Gory Dactyloscopy

A Major Qualifying Project Report

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Abstract

Modern methods of bloody fingerprint enhancement are difficult to execute due to various complications. The main concern with existing chemical stains is the lack of adhesion to angled surfaces, which obscures ridge detail. The current device for spraying these chemicals also decreases the amount of detail on the stained fingerprint due to low pressure and large droplets. The purposes of this thesis were to: improve the chemical staining by introducing an inert media to increase the viscosity of the chemicals for better adhesion, and to propose a spray device with higher pressure and superior atomization for the resulting product.

Introduction

The History of Fingerprints

The ridges and furrows on fingers and toes evolved to provide friction when gripping surfaces and permit the excretion of sweat and oil (Marieb and Hoehn, 2003).When surfaces are touched with bare skin, these secretions leave behind a duplicate of the print (Lee, 2001).The discovery of ridge detail on fingers and toes has been dated even as far back as the Neolithic and Prehistoric Age. Impressions depicting this detail were discovered on many man made items such as bricks and carvings. Dating back to ancient Egypt (1792-1750 B.C.) and early China (246 -210 B.C.), fingerprints were used as a personal symbol or seal. Prints were used to seal official documents or to prove authenticity and even as a personal sign off following a name (Ashbaugh, 1999).

The origin of fingerprinting as a form of identification has been disputed. Sir William Herschel is most commonly credited as the perpetrator of this form in the mid-1800s. Herschel used fingerprint sets as a form of identification for the East India Company to distinguish between the workers who looked so much alike. He was not the first person to suggest this; he would instead be better credited as the first person to standardize ridge pattern identification in European countries. Another pioneer in the field was Dr. Henry Faulds (late 1800s). He wrote a letter to Charles Darwin stating that “fingerprints can be easily classified and ridge detail is unique” (Ashbaugh, 1999). He referred to the Egyptians and Japanese who fingerprinted their criminals and suggested that it may be possible to capture criminals based on fingerprints left at crime scenes. This letter was forwarded to Darwin’s cousin, Sir Frances Galton, who at the time was an advocator of a different method (Ashbaugh, 1999).

In the late 1800s fingerprinting was given credit in the scientific community as an area of interest and study, but most believed it alone was just not detailed enough to identify a person. The lack of a classification system for large collections was not established and fingerprints seemed to only serve identification purposes in ten print sets. Fingerprinting was under a lot of scrutiny due to the rise of another, more thorough identification method that was popularized around the same time. The first official scientifically based criminal identification method was developed by Alphonse Bertillon, known as anthropometry (Ashbaugh, 1999).

Anthropometry detailed physical measurements of the human body. Sizes, proportions and detailed written descriptions were used to catalog and identify individuals. This method was first used in France, where criminals arrested in Paris were scrutinized and cataloged. Prisoners were put through a series of eleven measurement tests that each required different instrumentation. The tedious method involved gathering numbers for height, head length and width, arm span, seated height, length of the middle and pinky finger, foot length, forearm length, ear length and cheek width. These were selected based on the thought that weight gain or aging would likely not change these proportions much (Cole, 2001).

Along with these numbers each criminal's physical description was recorded in a similarly precise manner. Eye, ear, and lip characteristics were noted; facial hair, hair color, pattern of hair growth, eye-brow shape and color, mouth shape, neck description, shoulder build, overall bodily build, chin shape, head contours, forehead, nose shape, race, skin color, attitude, demeanor, voice patterns and language were also noted. Even with the description as detailed as listed, the notes were usually less descriptive with rather general terms. 'Medium', 'average', and 'normal' were commonly used phrases. Common Police who were undertaking the identification task did not use terminology specific enough to distinguish characteristics. Bertillon then created his own scientific vocabulary to increase the detail and sophistication of the process (Cole, 2001).

Problems with this system were noticeable when the practice moved its way to the colonies in the west. The individuals being cataloged looked to the operators of the method to be rather similar. There were also inconsistent measurements between operators running the tests. The amount of instrumentation and time it took to collect all the information was overwhelming. At about the same time, fingerprinting was making its own advancement. For fingerprinting to take the lead over Bertillon's method, a classification system needed to be developed (Cole, 2001). Galton, an original advocator of anthropometry, visited Bertillon and found the method less than impressive in application. He turned his area of interest to fingerprinting around the 1890s and drew insight from the Herschel and Faulds letters sent to him by his cousin Charles Darwin (Ashbaugh, 1999).

