Effect of Textile Substrate and its Processing on Blood Staining Pattern

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Abstract:
Modern lifestyle has paved the way for different textile materials in human life. People are interacting with various textile materials like floor coverings, couch spreads, articles of clothing and other miscellaneous applications. Additionally, our chaotic lifestyle results in different kinds of stains on textiles like tea, coffee, ketchup, etc. Bloodstain is one such stain usually found at a crime site. The impact of bloodstains on textile material depends on numerous factors like substrate nature, its texture, fiber composition, finishing treatments, room conditions, etc. Bloodstain Pattern Analysis (BPA) is a central issue of cutting edge logical research encompassing various factors associated with textile material. Out of these variables, in this paper, we have studied the effect of bloodstains on 200 gsm woven and nonwoven fabric after bleaching and bleach mercerization treatment. The same blood drop volume was used at different heights between the substrate and blood syringe to assess the impact.
Keywords: *Bloodstain pattern, Blood spread area, Fabric, Textile, Nonwoven, Woven.*

I. INTRODUCTION

Bloodstain pattern investigation began around 1895 in Poland by Eduard Piotrowski at the University of Vienna [1]. The greater part of the initial work was concentrated on bloodstain patterns on hard substrates. There is a dearth of research on modern textile materials and their bloodstain pattern behaviour. All things considered, textile material like shades, couch covers, clothes, tissue papers, covers and so on are typically the most accessible segment at a crime scene; one can get a great deal of data from this in the investigation process.

The complex and varied nature of textiles make bloodstain pattern analysis very knotty and challenging. The textile material properties vary with environmental conditions such as temperature, relative humidity and other variables such as type of finish, fabric construction type, fibre/ yarn types, blends and nature of textile. This complex nature of textiles has resulted in interest among researchers to understand the impact of these factors on bloodstain patterns.

Holbrook (2010) studied the resultant state of bloodstain pattern influenced by fabric qualities such as fabric material and absorbency. De Castro et al (2013, 2016) studied 100% Polyester and 100% treated cotton fabric and found that the blood drop stains were affected by various elements such as pre-washing, fibre substance and texture of the fabric. Taupin and Cwiklik (2011) stated that the texture of the fabric has an impact on bloodstain pattern; for example, whether it is woven or knitted. Taylor et al (2016) found that bloodstain analysts were unable to decode bloodstain patterns on textiles due to numerous factors associated with textiles like material type, manufacturing methods and advanced chemistry involved in the processing of textiles. The rapid improvements in textile manufacturing methods and finishing chemistry has made it increasingly difficult for bloodstain pattern analysts to comprehend the potential effect of these variables on the size, shape and flow of the bloodstain on textiles. This may result in wrong stain testing, or more regrettable, experimentally unsupportable or deceptive interpretative submissions.

Presently, nonwoven fabrics are being increasingly used for clothing in addition to their base applications in textiles such as wipes, cushions, etc. Nonwoven fabrics have unusual structure and properties, which is in contrast to both woven and knitted fabrics. Thus it is important to consider the blood staining pattern on nonwoven fabrics. In this research, bloodstain pattern examination was carried out on bleached and bleach mercerized woven and nonwoven textures.

II. MATERIAL AND METHOD

2.1. Fabric Manufacturing Methods:

Woven and nonwoven fabric of 200 gm/mtr^2 was produced from 100% cotton material on CCI SL 8900 sample weaving machine and Dilo Needle Punched sample machine respectively. Table 1 shows the process parameters followed for woven and nonwoven fabric.

TABLE 1 PROCESS PARAMETERS FOR WOVEN AND NONWOVEN FABRIC SPECIMEN

Weaving Process	**Nonwoven Process**
Fabric Width = 500 mm	Fabric Width = 500 mm
Weaving Technology – Gripper	Nonwoven Bonding Technology – Needle Punching
Machine RPM - 45	Needle Frequency – 800 strokes/min, 30 mm stroke
Machine Type – Single Head	Needle Stroke Arrangement – Double Up and Down
Weave – 2/1 Twill	Needle Density- 120 needles/inch^2

2.2 Fabric Finishing Parameters:
The produced samples were bleached using Peroxide method and then mercerized in relaxed conditions in the lab using standard recipe and process. The samples were then washed, neutralized and dried in the oven.

