FORENSIC ANALYSIS APPLICATIONS IN TEXTILE AND CHEMISTRY

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Abstract: *Evidence must be presented neatly and with care to solve forensic cases because the ability to resolve legal cases depends only on the availability of appropriate evidence. Evidence is used to uncover connections between the victim, the place and time of the incident, and the perpetrator in order to resolve the incident. One of the most important types of evidence examined in forensic investigations is textile materials. Because everyone who commits a crime or is a victim of crime is in contact with textile surfaces. Textile products such as clothing, furniture, knife marks on fabric, blood on car upholstery, vehicle upholstery found at the crime scene can be used as evidence to help solve the crime. During forensic examination, fibers can be classified according to certain criteria such as colour, shape, surface texture, thickness, fluorescent properties, and chemical composition. As a result of examining these classifications, the case can be clarified as quickly as possible. Otherwise, finding the perpetrator may become more difficult as time goes on.*

Keywords: forensic textile, luminol, textile evidence, Leucocrystal violet.

PRIMENA FORENZIČKE ANALIZE U TEKSTILU I HEMIJI

Apstrakt: *Za rešavanje forenzičkih predmeta dokazi moraju biti predstavljeni uredno i sa pažnjom jer sposobnost rešavanja pravnih predmeta zavisi samo od dostupnosti odgovarajućih dokaza. Dokazi se koriste da bi se otkrile veze između žrtve, mesta i vremena incidenta i izvršioca radi razrešenja incidenta. Jedna od najvažnijih vrsta dokaza koji se ispituju u forenzičkim istragama su tekstilni materijali. Jer svako ko počini krivično delo ili je žrtva zločina je u kontaktu sa tekstilnim površinama. Tekstilni proizvodi kao što su odeća, nameštaj, tragovi noževa na tkanini, krv na presvlakama automobila, presvlake vozila pronađeni na mestu zločina mogu se koristiti kao dokaz za pomoć u rasvetljavanju zločina. Tokom forenzičkog ispitivanja, vlakna se mogu klasifikovati prema određenim kriterijumima kao što su boja, oblik, tekstura površine, debljina, fluorescentna svojstva i hemijski sastav. Kao rezultat ispitivanja ovih klasifikacija, slučaj se može razjasniti što je brže moguće. U suprotnom, pronalaženje počinioca može postati teže kako vreme odmiče.*

Ključne reči: forenzički tekstil, luminol, tekstilni dokazi, Leucocristal violet.

1. INTRODUCTION

Trace evidence is a broad term that refers to "small, often microscopic fragments of various types of material that are transferred between people, places, and objects and remain there for an extended period of time." Trace evidence can be made up of a variety of materials, including hair, fiber, paint, soil, pollen, and Trace evidence is associative in nature in the context of a criminal investigation. Their forensic significance stems from the fact that trace evidence transmission can establish a link between suspects, victims, and crime scenes by implying contact between two people or between people and objects Textile fibers are without a doubt one of the most important forms of trace evidence because they have numerous classifications and subtypes, are physically and chemically distinguishable, can be processed in a variety of ways, and are easily transferable [1]. Individual fibers recovered from the crime scene and from an unknown source are compared to other fibers recovered from identified clothing belonging to a person suspected of being associated with the crime scene during forensic evaluation of textile fibers [2].

Textile materials play a significant role in forensic investigations. This is because everyone who commits a crime or is a victim of a crime comes into contact with textile surfaces. A pair of trousers, socks, a dress, or even an ordinary piece of fabric can be evidence that points to the murderer. In some cases, textile materials such as shirts, socks, belts, scarves, and pillows can also serve as crime tools [3]. Sometimes it is also possible to boldly solve murder cases using a typical fiber transferred from the murderer to the victim. Evidence of damage to textile products is extremely considerate in solving cases. Methods for analyzing textile damage are found by examining materials collected from the crime scene or by their photographs. Textile products that attract the attention of forensic scientists include fibers, yarns, fabrics, ready-made garments, home textiles, and furniture. These products are structures that build each other. Moreover, fibers form threads, threads form fabrics, and subsequently fabrics form textile products. These products can also be potential and meaningful evidence in criminal investigations. In some cases, potential evidence can also be considered as supporting evidence. Textile products should be scrutinized in detail. It is important to define a textile product using the terminology of the appropriate discipline correctly and completely [4].

