e. two or fewer fibers noted on sheddability tapings), reducing the pool of fibers transferred during contact amongst the general population.

No fibers were found on the everyday garments that could have come from the Hi-vis clothing samples in this study. This is somewhat surprising given how difficult it was to discriminate the samples from each other. However, given the low number of fibers recovered from the tapings and the fact that 48% of the sources in this study did not tend to shed, it should not be regarded as unusual.

There was also a considerable number of Hi-vis type fibers recovered from these everyday garments that were not polyester. We are aware that Hi-vis colored fibers are used in a wide range of garments that are not workwear, including sports and leisure wear and winter clothing (fleeces, hats and gloves). It is possible that sources of leisure wear do not fall under the regulatory requirement as they are not supplied by an employer to an employee for the purposes of work activity. On that basis they may fulfill a requirement of being "Hi-vis" (i.e. fluorescent and/or reflective) without meeting the precise regulatory needs in terms of luminosity and color space. We believe that the case example of the cyclist's jacket illustrates this point clearly showing that just because a garment is Hi-vis, does not necessarily mean that it should be treated as a poor target fiber type.

This does however present somewhat of a conundrum for those who need to interpret the findings in a case where yellow Hi-vis fibers are found on a surface that are indistinguishable from clothing of an offender. Whilst it may be unlikely to find such fibers on clothing by chance, the discrimination power in respect of such samples is so low that it raises the possibility that the fibers arose from a source other than the questioned garment.

It is our opinion that in general, interpretation of the evidential value of a textile fiber link involving these types of fibers should be treated with considerable caution. In particular, for case assessment purposes, pursuing such links should generally be given a low priority, unless there are case circumstances that dictate otherwise - such as supporting witness testimony that an offender wore such an item of clothing, or determining whether or not a weapon was used to damage the clothing, or the use of non-polyester Hi-vis fibers in the construction of the garment. In the case of the hit-and-run cyclist, three Hi-vis fibers were found on the outside of a car seized shortly after the alleged offence occurred. However the car was in a secure storage area for several weeks prior to the fibers being recovered by police. It was our view that the three (non-matching) Hi-vis fibers more likely arose from environmental factors. This demonstrates that in cases involving Hi-vis fibers, there is a need to understand what other sources of Hi-vis fibers could have been involved, particularly given how prolific the use of Hi-vis clothing is amongst police, paramedics, fire-fighters and other emergency services.

The manufacturing of Hi-vis clothing is an excellent example of government regulating the textile industry in terms of its manufacturing, to produce a product of very high uniformity in order to accomplish a very specific task of protecting employees' health and safety. It is in complete contrast to the manufacturing of clothing for everyday wear, which by its very nature requires manufacturers to produce clothing that is highly variable by design and construction.

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