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Effect of Garment Cleaning on the Recovery and Redistribution of Transferred Fibers

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ABSTRACT: In an attempt to remove incriminating evidence, a criminal may wash or dry-clean articles of clothing worn during the commission of a crime. This would be expected to remove contact trace material that might be present. In this study, articles of clothing were subjected to hand washing, machine washing, and dry cleaning following the transfer of fibers to them under simulated contact conditions. All three methods resulted in fiber loss, but the percentage of transferred fibers remaining varied from over 70% for any acrylic garment to less than 5% for a nylon garment, reflecting the persistence properties of these fabrics. In general, machine washing resulted in the poorest recovery of fibers. In all cases very few fibers in excess of 0.5 cm were recovered and there was some evidence of fragmentation of longer fibers. Fibers were also moved or redistributed away from the area of contact during cleaning.

KEYWORDS: forensic science, fibers, cleaning, clothing

It would not be unreasonable to expect some criminals to attempt to remove potentially damning evidence from clothing worn during the commission of a crime. The more obvious examples of this would be washing bloodstained clothing or semen stained underwear. It may be a less conscious act on the part of a criminal to attempt to remove fibrous contact traces. On an intuitive basis, cleaning might be expected to lead to fiber loss, although there is little factual evidence to evaluate the influence of cleaning. Saferstein [*1*], in discussing a murder case, has indicated that dry cleaning did not result in a total loss of transferred fibers. Following dry cleaning of a suit, six fibers, matching those of the victim's dress, were recovered from the jacket of the suspect.

This work was designed to investigate the effect of a number of cleaning methods on the subsequent recovery of transferred fibers.

Experimental Procedure

Textile Materials

A red 100% acrylic jumper of medium texture was used as a donor fabric for fiber transfer. Ten recipient garments (all previously worn) (Table 1) were used. In preliminary experiments, fibers were transferred using hand pressure as described previously [*2*]. This approach resulted

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TABLE 1—*Garments used as recipients for fiber transfer.*

Code	Fiber Type	Texture	Garment
R1	acrylic	medium rough	jumper
R2	acrylic	fine	jumper
R3	35% cotton, 65% polyester	fine	shirt
R4	35% cotton, 65% polyester	fine	shirt
R5	nylon	smooth	shirt
R6	nylon	smooth	shirt
R7	30% wool, 30% polyester, 40% mixed fibers	fluffy	jacket
R8	30% wool, 30% polyester, 40% mixed fibers	medium rough	jacket
R9	polyester	medium rough	jacket
R10	polyester	fine	jacket

in the following fiber length distribution: under 0.25 cm, 83%; 0.25 to 0.5 cm, 10%; 0.50 to 0.75 cm, 5%; and over 0.75 cm, 2%.

Thus, to study the persistence and redistribution of different fiber lengths, a different approach for fiber transfer was adopted. Fibers were removed from the donor garment and separated into the above four length categories. Approximately equal but known numbers of fibers from each length category were combined, and the "contact area" of the recipient pressed against the fibers using hand pressure. Any fibers not transferred were placed on the contact area and this was then folded and pressed together.

Recipient garments were then subject to:

(1) *hand washing*: the garment was washed, wrung, and allowed to dry;

(2) *machine washing*: the garment was included with other garments in a normal load and subject to a washing cycle before being dried; and

(3) *dry cleaning*: the garment was included with other garments in a normal load and subject to a commercial dry-cleaning cycle.

Following the wash cycle, fibers were recovered from different areas of the recipient garment (Fig. 1) using high adhesive tape and counted using a stereo microscope. All experiments were repeated three times.