1.1. Packaging Evidence

An evidence collector arrives at a crime scene armed with a variety of packing materials and tools, ready for any situation. To pick up small items, tweezers and similar tools can be used. Unbreakable plastic pill bottles with pressurized lids are ideal for storing hair, glass, fibers, and various other types of small or trace Most trace evidence found at crime scenes can also be stored in manila envelopes, glass vials with screw caps, sealable plastic bags, or metal pill boxes (Figure 1-A, B, C). To prevent the evaporation of volatile petroleum residues, charred material found at the scene of a suspicious fire incident must be packed in an airtight container. New paint cans or tightly sealed jars are advised in such cases (Figure 1-D) [5].

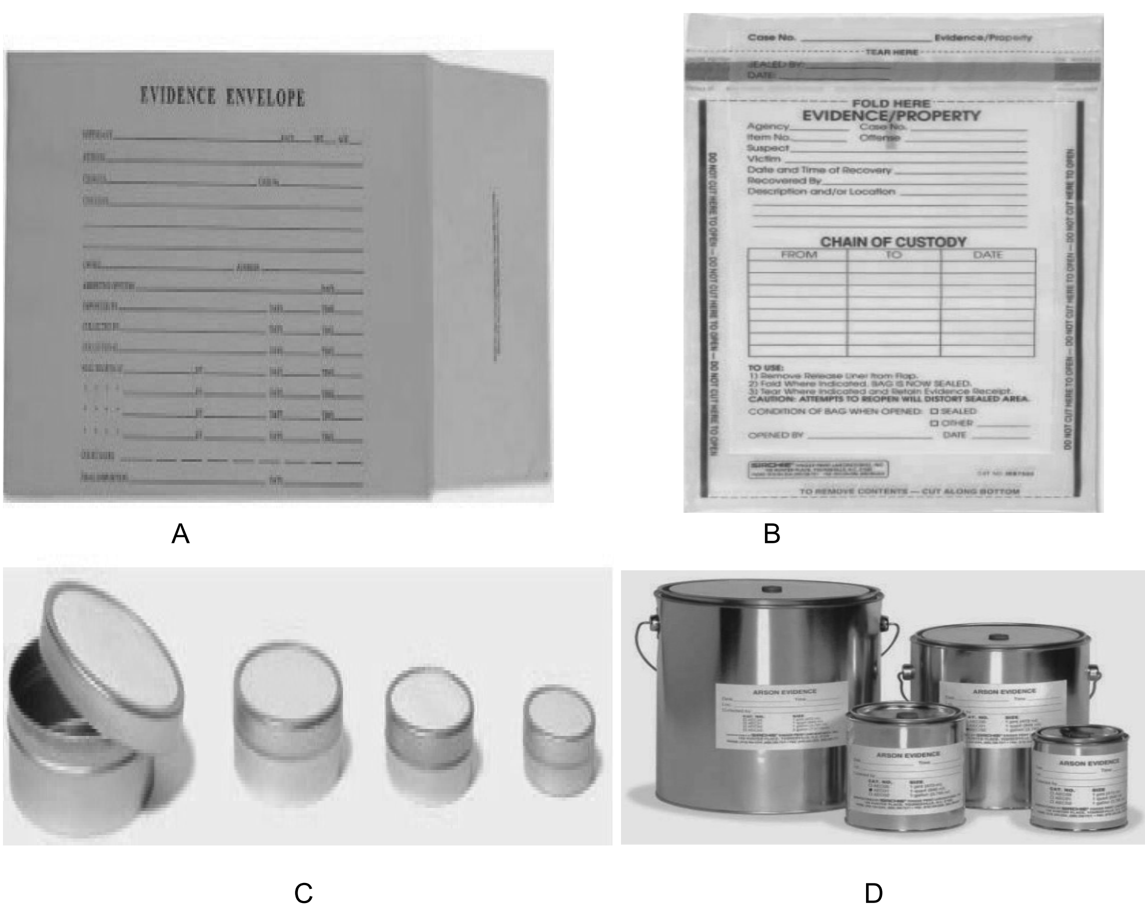


Figure 1: Evidence Containers [5]

2. BLOODSTAINS ON FABRICS

Bloodstain and pattern interpretation provides vital information and facts about crimes and accidents. The formation of bloodstains on nonabsorbent surfaces such as glass as well as semi-absorbent hard surfaces such as paper has been extensively studied However, less research has been conducted on absorbent surfaces, such as fabrics. Fabric, when compared to non-absorbent surfaces, can change the appearance and characteristics of bloodstains. The spread of blood on or in fabrics can alter the size and shape of a bloodstain, for example, large block-shaped stains can form on absorbent surfaces like glass, whereas circular stains form on nonabsorbent surfaces like glass. Because identifying and classifying bloodstains on fabrics is challenging due to their distortion (many sizes, appearances, and characteristics), we are currently limited in our capacity to effectively identify and describe them. For forensic analysts and/or scientists to interpret stained textiles in criminal investigations, they require a better and unambiguous understanding of the interactions between blood and textiles [6].

