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The Persistence of Body Fluids on Fabrics in Various Water Environment: A Mini Review

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Abstract: ***The body fluids detected at a crime scene can provide a lot of valuable information regarding the events which may have occurred and the individual(s)involved in the crime that may aid the investigation. Blood and semenare among the most significant body fluids, others include saliva, urine and faeces. The DNA profile obtained from these fluid stains can be extremely useful in the identification of the culprit(s) in cases of death by suicide, homicide, strangulation, kidnapping, drug abuse, harassment, among others. While evidence collection is performed as soon as the crime has occurred and reported, there are instances when there might a time delay between the occurrence and reporting of the crime. In such cases, the stained fabrics may have been submerged in water depending on the type of crime scene. Retrieving valuable information from such evidences can be challenging, In the present review, a detailed examination of the methodologies given in the literature for the analyses of body fluid-stained fabrics has been performed.***

Keywords: Persistence, body fluids, fabric stains, water environments, forensic investigation

1. Introduction

The primary purpose offorensic investigation is to find evidences that can link the criminal with the crime. The identification of different body fluids such as semen, blood, saliva, breast milk, vomit, urine,sweat and faecal matter is performed in various forensic serology cases. These fluids play a crucial role in criminal investigations and theirpresence on fabrics must be identified based on chemical and instrumental methods. Many body fluid stains remain undetectable or are present in very small amounts such thatthe evidence is not sufficient to be presented in the court of law to support the case[1]. In cases where violent crimessuch as rapes, assaults, and robberies, these fluids play a significant role in identification of the criminals as these might be the only connecting link between the suspect, victim and crime in accordance with the Locard's Principle of Exchange. In general, apart from blood and urine which maybe found in fluid state, these fluidsare either collectedas wet or dry messes on garments, fabric pieces, floor, dividers, and/orothersurfaces, oras swabsfrom the belongings of the suspect/victim [2]. Such fluids/ stains/ swabs recovered from a crime scene are of a great importance to forensic investigators since they contain significant DNA evidencefor criminal profiling thatprovides evidence for the identification of individuals involved in the crime [3].

In violent criminal cases such as sexual assaults, the stained fabric may be subject to submersion in water either intentionally or accidently. In either case, body fluid stains may only persist on the fabric for a certain period of time. Therefore, the study of the persistence of body stains and their detection on fabrics is significantto establish the identity of individuals involved in the case.

Body stains are often found on clothes of individuals, carpets, curtains, and other upholsteryfabrics. There is wide range of fabrics with various characteristics that are used in different world regions for their different properties. The properties of the fabric is important in forensic serology cases as they would absorb fluids to different degrees and the stains would thereforebe available on the fabric for variable periods of time[4-6].In India, the most commonly used fabrics include cotton, linen, jute, silk, wool, georgette, and velvet and a brief description of these fabrics is given in Table 1.

2. Body Fluids

Different body fluids are encountered in forensic cases especially those of a violent nature. When the fluids come in contact with the fabric in the surrounding of the suspect and/or victim, these are absorbed as stains by various degrees depending on the property of the fabric. The detection of such fluid stains may be a challenge especially when the fabric is recovered from water environments in fully or partially submerged conditions.

2.1 Semen

During the investigation of sexual assault cases, semen is the main biological evidence that is examined to create a DNA profile to distinguish the identity of the perpetratorfrom other suspects and victim [30-32].Semen is most likely recovered from the body and clothing of the victim as the perpetrator fails to use any contraceptives [33].