After studying various prints and patterns, a basic set of four fingerprint patterns emerged: the arch, tent, loop, and whorl (see Figure 1) (Lee, 2001). A person's ten fingers were cataloged using these patterns and a ten letter code indicating the type of pattern on each individual finger was recorded and filed. Unfortunately, the variety with the four basic patterns was not enough and some ten letter identification codes were repeated often (Cole, 2001). Eventually, the small ridge characteristics that Faulds had previously referred to were identified and classified (see Fig 2). These small detailed ridge patterns made up the four basic patterns (Lee, 2001). With so many ridges and so many ridge characteristics, it is improbable that there are two people with the same fingerprints.

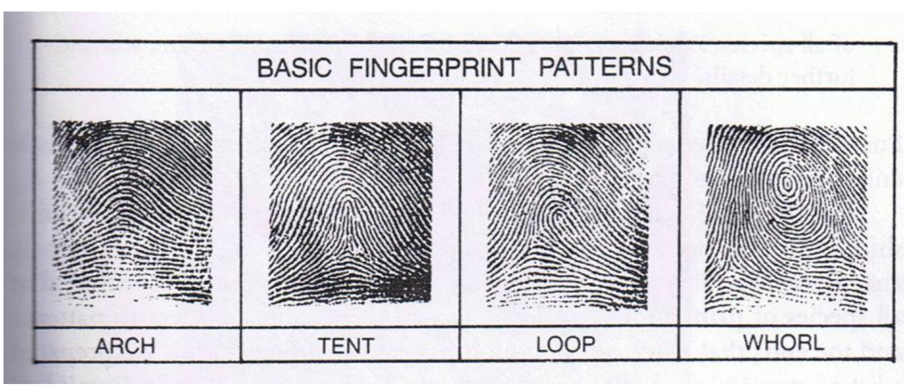

Figure 1: Basic Fingerprint Patterns

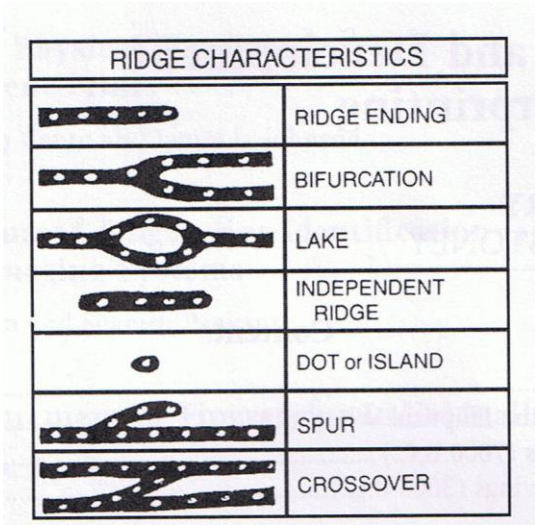

Figure 2: Ridge Detail

Ivan Vucetich, creator of another fingerprint analysis method, is also a man not as well known in the fingerprint field. He devised a much more complicated system of identification which involved 101 classifications of prints; this method was too complex and difficult to understand to be used effectively. He did however identify this qualitative visual technique as a science, and named it dactyloscopy, the science of looking at fingers. His idea caught on and began tipping the scale away from Bertillon's method (Cole, 2001). However, Vucetich's classification system was not popularized.

Another man, Sir Edward Henry, was working on his classification system at the same time. His filing system was based on four fractional values by placing the classification on the left hand over the classification on the right hand. This filing scheme detailed print patterns on each hand. The first value involved counting the number of whorl patterns on the fingers of the hand using a complicated mathematical formula. The second value indicated further classification of each finger with the other three patterns, (tent, arch, or loop) each bearing a letter. The third fractional value indicated whether the patterns were inner or outer facing patterns, and finally the fourth fractional value counted the number of ridges in the pattern on the little fingers. This system became known as the Henry System and is the most commonly used method due to its ability to narrow the search for a matching fingerprint to a small subset of known prints using print details (Cole, 2001).

Fingerprint analysis eventually became the forerunner in the forensic field. One of the most well known cases of mistaken identity helped turn organizations in favor of fingerprinting. On May 1, 1903, a man named Will West was placed into the Leavenworth Penitentiary in Kansas State and his measurements were taken via the Bertillon method. West's measurements already fit the description of a William West who was convicted of murder. Will denied the conviction and stated that he was not the same man. The prison soon discovered another man was already at the penitentiary for that crime. The two men looked amazingly similar (see Fig. 3 and Fig. 4) and their Bertillon measurements were almost identical (see Fig.5). The two men were fingerprinted and the prints were clearly distinguishable (see Fig. 6). This incident demonstrated the capability of fingerprinting to identify individuals who were so similar in features, and practically signed the death certificate of the Bertillon method (Cole, 2001).