The analysis and examination of bloodstains and their forms helps us to have a clear concept about forensic events. Bloodstains are unambiguously important to forensic events. Bloodstains on various surfaces can be used in some cases to confirm or refute a person's testimony. Bloodstains can change the appearance and properties of fabrics. Blood splatter on or in fabrics can change the size of the fabric. When blood affects a fabric, it first touches a single spot, then collapses and the liquid molecular layer spreads across the fabric. As a result, the fabric may shrink. But bloodstains can sometimes be found on people who help the victim. This is an example of how bloodstains cannot always be used as an accusation.

But transmission of bloodstains does not always mean an innocent interaction; they can also be splattered during attack, defense, or combat. A transferred bloodstain is a bloodstain that results from contact between a surface contaminated with blood and another surface [4].

3. DAMAGE ANALYSIS

Damage analysis of clothing is a crucial tool for forensic investigations. Among the many applications studied, comparison of damage to clothing and injuries to the body in the case of a traumatic death and analysis of evidence (such as blood, seminal fluid, vaginal secretions, and other bodily secretions) found on clothing can provide meaningful information. In the case of a death by firearm, gunshot residue on clothing is important to determine the distance of the shot and to identify the ammunition fired. In addition, examining the characteristics of the textile damage is important to have a clear understanding about the dynamics of an event or to verify the statement of a witness [7]. Textile damage investigation is a niche area of the forensic science, and it refers to the investigation and analysis of textiles that may have been damaged and usually has legal implications. Textile detachment morphology is another term that is frequently used. It is required to characterize the morphology of the damaged textile, yarns, and fibres, and relate them to the textile construction in order to identify forms of damage. The morphology of the textiles, yarns, and fibres at and near the textile damage in question contains the majority of the information that aids in determining the cause of damage. The majority of this morphology is assessed with the naked eye and at modest magnification (e.g., with a stereomicroscope). The data that can be recorded at this level varies greatly depending on the damage and the textile it encounters. Drawings, photographs, and notes can all be used to document the information [8].

3.1. Sharp-Force Damage

Kitchen knives and hunting knives are the most regularly utilized weapons in sharp force attacks, accounting for 49 percent and 23 percent of all attacks, respectively. Other sharp weapons, such as screwdrivers, broken glass, scalpels, scissors, wire, trash, axes, machetes, swords, crossbow bolts, and razor blades, can also be used to investigate. The more unusual the morphology of the destroyed material is, the more distinctive the weapon is in its features. Knives, on the other hand, are typically mass-produced, making it difficult to ascribe textile damage to a single knife with statistical confidence. In the forensic literature as well as among knife makers, terminology regarding knife attributes varies greatly. The physical features of the blade and handle determine the force necessary for penetration and the damage that results. Traditional blades, drop point, clip point, spear point, sheepsfoot, tanto, and trailing point are all common blade geometries (Fig. 2). A multitude of blade parameters, including tip radius, blade thickness, and individual edge sharpness, are influenced by blade geometry. The impact of blade tip and edge sharpness on the morphology of damage is determined by how the blade is utilized. The damage morphology of garment fabrics shows the changes in morphology when a textile is stabbed by a sharp or blunt weapon (both tip and edge) (Fig. 3) [9].

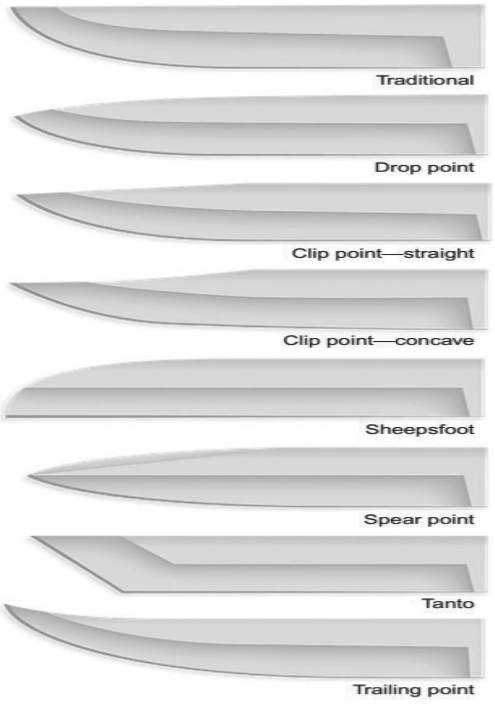


Figure 2: Geometries of blade [9]

