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The Retention and Recovery of Transferred Fibers Following the Washing of Recipient Clothing

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ABSTRACT: Laboratory coats which had been subjected to contact with a yellow polyester/cotton polo shirt and were subsequently sent to an external laundry service. Surface debris tapings were taken from the items on return, and these were searched for fibers originating from the target garment. Additionally, a mock assault by an ''assailant'' wearing a blue acrylic top was carried out on various ''victims'' who, after returning home, discarded their upper clothing prior to domestic washing. Surface debris tapings taken from this clothing after drying were searched for fibers originating from the target garment using the FX5 automated fiber finding equipment (Foster & Freeman). The number of garments demonstrating the retention of target fibers, as well as the number of retained fibers, were noted.

KEYWORDS: forensic science, fibers, retention, washing, automated fiber finder, FX5, acrylic, recovery

Various studies (1–5) have demonstrated the loss of transferred fibers with time, and the effect on activity on the loss rate. Because the perpetrator of a crime may wash his (her) clothing in the belief that evidence linking him to a scene or victim can be destroyed, this study was carried out to establish how effective such an activity would be at eliminating trace evidence in the form of a fiber transfer. To this end, domestic and commercial laundering was carried out on garments which had been subjected to a fiber transfer. To facilitate the searching of surface debris tapings taken from the recipient garments, the FX5 Automated Fibre Finder (Foster & Freeman, Evesham, England) was employed in part of this study.

Materials and Methods

A yellow polyester/cotton polo shirt and a blue acrylic knitted top were obtained for use as target garments. The constituent fibers of each garment were examined and their appearance under white light and fluorescence microscopy (Leitz Wetzlar) was noted.

Visible range Microspectrophotometry (MSP) (Nanospec 200 AFT/Leitz Diaplan) was carried out on each of the constituent fiber types.

The first part of the study involved laying the yellow polo shirt on top of a previously labeled lab coat, which was then rolled up over the shirt and subsequently twisted tight for 10 s. After removing the polo shirt, the lab coat was then placed at the collection point (as normal) for laundry. The lab coats were labeled using the date of contact followed by a letter identifying each coat (for example, 210497A). Three lab coats were subjected to this contact each week, for a total of five weeks. The average time for the return of the laundered items to the laboratory was two weeks. On return to the laboratory, surface debris tapings (100-by-150-mm Scotch Tape 822 pads) were taken from the labeled lab coats. These were searched visually using low-power microscopy (10× Nikon SMZ 2B) for fibers originating from the target garment.

The second part of the study comprised an ''assailant'' wearing the knitted blue acrylic top and hugging/lifting followed by ''piggybacking'' a ''victim''—each for 10 s. All of the ''victims'' were laboratory workers and the ''attacks'' were carried out at the end of the working day. The ''victim'' was instructed to remove his upper clothing for laundering on his return home. Since the purpose of this part of the study was to mimic a real-life scenario, no attempt was made to standardize activity after transfer, method of washing and drying, or time between transfer and removal of recipient garments. The length of time between the initial contact and garment removal was noted, as was the method of washing and drying and the fiber composition and type of recipient clothing. After drying, surface debris tapings were taken from the recipient garments and these were stuck to an A4 size polyester sheet according to a supplied template, for subsequent searching by the FX5 fiber finder (7).

(It is beyond the scope of this paper to describe the technical and operational details of this instrument, which can be obtained from Foster & Freeman). All surface debris tapings searched by the FX5 were checked visually for false inclusions and exclusions. None of the ''victims'' possessed items of a fiber type/color similar to the target garment in their homes.

In both parts of this study, all ''suspect'' fibers found on the tapings were removed and mounted individually in DePeX (BDH laboratory supplies, Poole, England) for subsequent comparison microscopy and MSP.

In order to give an indication of the baseline number of fibers transferred in each case, tapings were taken from a single recipient garment from each part of the study, immediately following contact ($\Delta T = 0$).

Results and Discussion

The results of both parts of the study show that despite significant post transfer activity, target fibers were still detected on some of the recipient garments after washing.