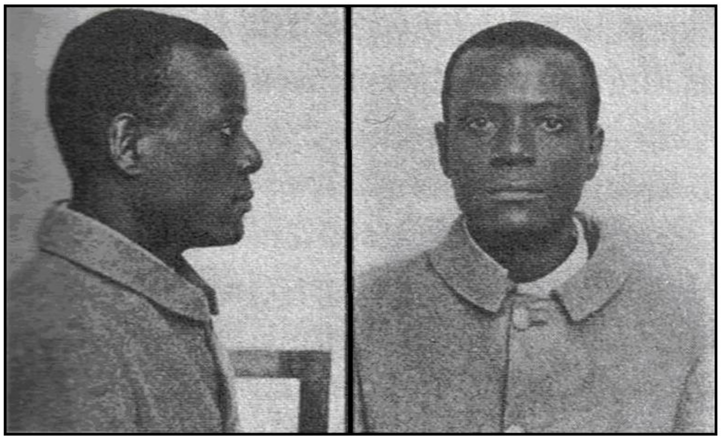

Figure 3: Will West Mug Shot (Cole, 2001)

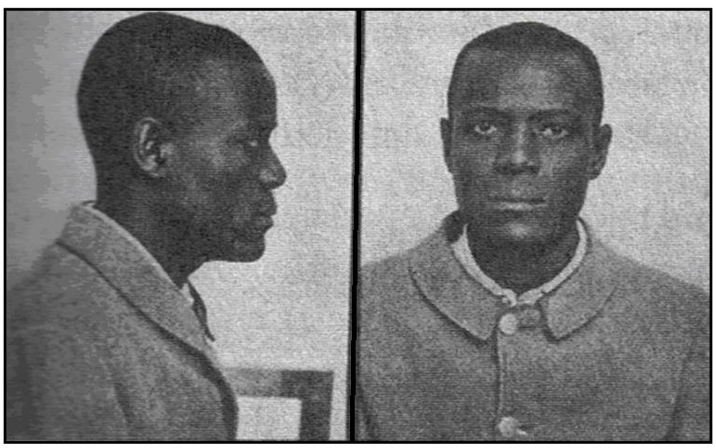

Figure 4: William West Mug Shot (Cole, 2001)

Measurement	Head length	Head breadth	Middle finger	Foot length	Forearm length	Height	Little finger	Trunk	Arm span	Ear length	Cheek width
Will West	19.7	15.8	12.3	28.2	50.2	178.5	9.7	91.3	187.0	6.6	14.8
William West	19.8	15.9	12.2	27.5	50.3	177.5	9.6	91.3	188.0	6.6	14.8

Source: Harris H. Wilder and Bert Wentworth, *Personal Identification: Methods for the Identification of Individuals, Living or Dead* (Boston, 1918), 33.

Figure 5: Anthropometric Measurements of the West Men (Cole, 2001)

A B

Figure 6: Fingerprint of Will West (A) and Fingerprint of William West (B) (Cole, 2001)

Prints found at crime scenes started being used to identify suspects. Like any new science, the technique had its difficulties in court and many questions were asked. Who could determine whether or not a fingerprint belonged to an individual? It may be easy for an untrained eye to see the characteristics in clean, inked fingerprints, but at a crime scene, fingerprints are far from perfect. At a crime scene prints can be smudged or blurred, overlapping, or even partial. Fingerprinting soon became a method for experts who had studied thousands of different prints and analyzed the smallest ridge details. Are fingerprints specific enough to tell family members or even twins apart? To prove to the court that fingerprints were unique from person to person, a lawyer brought in a set of identical twins and took fingerprints from both of them. They were shown to the court and it was noted that although the prints had similar characteristics and patterns, they were in fact different (Cole, 2001).

Dactyloscopy is based on what are now called the laws of fingerprints: first, fingerprints never change from birth (with the exception of abrasions and permanent scarring), and second, no two fingerprints are identical, though some may be rather similar. Every finger, toe, hand and foot has a distinctly different pattern and each set of prints is different from person to person. However, even today there are no standards for fingerprinting in court. Throughout history 12 ridge detail areas were generally accepted as sufficient to prove identity. Currently, in the United States, even as few as 7 or 8 specific characteristics are acceptable for positive identification if confirmed and approved by a fingerprint expert (Lee, 2001).