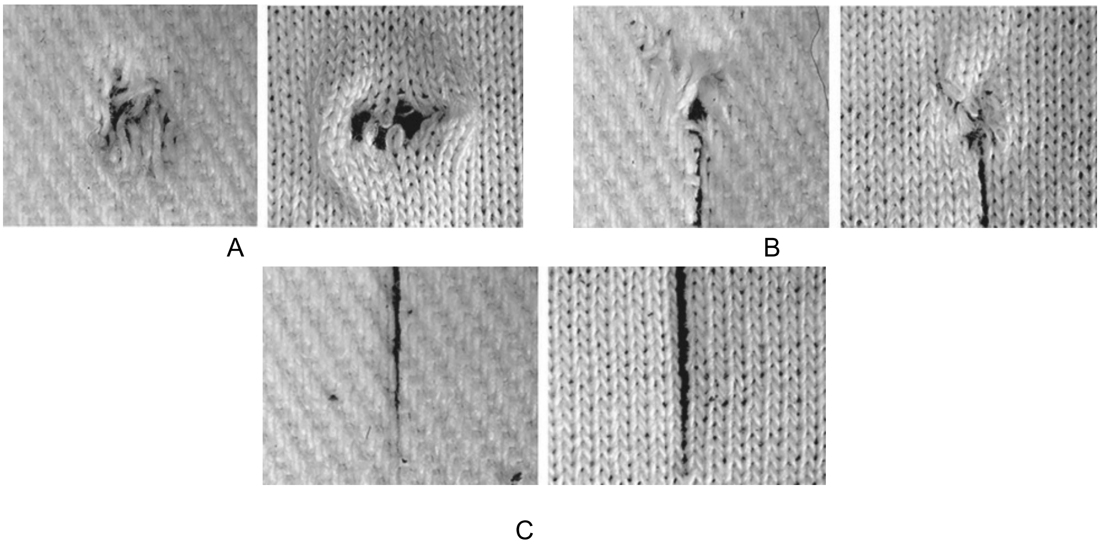
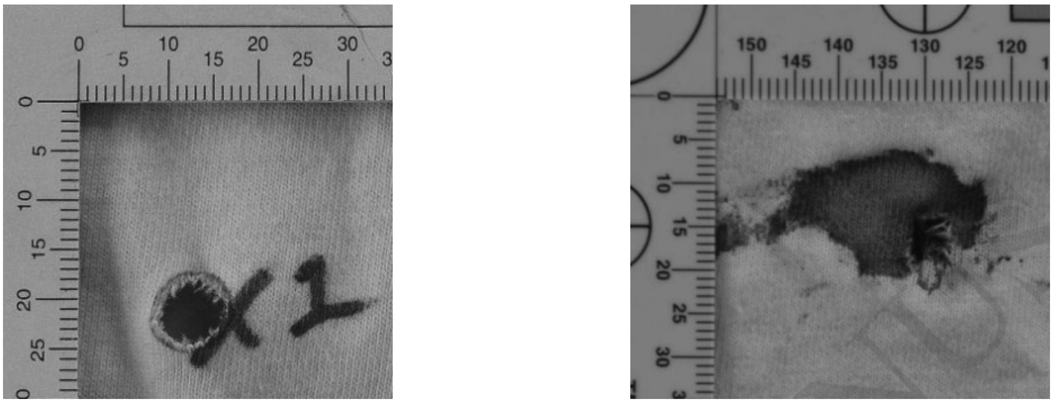


Figure 3: A: Phillips head screwdriver, B: Hunting blade, blunt edge, C: Hunting blade, sharp edge [9]

3.2. Blunt Impact Damage

In forensic cases all throughout the world, blunt force trauma is the major cause of injuries and mortality. Blunt force trauma is an injury induced by a low-kinetic-energy encounter with a dull, hard item or surface that might be difficult to interpret [10]. A ballistic hit on the human body frequently causes serious or fatal injuries. When someone is shot, they are frequently wearing clothes that has been ruined by the projectile's perforation. In the literature, there are extremely few reports of such textile deterioration. Some are laboratory-based investigations of clothing or materials imitating clothing mounted on a simulant, while the majority are case studies and investigators' experiences (e.g., gelatin, foam, pig tissue). The morphology of other fibre ends caused by ballistic impacts includes shear, tensile, and longitudinal cracking and can be confused with other causes of textile damages, such as impacts with edged blades. Figure 4 gives a visual representation of the damage conducted by 2 different bullets on the fabric. [11].