2.3 Blood Drop Impact Instrument:
The specimen was placed on a platform of fabricated (devised) instrument. The syringe carrying human blood was adjusted at a height of 30 cm, 40 cm, and 50 cm to alter the blood impact force on the substrate. The same volume of blood was dropped on the fabric from these heights to analyse the bloodstain pattern on fabric specimen. Furthermore, the syringe was held exactly perpendicular to the fabric specimen as shown in Figure 1 depicting the schematic diagram of the instrument used for testing the bloodstain pattern analysis.

2.4 Test Methods:
The bleached and bleach mercerized fabric specimens were tested as per ASTM standard methods for thickness, air permeability and water absorbency by sinking method and drop test method. Bloodstain pattern on specimens was characterized by blood spread area calculated using the graphical method.

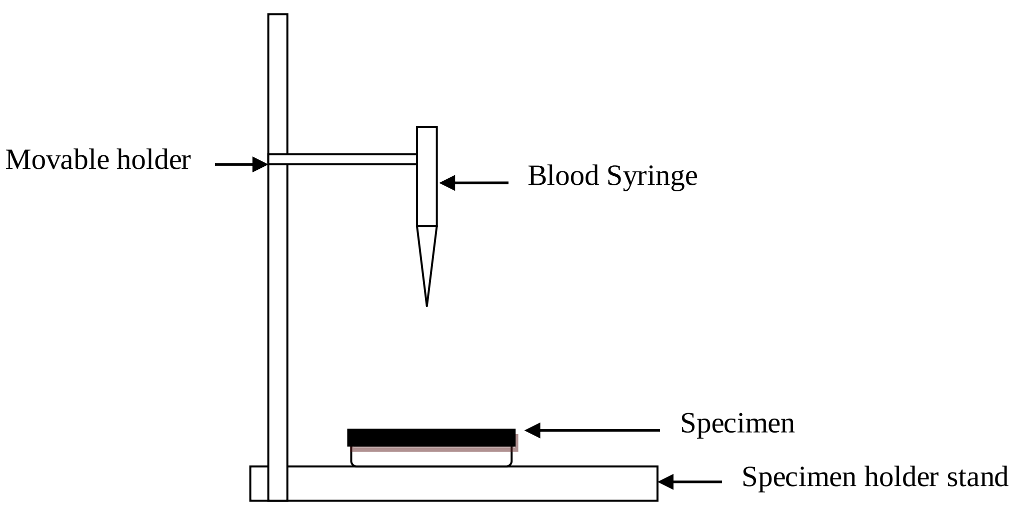


FIG 1 SCHEMATIC ARRANGEMENT OF BLOOD DROP INSTRUMENT

III. RESULTS AND DISCUSSIONS

3.1. Fabric Thickness, Water Absorbency, and Air Permeability:
Due to the very nature of the fabric forming method, nonwoven fabric shows higher thickness, bulkiness, porosity and air permeability than woven fabric having the same areal density as shown in Table 2.
Bleach mercerized specimen shows greater thickness than bleached specimen of woven and nonwoven fabric because mercerization was carried out under a relaxed state, and during mercerization, cotton material swells. This swelling is more prominent in nonwoven fabric than woven fabric due to its bulkiness.

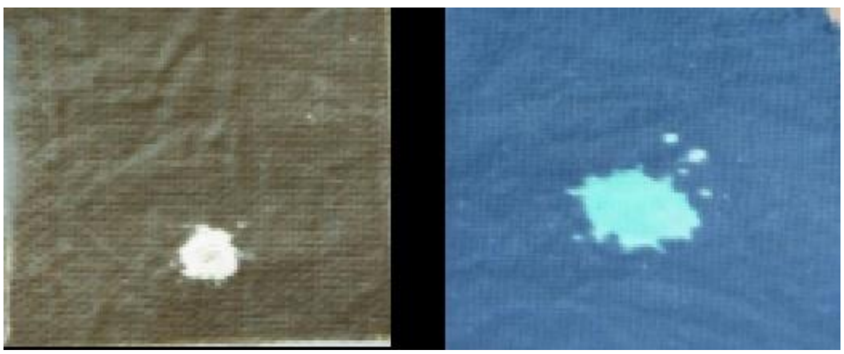
TABLE 2 TEST RESULTS OF WOVEN AND NONWOVEN FABRIC SPECIMEN

Test Parameter	Woven Specimen		Nonwoven Specimen	
	Bleached	Bleach-Mercerized	Bleached	Bleach-Mercerized
Thickness (mm)	1.07	1.38	3.09	5.9
Air permeability (cm^2/cm^3/sec.)	122.6	117	174	165
Absorbency (sinking method) (sec.)	NA	48	NA	20
Absorbency (Drop Test)	NA	Instant	NA	Instant