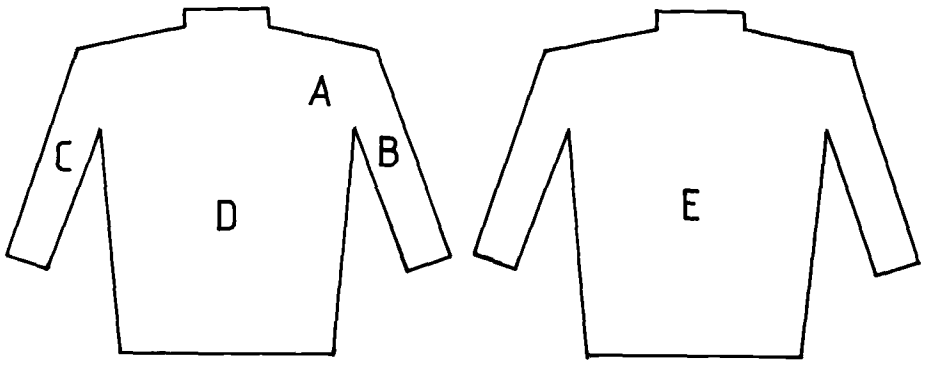
A range of precautionary measures were taken in the laboratory and during the wash cycles to eliminate contamination as far as possible. These involved considerable care in the handling of donor and recipient garments and the inclusion of "blanks," recipient garments with no transferred fibers in the wash cycles.

Only the occasional single red fiber was recovered from the blanks and never more than one fiber on any one garment.

Results were subject to analysis of variance using a minitab computer program.

Results and Discussion

In previous transfer and persistence work [*2,3*], fibers were transferred onto fabric squares, that were lined to aid in the counting of fibers. Preliminary work in this study using fabric squares pinned onto garments presented problems in that the squares sometimes became detached from recipient garments. Further, an important aim of this study was to examine the



A: area of transfer
B: remainder of left sleeve
C: right sleeve
D: front
E: rear

FIG. 1—*Diagram showing area of fiber transfer and areas subsequently taped.*

movement of fibers away from the contact area. Clearly, attaching fabric squares to garments might not give a true estimate of the effects of different cleaning methods where the fibers were not directly transferred to the recipient.

A second aim of this study was to examine the fate of fibers within different length categories. As only a very small percentage of fibers are normally found in the longer length categories using the standard transfer technique, it would be difficult to comment on the persistence and redistribution of these fibers. Thus, the approach described in the Experimental Procedure section was adopted in an attempt to overcome these limitations.

However, where comparison was possible preliminary experiments with fabric squares gave similar results to those obtained with whole garments (data not presented). The results for hand and machine washing can be compared as the same recipient garments were used. The garments subjected to dry cleaning bore labels indicating this as the preferred method for cleaning.

The results presented in Tables 2 and 3 show the percentage recovery of fibers for six garments subjected to hand and machine washing, respectively.

Total percentage recovery varied from approximately 75% down to less than 3%. Analysis of

TABLE 2—*Percentage of fiber recovery from recipient garments after hand washing: grouped by area of recovery.*

	Garment Code					
Area	R1	R2	R3	R4	R5	R6
A[a]	38.6 ± 6.5	22.0 ± 7.1	19.6 ± 3.2	30.0 ± 8.9	2.6 ± 0.4	0
B	14.0 ± 1.6	12.3 ± 2.4	12.0 ± 1.6	9.6 ± 2.4	3.6 ± 2.0	1.0 ± 0.8
C	8.0 ± 2.9	7.6 ± 0.4	5.0 ± 1.4	8.3 ± 1.4	2.0 ± 0.8	0.6 ± 0.9
D	4.6 ± 2.0	18.9 ± 3.7	8.9 ± 1.4	13.3 ± 3.6	3.3 ± 1.0	0.9 ± 0.7
E	9.3 ± 3.2	13.6 ± 4.1	7.0 ± 2.1	7.3 ± 5.7	0.6 ± 0.9	2.3 ± 1.2
% Total	74.5	74.4	52.5	68.6	12.1	4.8
% Redistribution	35.9	57.6	32.9	38.5	9.5	5.0

[a]Area of contact/fiber transfer.