Table 1 shows the results of the first part of the study using the polyester/cotton polo shirt. Comparatively few transferred fibers were found remaining. In one case only were both fiber components of the target garment found.

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Since each of the recipient garments was sent out to an external laundering company, no information was available on the nature of the garment load these items were mixed with during laundering. To establish if any retained target fibers could have come from another source, three ''blank'' recipients were also sent after all the recipient garments had been returned to the laboratory. No target fibers were detected on these items. Nevertheless, the presence of only very small numbers of target fibers on some of the recipient items has to be of limited value, because the possibility of an external source for these target fibers in the washing load cannot be eliminated.

Interestingly, when the transferred fibers were initially examined microscopically, all were found to match under white light, but showed marked differences in terms of ultraviolet (UV) and blue fluorescence from the controls taken from the target garment. In order to find out if these differences could be attributable to the presence of optical brighteners, a piece of the target garment fabric was cut out, stapled to a lab coat (used purely as a ''vehicle''), and sent for laundering as normal. On return to the laboratory the treated fabric was examined and found to match the recovered fibers in both white light and fluorescence microscopy. To eliminate the possibility of secondary contact with the recipient items during laundering, this procedure was carried out after all the recipient garments had been returned to the laboratory.

TABLE 1—*Number of target fibers recovered after washing (orange polyester and cotton).*

Lab Cost	No. of Matches
1	2 cotton 3 polyester
2	3 polyester
3	2 polyester
4	1 polyester
5	1 polyester
6	1 polyester
7	1 polyester
8	1 polyester
9	1 cotton
10	0
11	0
12	0
13	0
14	0
15	0

NOTE: >200 fibers (est. 74% polyester, 26% cotton) recovered from lab coat at $\Delta T = 0$.

Table 2 shows the results of the second part of the study using the blue acrylic sweater. A wide variation was found in the number of recovered matching fibers, with no apparent pattern emerging in terms of garment type, time of wear, etc. No effect attributable to optical brightener was observed.

The FX5 fiber finder appeared to perform well with this fiber type—in no instances did the human searcher find fibers where the machine did not. The number of false inclusions by the machine were compatible with that of a human searcher using low-power microscopy. In situations where the FX5 found more than 100 fiber ''hits,'' 20 of these were randomly selected and removed for further comparison. In each case where this situation arose, all of the randomly selected fibers were found to match the target garment fibers.

Figure 1 shows the size distribution frequency for blue acrylic fibers recovered from all recipient garments ($\Delta T > 0$), compared with those found on a polyester/cotton shirt at $\Delta T = 0$. The comparison of size distribution indicates that the larger fiber fragments are lost, preferentially following contact; this finding is in agreement with other retention studies (1–3).

The results show no discernible pattern of numbers of retained fibers with time or garment type. The variations in washing, post-transfer activity, time, and drying methods for each garment negate any attempt to predict the likelihood of recovering transferred fibers after washing. It would seem logical, however, that in situations where the rate of loss of transferred fibers has been minimized (for example, favorable post-transfer time and activity), then the chances of fibers being retained after washing may be greater. In this study, post-transfer time (ΔT) in itself did not prove to be a determining factor as some of the garments retained more fibers than those with a shorter ΔT. The variability of the force of the initial transfer may be one explanation for the differences in persistence between similar garments, as similar studies (2,3) have