Table 1: Commonly encountered fabrics in Forensic Cases

S.No.	Fabric	Origin	Description	Properties	Reference
1.	Cotton	Cotton plant (*Gossypium*)	Primarily made of cellulose, are multi-layered, and give the appearance of a twisted ribbon.	These are crystalline in structure and are 25% stronger in wet conditions. Additionally, they get damaged by fungus, and are weakened when exposed to sunlight for prolonged periods of time. It is a good conductor of heat and easily catches fire. Cotton fibres can be extracted and bound together to form yarn which is used to spun cotton fabric. Mercerised cotton fabrics have increased strength and can be dyed better.	[7-9]
2	Linen	Flax plant (*Linumusitatissimum L.*)	Linen fabric is produced from very fine fibres which are obtained and is the oldest natural fibre.	Linen is similar to cotton in being a cellulose polymer, however its crystallinity is relatively higher, therefore it is stronger, crisper, stiffer and gets wrinkled more easily. Linen is one of the strongest fibres and is hydrophilic in character. Thus, the fibres swell by absorption of water uptake and that results in reducing its mechanical strength.	[10-14]
3	**Jute**	Jute plant (*Corchorus capsularis)*	Jute plant grows mainly in warm and moist regions and is one of the low-cost natural fibres.	The fibres have high tensile strength because of the crystalline cellulose content and low-cost are the main reasons for its use in making carpets, rugs and furniture coverings etc. However, these fibres have lower resistance to moisture, acid and UV light.	[15-16]
4	**Silk**	Cocoons of larvae of mulberry silkworms (*Bombyx mori*)	Silk fibres are among the most popular fabrics. Silk is known for its lustrous texture and mechanical strength, and the structure of silk is semi-crystalline.	Natural silk fibre is produced by coating the filament of the silk fibre, fibroin with a water-emulsifiable protein glue called sericin. Conformational changes of fibroin has also been reported upon immersing silk in water.	[17-20]
5	**Wool**	Sheep, goat, rabbit and other animals.	Wool fibres are one of the most commonly used natural fibres of animal origin.	These have excellent warmth-retaining property due to their hierarchical structure.The fibres are non-cellulosic and soak up water vapours from air, and, once immersed in water, they take up considerable amounts of liquid.	[21-24]
6	**Georgette**	Synthetic (woven silk)	Georgette is a fine, loose flowing, lightweight, matt fabric and is commonly used for making cheap to expensive garments.	Georgette silk fabric is made by plain weave with raw silk where it is twisted with mulberry silk that leaves a creased visual effect and to some degree rough touch feeling. Because of this unique structure, georgette stands apart from other silk fabrics [26]. Silk georgette is soft, has low tensile strength but is hard in compression [27].	[25-27]
7	**Velvet**	Synthetic and natural	Velvet is a smooth and shiny fabric which is comparable with the weave of silk, rayon and other synthetic fibres.	While originally, velvet was made from silk, in the present times it can be made from other fibres such as linen, cotton, wool etc. The water absorption property of velvet is poorer than other fabrics.	[28-29]

In cases where the time period between the commission of the crime and the examination of physical evidence is extremely important. As vaginal swabs can only test positive for semen for up to 24 hours, semen stains on the fabric may be the only evidence available for examination [33]. In water-submerged stained fabrics, the identification of spermatozoa, is dependent upon various factors. Due to increase in the water submersion time, spermatozoa and acid phosphatase testsmay give false negative tests. Additionally, natural water contaminants such as organic and inorganic particles in water can also lead to the deterioration of the seminal fluid [34].

Nabiet al. [35] in their study on persistence of semen on different fabric types in different water conditions havereported thatchiffon, silk, polyester,khaddar and linen textures can hold seminal material which can be identified even after 14 days. In contrast, it is also reported that a seminal stain that is left on a clothing for an extensive period before exposure to water will give better results than the one that is washed or submerged right after the deposition[36, 37,38]. However, In an effort to eliminate the evidences or because of the location of dead body, the fabric evidences may be washed with water. In a case reported by Bischof, a victim of rape was compelled to swim in order to destroy any evidence from the clothing of that victim [39].A similar case was reported in Sydney, in which the bodies of rape victims were forcibly washed after assault [40]. In another case,that was reported in 2014, the female victim was thrown into the sea after she was sexually assaulted by a cruise ship worker [41].Moreover, in most cases, the victims would themselves take shower, and wash or drench their garments right after the assault, that will significantly affect the recovery of the expected evidences[33].

2.2 Blood

Blood is among the most significant evidences that can be useful for establishing the link between the accused and crime and also in reproducing the crime scene by providing valuable for DNA evidence for profiling. Blood splatter is a common occurrence in most violent offences such as murder and assaults[42]. In an effort to eliminate blood evidence, the perpetrator will usually wash down the surfaces and objects such as clothing stained with blood [42, 43]. Due to washing, the concentration of blood can change, it can

become diluted and difficult to see with the unaided eye. Furthermore, washing can completely or partially remove the stains [43, 44], thoughthese may still be found even after washing the clothes with detergents. The use of cleaning agentsby the perpetrators to eliminate blood stains and other evidences from the crime scenemay result in denaturisation of protein for example, haemoglobin [45].

In a study on the detection of dried bloodstains on various fabrics, Mushtaqet. al. have reported that even after washing with detergents, cotton and khaddar retain bloodstains. Other fabrics such as nylon or polyester, bloodstains showed different concentrations of bloodstains as these were easier to remove from such fabrics [46]. In another study [47]on the identification of bloodstains on cotton fabric, the researchers found that hand washing in cold water (30°C) did not eliminate or totally obliterate the stains although, machine washing in steaming hot water (60 and 95°C) with a commercially available detergent adequately eliminated apparent bloodstains, even though positive results for blood were found for all the samples. Therefore, it was concluded that detection of stains of blood is possible on cotton fabrics even after the fabrics are washed in machine with detergents.However, in a study by Ünsal Sapan, et.al.[48]an effort was made to collectDNA after washing fabrics of cotton and nylon with detergent at 40 °C, 60 °C and 90 °C. The researchers reported loss of DNA on comparison of fabrics of nylon with fabrics of cotton because of the non-absorbent nature of fabric of nylonthat was more permeable. Additionally, the rate of DNA extraction from the stains of blood on various kinds of clothing on washing at a various temperature ranges was also variable. Nonetheless, bloodstains on fabrics are excellentsource of evidence that can be useful in revealing the identity of the criminal and therefore, their must be identified even on water-soaked fabrics.