A B

Figure 4: Impact of Bullets (A: 9mm Luger HP, B: .357 Magnum) [11]

The shape of the projectile, the size of the projectile, the speed and velocity at which it penetrates the fabric all affect the damage done to the fabric. A microscopic examination should be performed to examine the damage. Differences in the fabric will affect the size and shape of the holes caused by the ammo. In some cases, an attempt is made to achieve results by replicating the damage with a damage simulation. Lead particles can also be found around the holes in the fabric. To study bullet holes in textiles, the details of the damage should first be examined using a microscope and the relationships between the damage and the bullet should be studied. Due to the elastic nature of fabrics, the diameter of the bullet hole and the diameter of the damage may not have a 100% match. Bullet holes in clothing can usually be described as circular, but if the bullet deviated on impact, the area will be more uneven and show more wear. It looks like a moth has been eaten. There may be dark spots around bullet holes in the textiles [12].

4. FORENSIC METHODS USED IN TEXTILE PRODUCTS

Textile products such as clothes, furniture and vehicle upholstery found at the crime scene can be evidence in illuminating the crime. Cloth scraps and their fibers can be important evidence to solve the case during forensic investigation. This type of evidence can be obtained from the victim's or suspect's clothing. A piece of cloth, the mark left by the knife on the cloth, the blood stain on the car upholstery can be examples of such evidences. Fibers can be classified according to color, shape, surface properties, thickness, fluorescent properties, and chemical composition in forensic examination. Traces of evidence can be transferred from the offender's clothes to the victim's clothes or to the victim's body. For example, fibers found under a victim's nails, or in their hair. This type of evidence is mostly sought in cases such as murder, sexual assault, beating, as well as in order to understand whether physical contact has taken place between the suspect and the victim [13]. Cellular materials such as DNA that help forensic analysis to solve the case can be transferred to the fabric at the suspect's contact. The amount of DNA is believed to increase with the pressure applied to the fabric and the time spent on the fabric. The application used for analysis is to remove the substance to be analyzed by cutting the tissue and then placing it in a sterile tube, or by pressing the tape against the tissue and then placing the tape on the sterile tube or the surface of the tissue. Then rub it with a sterile cotton swab. The swatch, tape, or swab DNA is then extracted from cell debris and other components using specific procedures. This extraction method results in DNA loss because there is no absolutely accurate and effective method for extracting DNA from the sample. During the extraction process, the tubes are replaced at all stages. This change can lead to contamination and errors. In addition, the use of extraction kits is quite expensive [14]. Most forensic genetic analysis methods use short tandem repeats (STRs) to provide distinctiveness. Many laboratories believe that manual Kelex or organic extraction methods are more dependable than automated methods. The common factor in all extraction methods is the necessity of isolating pure DNA without co-extracting polymerase inhibitors and other PCR inhibitory components. These inhibitors include fiber dyes such as jeans indigo, blood heme which is a precursor to hemoglobin, soil humic acid, and hair sample melanin. The amount of co-extracted inhibitor may vary depending on the extraction method and sample. Forensic evidence samples such as cloth may contain the cloth itself and various PCR inhibitor components such as blood and soil [15]. Analyzing fingerprints on the fabric is more difficult as it is notorious. However, forensic labs are trying to analyze fingerprints left on the fabric. Two methods are used to increase the traceability of fingerprint on the fabric. These methods are CA fume and vacuum metal deposition (VMD). Synthetic fibers are less absorbent and hydrophilic in nature in comparison to natural fibers. Therefore, fingerprints remain on the surface of synthetic fibers for a long time. Cyanoacrylate (CA) smoking is one of the fingerprint analysis methods used on fabrics. CA-Fuming is a method of analyzing fingerprints by smoking cyanoacrylate adhesive. Studies have shown that Lumicyano™ is more suitable than CA smoke for analyzing fingerprints on non-porous surfaces. Lumicyano™ is an effective method for analyzing fresh fingerprints on dark fabrics. This is a more useful Lumicyano™ method for analyzing fingerprints on dark polyester fabrics than Silver VDM. The number of yarns and the knitting pattern of the fabric are crucial factors that affect the quality and transparency of the trace [16]. Vacuum Metal Deposition (VMD) and Cyanoacrylate Deposition (CAF) are used to analyze fingerprints on smooth, non-porous surfaces. VMD was in investigation for microanalysis of fabrics in the 1970s, but the use of VMD was discontinued because radioactive sulfur dioxide was more convenient. When CAF was used in the 1990s, VDM came to use again. The VMD and CAF methods can look quite different on the same board due to the interaction of different fingerprint components. Nylon displays fingerprints better, so it is observed in more detail with VMD method [17].