TABLE 3—*Percentage of fiber recovery from recipient garments after machine washing: grouped by area of recovery.*

Area	Garment Code					
	R1	R2	R3	R4	R5	R6
A[a]	21.0 ± 4.9	10.6 ± 7.4	6.0 ± 4.0	3.6 ± 3.2	0	0
B	18.0 ± 8.6	2.0 ± 0.8	13.0 ± 5.7	8.0 ± 2.9	2.0 ± 0	1.0 ± 0.8
C	9.6 ± 0.9	2.3 ± 0.9	7.6 ± 1.2	7.0 ± 4.9	1.6 ± 1.2	0.3 ± 0.4
D	12.6 ± 2.0	4.6 ± 0.2	16.3 ± 2.0	14.3 ± 5.6	2.6 ± 1.5	1.0 ± 0.4
E	8.3 ± 2.8	2.6 ± 1.2	8.0 ± 2.9	7.0 ± 9.2	1.3 ± 1.2	0.6 ± 0.4
% Total	69.5	22.1	50.9	39.9	7.5	2.9
% Redistribution	48.5	11.5	44.5	36.4	7.5	2.9

[a]Area of contact/fiber transfer.

variance for the hand washed garments showed that the area of fiber recovery and garment type gave significant[3] variation and there was a significant interaction between these two factors. However, only the garment type gave a significant effect when garments were machine washed.

This difference can be attributed to the greater redistribution of fibers caused by machine washing. With the exception of Garment R2, the overall fiber recovery after hand and machine washing from recipient garments was comparable. That there was no significant difference between hand and machine washing with the data from area distribution was confirmed by a three-factor analysis of variance. Clearly, fiber recovery was related to the fiber composition of the recipient garment with acrylic proving the best fabric for fiber retention followed by polyester, then cotton, and very low retention by nylon fabrics. Percentage redistribution away from the area of contact (A) was always considerable and, with nylon fabrics, almost complete.

Tables 4 and 5 show the percentage recovery of fibers for the same six garments subjected to hand and machine washing, but with the data expressed in the size categories. These percentages should be compared against 25%, the original level of transfer for fiber size ranges a, b, c, and d.

Analysis of variance for the hand washed garments showed that the size of fibers and garment type gave significant variation (at the 5% level). The same factors were significant at the 1% level with machine washed garments. There were no significant interactions. A three-factor analysis of variance showed no significant difference between the two methods of cleaning.

Fiber recovery from nylon garments was at such a low level that no sensible interpretation can be made as to the effect of fiber size on subsequent recovery.

With the hand washed garments, loss of longer fibers in excess of 0.5 cm was greater than for shorter fibers. In fact, with acrylic recipients, in some cases a larger number of fibers were recovered in the 0- to 0.25-cm category than were originally transferred. This may be explained by either the presence of contaminant fibers or by fragmentation of longer fibers during the wash cycle. Blank trials, described in the Experimental Procedure section, indicated no significant occurrence of spurious, extraneous fibers.

The trends described for hand washed garments were even more obvious with machine washed garments where loss of fibers 0.5 cm and above was even more marked. One exception to the greater recovery of fibers less than 0.25 cm in length was found with Recipient R2 which is reflected in the low overall fiber recovery.

As different garments were used for dry cleaning, the data relating to dry cleaning are not directly comparable to the effects of hand or machine washing. Table 6 shows fiber recovery for

[6]Unless otherwise stated, all significant results were at the 1% level.

TABLE 4—*Percentage of fiber recovery from recipient garments after hand washing: grouped by fiber length.*

	Fiber Size Range, cm	Garment Code R1	R2	R3	R4	R5	R6
a	<0.25	28.6 ± 3.0	27.0 ± 6.3	18.6 ± 1.6	21.3 ± 2.0	8.0 ± 4.5	3.6 ± 2.8
b	0.25 to 0.50	14.6 ± 3.3	19.0 ± 2.4	11.3 ± 1.8	17.0 ± 0.8	1.4 ± 0.4	0.3 ± 0.4
c	0.50 to 0.75	12.6 ± 1.2	15.8 ± 4.0	10.0 ± 0.8	14.6 ± 1.2	1.4 ± 2.3	0.6 ± 0.4
d	>0.75	18.7 ± 2.1	12.6 ± 2.8	12.6 ± 2.0	15.6 ± 1.6	1.3 ± 1.2	0.3 ± 0.4
% Total		74.5	74.4	52.5	68.5	12.0	4.8