Forensic Science

In forensic science, fingerprints are recognized as important evidence. Unlike eye witness testimony, in which memories can be recalled incorrectly or even forgotten, fingerprints are infallible. In conjunction with other evidence, it can be the strongest link to prove someone's identity at the scene of the crime.

For fingerprint evidence to be an effective tool, the crime scene must be secured and processed properly to ensure nothing becomes destroyed or altered. Many people are involved with the processing of the scene and the different units of a team working on a particular case each have separate tasks that need to be accomplished correctly and in an efficient and effective manner. If evidence is not properly collected, stored, and transported, it is no longer viable.

In forensics, fingerprints can be classified into one of three types. Difficult to see or hidden prints are known as latent prints; these are normally oil and sweat residues left by the skin. Prints of this nature left on porous surfaces such as paper or cardboard are generally revealed by chemicals such as ninhydrin or silver nitrate, which are sprayed onto the surface of the object. Prints left on non-porous surfaces such as glass, metal, plastic, polished wood, etc. are generally revealed by applying fingerprint powder. The surface the print is found on determines the color of the powder used, and the print is then photographed and often lifted with transparent tape (Cowger, 1993).

Prints that are detectable by the naked eye and that do not require enhancement are called visible prints. Visible prints are generally found in oil, creams, and feces. Because of their visibility, no enhancement is needed for photographing (Cowger, 1993).

The last type, plastic impressions, results when prints are displaced into a more solid surface such as soap, wax, wet paint, or grease. Some development of these prints may be needed in order to photograph the print. Light can be used to help increase shadow or highlight print ridges, and chemical stains or powders maybe be needed to enhance surface contrast (Cowger, 1993).

Bloody Fingerprint Enhancement

Bloody fingerprints are generally classified as a type of visible print because the contrast between ridges and furrows are obvious due to the color of blood. However, blood smears easily and can sometimes require additional enhancement when analyzing ridge detail for identification. As surfaces are touched repeatedly, bloody prints can become latent as the red coloration fades, though the iron in the heme is still present. Fingerprints made in blood are commonly enhanced chemically using stains to make ridge detail more obvious (Cowger, 1993).

The possibility of DNA evidence from the blood is also a consideration when enhancing prints. Studies have been done showing that PCR can still be preformed on blood samples after enhancement chemicals have been added, however, chemicals that require destaining solutions retain less DNA (Fregeau, 2000).

Bloody fingerprints are a unique type of fingerprint. The chemicals and methods of development used to enhance these prints are different than ordinary latent or visible prints, but the process is less than ideal.

Chemicals

One of the first and most popular chemicals was Benzidine. It was banned by the federal Occupational Safety and Health Administration in 1974 due to its carcinogenic properties and the hazards it posed to the people using it (Lee, 1991). Current chemical stains are safer than Benzidine and have shown no long term detrimental effects. However, proper handling of these chemicals is required, including the use of air respirators, gloves, and safety goggles.

There are two major types stains used for bloody fingerprint enhancement. The first type reacts with heme in the blood (Lee, 1991). Heme is a prosthetic group of hemoglobin (deep red colored) whose central Fe (II) atom is the site of reversible oxygen binding (Voet, 2008) (Merriam-Webster, 2009). The heme catalyzes an oxidation reaction by splitting hydrogen peroxide molecules into a hydroxyl radical and a hydroxyl ion by donating an electron via the Fenton reaction. The hydroxyl radical then steals an electron from the nitrogen lone pair which causes the production of a double bond, a double bond shift. The reagent is oxidized, producing a color change (see Fig. 7). The second type of reaction is a protein stain, which colors protein molecules, in blood for instance (Lee, 1991).

The current most popular reagent is Leucocrystal violet, a heme stain. Other heme stains, including Leucomalachite green and phenolphthalein, are popular plausibility stains. Plausibility stains change color and indicate that the substance is plausibly blood rather than definitively identifying it. These tests may have problems in cars or areas with heavy metals (Lee, 1991). Other common chemical stains include Hungarian Red, Amido Black, Crystal Violet and Commassie Blue: these are protein stains (Lee, 1991). Each of these has similar problems including short storage capacity, lack of chemical adhesion to surfaces, and limited enhancement ability. Two heme-reacting chemicals were used in this experiment: Leucocrystal Violet and Leucomalachite Green.