2.3 Saliva

In forensic investigations, saliva is often found on cigarette butts, the edges of cups, the rims of bottles and other places. Saliva can also be found in an cases of sexual assaults [49]. The identification of saliva on these surfaces might assistin crime scene investigations to reveal the identity of individuals present at the crime scene [50-52]. Furthermore, DNA can also be recovered from the cellular material present in the saliva. Saliva stains have been identified in a range of fabrics such as cotton, fleecy and denim,polyester/cotton blend[53].

2.4 Urine

Dried urine stains are usually found on a crime scene and are recovered majorly from the upholstery fabric [54]. It is challenging to perform non-destructive detection and confirmation of urine stains from a fabric as urine is a heterogeneous body fluid and its composition varies in species, individuals and even in the same individual due to various factors such as diet, medical history, water intake, among others[58].Urine is made of 95% water and the remaining 5% consists of metabolites, urea, organic compounds and salts [55]. Therefore, for confirmation of urine in forensic examinations, high concentrations of urine are normally required. Additionally, in a recent study [56] dried urine stains containing narcotic drugs were left on a cotton fabric. These were extracted by mixing the stains with distilled water, normal saline and other solutions. Results indicated that there was no effect of dissolution of urine sample with distilled water on the detection of narcotic drugs in the samples, although the fabric itself wasn't used directly.

A brief description of some of the commonly encountered body fluids in forensic cases is summarized in Table 2.

Table 2: Identification of body fluids

S.No.	Body fluid	Description	Presumptive/ Chemical test	Instrumentation	Reference
1	Blood	Most commonly encountered body fluid.	Haemoglobin in the blood is detected using Kastle-Meyer test.	Alternate light source(ALS) can be used for detection of latent blood stains. Attenuated total reflection (ATR) Fourier transform infrared (FT-IR) spectroscopy is used for non-destructive analysis of blood stains etc.	[57-58]
2	Saliva	Saliva cannot be identified by the naked eye because of the absence of noticeable constituents.	Starch-iodine test for amylase.	Fluorescence,colorimetric and/or immunochromatographic screening tests.	[58–59]
3	Urine	Urine stains are not easy to identify since they are generally pale, diffused and cover a large area.	Presumptive tests for urine generally detect the presence of urea, urease or uric acid.	For the confirmatory detection and identification of urine on the fabrics directly Raman Spectroscopy can be used which is a non- invasive and non-destructive technique.	[60-61]
4	Semen	The type of water-soluble enzyme found in a variety of living tissues, with seminal acid phosphatase (SAP) are acid phosphates that are 50 times more abundant in semen than in other body fluids.	The acid phosphatase (AP) test is the most frequent and long-standing method for presumptive testing of the semen. Microscopic inspection of spermatozoa is the most often used approach for confirming the identity of semen.	The cheap, secure and direct detection method used for detection of potential stains of semen present at the scene of crime is ALS (Alternate Light Source).	[62-63]

3. Conclusions

Body fluids are significantin crime investigations their identification can establish a link between the accused and the crime scene as these may be useful in DNA profiling of individuals. These fluids are mostly found as stains on surfaces and fabrics are the most abundant source in forensic cases. In violent crimes involving murders, sexual assaults and some cases of suicides, the body is thrown or hidden in water bodies; therefore, the detection of body fluids on fabrics becomes vital for investigation.These stains may be washed out partially or completely by submerging the fabrics in water intentionally or unintentionally. In some cases, the stains may get diluted or degraded and extraction may not be possible. In other cases the stains from body fluids may test positive in fabrics even after washing with detergents, dependent on the properties of the fabric. Highly absorbent fabrics like cotton can hold more stains as compared toloosely woven such as polyester and nylon. Additionally a stain that is remaining on a fabric evidence for a longer period prior exposure to water will give better result.The one that is washed or submerged in water immediately after the deposition. Several techniques can be employed for the extraction of such stains from different fabrics. While literature abounds with research on fabrics stained with semen, very few studies have been performed on blood, saliva, and urine. There is a need for further studies with regard to these fluids. This mini-review has highlighted the significance of testing of body fluid stains on fabrics for DNA profiling of individuals even after being recovered from different water environments days after attack.

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