Figure 5: Sample determined by VMD in nylon sample (Day 3) [17]

Security forces fight drug dealers. Cocaine smugglers who transport drugs, use concealment methods for bottled liquids, cans, milk, wax, bookbinding, beer cans, clothing, and more. Cocaine impregnation is commonly used by smugglers. This method is based on the principle of pouring a cocaine solution into clothing and evaporating the solvent. Raman spectroscopy is a successful method for analyzing cocaine in a matter [18,19]. Raman spectroscopy can be used to detect cocaine absorbed in the fabric. Confocal Raman microscopy reveals the presence of cocaine and N-methyl-3,4-methylenehydroxyamphetamine in natural and synthetic fibers [20]. Before committing a crime, criminals use different methods to hide or destroy the evidences as much as possible. Gloves, masks, or special clothing that leave no trace are used by the criminals. Washing blood-stained clothes are one such method of destroying the evidence of crime. Luminol is used to detect bloodstains on fabrics. With the help of luminol, you can even detect many bloodstains that are invisible to bare eye, so you can perform DNA analysis. Contrary to widespread belief, it is difficult to remove blood stains from fabrics. Even if the fabric is thoroughly washed and cleaned, Luminol will reveal weakly concentrated stains. Luminol is especially useful in forensic medicine to detect bloodstains even when cleaning tissue [21]. Leuco Crystal Violet is used to visualize and analyze occult bloody shoe marks at crime scenes. This is a partially safe, cheap, and convenient way. Since the content contains a fixative, it can be easily applied to any surface and the blood will be visible. This technique is much more convenient than using Luminol. It operates in ambient light and can display traces, making it easier to investigate crime scenes. Leuco crystal violet can cause color changes on the surface of the substrate. This discoloration can be removed by using amide black. The LCV app is a quick and effortless way to view your traces. Prior to LCV, blood shoe marks were analyzed using amide black (naphthol blue-black), diaminobenzidine (DAB), and luminol. Amide Black and DAB are not useful as they are difficult to use in carpeted rooms. For this reason, it is necessary to wash the substrate after using amide black or DAB [22]. Luminol and LCV are reagents used to analyze bloodstains in crime scenes. Luminol was first used in 1937. Luminol is used by the security forces. Blue/green chemiluminescence is observed from the reaction of luminol and hemoglobin. Dark environment is required to observe the bloodstains. LCV is another blood reagent used for onsite analysis. LCV catalyzes hemoglobin in the blood. The difference between LCV and Luminol is that they are visible in ambient light. LCV appears on brightly colored surfaces by staining blood from deep purple to black. Bodziak found that visible bloodstains in tissues were most often observed with DAB or amide black reagents [23].

Figure 6: Image after using LCV [23]

Figure 7: Image after using Luminol [23]

5. CONCLUSION

Evidence is vital to solving forensic cases, so it must be collected and maintained in a professional, proper and careful manner. Forensic sciences, technological tests and applications used in police investigations are used in the resolution of forensic cases. For the resolution of forensic cases, it is necessary to have the right evidence. In forensic textiles, these findings can be clothes, trousers, socks, scraps of fabric or even fibers. The mentioned findings may have been damaged during the incident, but since the criminals or victims are in contact with textile materials, textile products are especially important in terms of evidence for solving crime mysteries. The raw materials of textile products vary from product to product. This phenomenon can complicate analysis as the rate of blood absorption or fingerprint traceability is not the same for all fabric types. This can result in evidence being lost or overlooked. This may make it more difficult for the perpetrators to be caught. For this reason, scientists are trying to minimize these difficulties by developing various new methods and chemicals so that evidence can be obtained more quickly, precisely, and efficiently. One of the goals of future research is primarily to develop it to facilitate the work of people in the forensic field, especially for faster and clearer observation of chemicals used in different types of textile evidence.

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