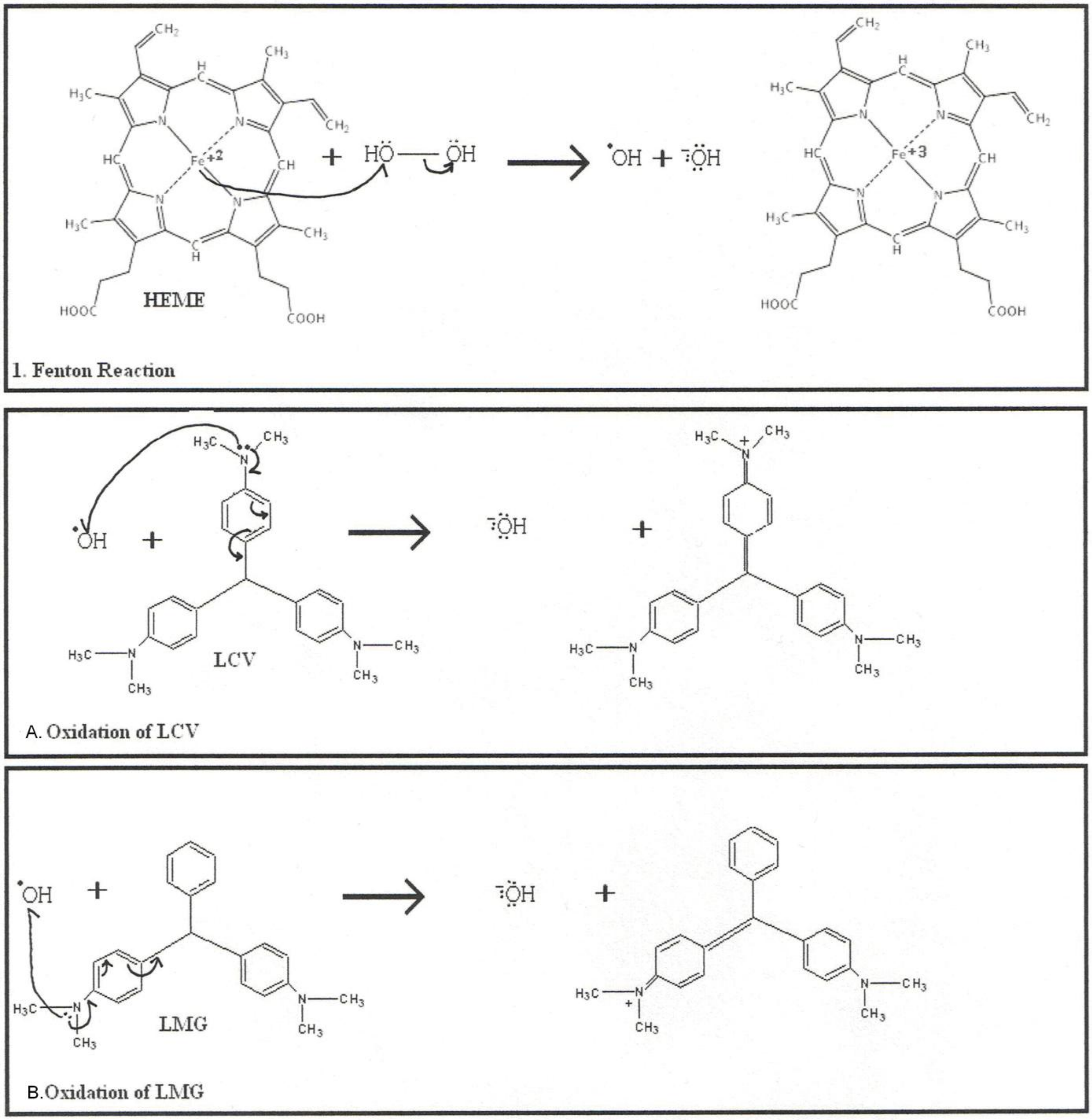

Figure 7: Mechanism of Reaction: Leucocrystal Violet (A) and Leucomalachite Green (B)

Several field and laboratory agents were interviewed to ascertain their opinions of the current status of Leucocrystal Violet. In general, the benefits identified by those interviewed included: easy to make, can be purchased in a premixed formula, shelf life is less of an issue, only what is needed is produced, no odor, and develops detail quickly. Problems with the chemical were also identified. As Janis Ford summarized, “Leucocrystal Violet tends to run on vertical surface[s], needs to be improved so it doesn’t run and ruin the ridge detail.” Mike Harris added, “LCV runs . . . especially on second coats, compromising print detail”. Janis Ford and Jenna Doty agree, “. . . [On vertical surfaces] you have to be careful with misting technique and try not to spray directly on the surface (you need to lightly mist).” “[LCV] has a very wet appearance, you must spray over not on so as not to remove [fingerprint] detail.”