TABLE 5—*Percentage of fiber recovery from recipient garments after machine washing: grouped by fiber length.*

	Fiber Size Range, cm	Garment Code R1	R2	R3	R4	R5	R6
a	>0.25	32.3 ± 4.7	9.0 ± 4.3	25.6 ± 12.6	26.3 ± 22.4	5.0 ± 1.6	2.3 ± 0.4
b	0.25 to 0.50	21.3 ± 2.8	4.0 ± 1.6	13.6 ± 8.0	8.6 ± 8.0	1.6 ± 1.2	0.3 ± 0.4
c	0.50 to 0.75	10.3 ± 2.0	4.0 ± 3.5	6.1 ± 5.6	3.6 ± 0.4	0.3 ± 0.4	0
d	>0.75	5.6 ± 2.6	5.1 ± 4.9	5.6 ± 5.1	1.4 ± 0.9	0.6 ± 0.9	0.3 ± 0.4
% Total		69.5	22.1	50.9	33.9	7.5	2.9

TABLE 6—*Percentage of fiber recovery from recipient garments after dry cleaning: grouped by area of recovery.*

Area	Garment Code R7	R8	R9	R10
A[a]	3.6 ± 0.9	11.0 ± 5.7	4.0 ± 3.7	6.0 ± 1.6
B	8.0 ± 2.9	7.6 ± 4.4	7.6 ± 6.0	8.6 ± 4.9
C	6.3 ± 0.9	4.0 ± 2.9	9.6 ± 3.2	9.3 ± 4.4
D	14.3 ± 1.3	9.6 ± 3.1	10.0 ± 5.3	8.9 ± 3.2
E	7.6 ± 3.0	7.0 ± 3.7	8.6 ± 2.0	4.6 ± 2.0
% Total	39.8	39.2	39.8	37.4
% Redistribution	36.2	28.2	35.8	31.4

[a] Area of contact/fiber transfer.

the different areas of four garments. Analysis of variance gave no significant variation between the garments or within the areas. In all garments percentage recovery was in the order of 40% with between 30 and 35% of those fibers being recovered from areas of the garment away from the point of contact.

When the recovered fibers were classified into size categories (Table 7), analysis of variance gave a significant difference for the recovery of different fiber length categories with no difference between garments. Clearly, the longer the fiber the poorer and recovery with again an indication of possible fiber fragmentation producing shorter fibers for Recipients 9 and 10. These garments were 100% polyester while R7 and 8 were mixed fiber composition.

TABLE 7—*Percentage of fiber recovery from recipient garments after dry cleaning: grouped by fiber length.*

	Fiber Size Range, cm	Garment Code R7	R8	R9	R10
a	<0.25	24.3 ± 2.0	21.0 ± 10.2	32.0 ± 16.7	31.9 ± 14.5
b	0.25 to 0.50	10.3 ± 2.4	12.3 ± 5.4	7.0 ± 7.7	3.6 ± 1.2
c	0.50 to 0.75	3.0 ± 2.4	4.6 ± 0.8	0.8 ± 0.90	1.3 ± 0.9
d	>0.75	2.3 ± 0.9	1.3 ± 0.9	0	0.6 ± 0.9
% Total		39.9	39.2	39.8	37.4

Conclusions

The results of this study indicate that:

1. The number of fibers retained by clothing following cleaning depends on the fiber composition and, to a lesser extent, fabric texture of the recipient garment.
2. There is little difference in overall retention when hand washing is compared to machine washing, but the latter results in greater movement of fibers away from the original area of fiber transfer.
3. Although it is not possible to compare directly hand and machine washing with dry cleaning, as different fabrics were used, the same trends for persistence and redistribution were shown for dry cleaning.
4. Longer fibers are lost to a greater extent than fibers under 0.25 cm in length, irrespective of the method of cleaning.
5. There is an indication that fibers may be broken or fragmented during washing.

It may be concluded from the results of this study that it is worth examining clothing for extraneous fibers even when it is known that the garments have been cleaned. However, caution should be applied in placing any importance on the positioning of such fibers because of the movement of fibers away from the original area of transfer.

Acknowledgment

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