TABLE 2—*Number of blue acrylic fibers retained after washing.*

Garment/No.	Fiber Comp.	Washing Method	Drying Method	ΔT (h)	No. of FX5 Hits	No. of ''Agreed'' Hits	No. of Matches[a]
1. Shirt	Poly/Cot	machine	indoor	6	2	2	2
2. Sleeveless top	Acr/Nyl	machine	indoor	4	1	1	1
3. Sweatshirt	Cot	machine	outdoor	3	5	1	1
4. Shirt	Poly/Cot	machine	indoor	2	2	0	0
5. Shirt	Poly/Cot	machine	indoor	2	19	9	3
6. Blouse	Vis/Nyl	machine	indoor	1	2	2	2
7. Shirt	Poly/Cot	machine	indoor	1	0	0	0
8. Shirt	Poly/Cot	machine	outdoor	4	1	0	0
9. Top	Vis	machine	indoor	1	34	29	29
10. Blouse	Poly	machine	indoor	7	21	21	19
11. Shirt	Poly/Cot	machine	indoor	1.5	117	20[b]	20
12. Blouse	Cot	machine	indoor	2	21	21	19
13. Blouse	Silk	hand	indoor	4	3	2	2
14. Body stocking	Cot	machine	indoor	2	>100	20[b]	20
15. Blouse	Silk	machine	indoor	0.5	0	0	0

Vis = Viscose, Cot = Cotton, Acr = Acrylic, Nyl = Nylon.
[a]Matches after microscopy and microspectrophotometry (Nanospec 200 AFT).
[b]Denotes randomly selected agreed FX5 hits.
ΔT = Time between contact and removal of garment.
>200 fibers recovered from polyester/cotton shirt at $\Delta T = 0$.

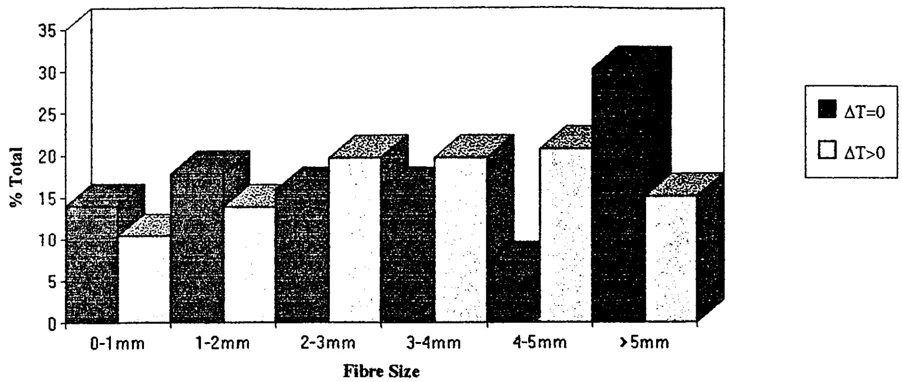

FIG. 1—*Fiber size distribution.*

shown that higher-pressure contacts between donor and recipient garments result in greater persistence. It has been postulated (4) that fibers which persist a long time after transfer do so because they are strongly bonded mechanically to the recipient garment.

The presence in some cases of high numbers of persisting transferred fibers in this study suggest that washing a garment may not be efficient in removing these as perhaps expected. Some possible explanations for this are:

(*a*) The transferred fibers may be strongly bonded to the recipient fabric and therefore resist removal by washing.

(*b*) What fibers are removed by the washing process will end up as a suspension, which as the water is drained (as in an automatic washing machine) or removed (hand washed) will be repopulated/redistributed to a lesser or greater extent on the recipient garment. The redistribution of transferred fibers on a recipient garment as a result of washing has been demonstrated in a study similar to the present one (3).

(*c*) If a garment has been folded over on itself or pulled inside out, then this may decrease the amount of transferred fibers being lost into suspension.

Although each of the above points (or combinations of them) may provide explanations why transferred fibers persist after washing, clearly if a large number of transferred fibers are retained immediately prior to washing, then this in itself has to be a significant determinant.

Conclusion

The objective of this study was not to look into any one salient aspect of fiber transfer/persistence, but rather to try to mimic a real-life scenario and establish the outcome. The results show that transferred fibers can persist on recipient garments even after significant post-transfer time followed by washing; however, due to the many variables present in the described scenario, it is not possible to predict a successful recovery. The results also show that in the case of the blue acrylic target fibers used in the study, at least the Foster & Freeman FX5 Automated Fibre Finder appeared to perform as well as a human searcher.

The implications of the study are clear. In real casework, however, the need to check for alternative sources of the transferred fibers cannot be overemphasized.

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