Single Factor ANOVA shows that air permeability of bleached and bleach mercerized woven (p-value = 0.215 > 0.05) and nonwoven (p-value = 0.351 > 0.05) fabric is not statistically significant. But the thickness of the woven and nonwoven specimen shows statistically significant change (p-value = 0.000 < 0.05) between bleached and bleach-mercerized specimens. Water absorbency of both fabrics increased after the mercerization process.

3.2. Blood Stain Pattern:

Bloodstain pattern analysis is characterized by blood spread area on fabric specimen. Table 3 shows the blood spread area for bleached and bleach mercerized woven and nonwoven specimens for different drop heights. As drop height increases, the blood spread area also increases because of the impact force at which blood is interacting with the textile substrate. This is true for bleached and bleach mercerized woven as well as nonwoven fabric specimens.



(a) (b)

FIGURE 2 BLOODSTAIN PATTERN ON FABRIC FOR BLOOD DROP HEIGHT OF 30 CM
(a) Bleached specimen, (b) Bleach-Mercerized specimen

Blood spread area of bleach mercerized specimens of woven and nonwoven fabric is higher than the bleached woven and nonwoven specimen. Since the mercerization process increases the affinity of specimen towards water, which helps in spreading of blood on the specimen through wicking action, therefore bleach-mercerized samples of woven and nonwoven fabric show higher blood spread area compared to bleached fabric samples.

The blood spread area of bleached and bleach-mercerized nonwoven fabric is less than that of woven fabric as a result of porous and fibrous nature of nonwoven fabric, which allows blood to diffuse into the fabric structure whereas, in case of woven fabric, due to flat, compact structure, blood spreads over the area.

TABLE 3 BLOOD SPREAD AREA FOR DIFFERENT SPECIMENS

Blood drop height (cms)	Blood Spread Area ($inch^2$)			
	Woven Specimen		Nonwoven Specimen	
	Bleached	Bleach-Mercerized	Bleached	Bleach-Mercerized
30	0.1404	0.3086	0.1463	0.1711
40	0.1886	0.3204	0.1498	0.1908
50	0.2374	0.3462	0.1503	0.2246

Two factors ANOVA with replication shows that the blood spread area of woven and nonwoven fabric is significantly affected by both blood drop height and the treatment given to fabric sample as shown in Table 4 and Table 5 by p-value, which is less than 0.05.

TABLE 4 TWO FACTOR ANOVA FOR WOVEN FABRIC SPECIMEN

Source of Variation	SS	df	MS	F	P-value	F crit
Treated Woven Samples	0.159461	1	0.159461	650.2863	6.78E-19	4.259677214
Blood Drop Height	0.0334	2	0.0167	68.1031	1.28E-10	3.402826105
Interaction effect	0.010462	2	0.005231	21.33283	4.74E-06	3.402826105
Within	0.005885	24	0.000245			
Total	0.209209	29				

TABLE 5 TWO FACTOR ANOVA FOR NONWOVEN FABRIC SPECIMEN

Source of Variation	SS	df	MS	F	P-value	F crit
Treated Woven Samples	0.016497	1	0.016497	770.6093	9.42E-20	4.259677
Blood Drop Height	0.004243	2	0.002122	99.10654	2.52E-12	3.402826
Interaction	0.003077	2	0.001538	71.85683	7.37E-11	3.402826
Within	0.000514	24	2.14E-05			
Total	0.024331	29				

IV. CONCLUSION

The fabric structure and treatment plays an important role in controlling bloodstain pattern on fabric. Nonwoven fabric, being porous and permeable, the fibrous structure does not allow blood to spread over the fabric area, but absorbs the blood into its structure. Whereas, the woven structure is flat, which enables blood to spread over an area. As a result, bloodstain area is greater in case of woven fabric than nonwoven fabric. Also, mercerization makes the fabric more absorptive due to which blood spreads over a wider area on fabric than on bleached fabric of both types. Therefore, while analysing bloodstain pattern on fabric, its structure and the type of chemical treatment given has to be considered.

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