Leucocrystal Violet is a very watery substance which makes spraying fingerprints on a wall, door, or ceiling difficult. There is little adhesion to the print and the liquid runs down the surface in drops. This makes enhancement of ridge detail less than optimal.

Leucocrystal Violet ($C_{25}H_{31}N_3$ – See Fig. 8) is the reduced form of Crystal Violet. Crystal Violet is also known as Hexamethyl Violet or Gentian Violet and is often used for gram staining (Merriam-Webster, 2009). Leucocrystal Violet is a white powder (MW: 373.54) that, when mixed in solution, produces a clear liquid (Sigma Aldrich MSDS[1], 2009). When this chemical comes into contact with blood it becomes a purple/violet color. The first forensic application of Leucocrystal Violet was introduced by John F. Fischer in1993 to the FBI for enhancement of bloody footwear and fingerprint impression evidence (Bodziak, 1995).

Leucocrystal Violet has a moderately low storage capacity, retaining its potency for approximately one month. The Leucocrystal Violet solution should be stored in a cool, dry environment. After staining, Leucocrystal Violet rapidly degrades via a combination of biodegradation, photodegradation, and radicals in the solution (Chen, Chiing Chang et al. 2007, Chen, Chih-Hung et al. 2008). Biodegradation has been most widely investigated and seems to be the primary source of the dye’s color loss over time. Photodegradation appears to have minimal impact on color loss unless it is in the presence of a heavy metal or semiconductors. Radicals present in solution, especially after Leucocrystal Violet’s reaction with hydrogen peroxide and heme, also contribute to this chemical's degradation (Chen, Chiing Chang et al. 2007).

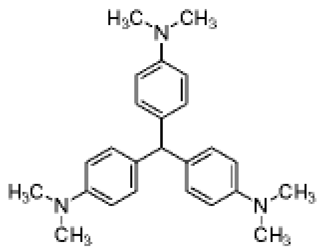

Figure 8: Chemical Structure of Leucocrystal Violet

(Sigma Aldrich MSDS, 2009)

Leucomalachite Green ($C_{23}H_{26}N_2$ – See Fig. 9) is the reduced form of Malachite Green. Malachite Green is also known as Aniline Green, Basic Green 4, or Victorian Green B in the dye industry (Goff and Wood, 2008). It is a white powder with a slight green tint (MW: 330.46) and produces a slightly green tinted solution (Sigma Aldrich MSDS[2], 2009). When this solution comes into contact with blood and hydrogen peroxide applied, it turns a dark blue/green color (Moore, 2008).

Leucomalachite Green is air and light sensitive and it is recommended to be mixed on site. Traditionally the chemical was used in the field of serology, the identification of evidence as possible bodily fluids such as blood, saliva, and urine (Moore, 2008). It was commonly used as a presumptive blood detection test by swabbing the possible blood with a cotton swab and adding a drop of the Leucomalachite Green reagent and hydrogen peroxide. The blue/green color change on the swab indicated a strong possibility that the substance was in fact blood (Cox, 1991). However, some spray applications of this reagent have been used in other studies on enhancement of residual blood fingerprints, especially on porous surfaces (DeHaan, Clark, *et. al,* 1997).

Like Leucocrystal Violet, Leucomalachite Green produces dripping on ceilings and running down angled surfaces. This slightly more viscous solution produces more damage when running and smearing due its tendency to clump. The viscosity is not high enough to stick to the fingerprint on angled surfaces or ceilings. This substantially decreases the ridge detail of the fingerprint and produces a blurry stain with varying color densities.

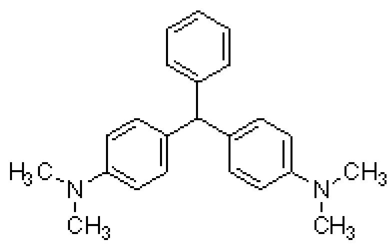

Figure 9: Chemical Structure of Leucomalachite Green

(Sigma Aldrich MSDS, 2009)

Thickening Medium

Sodium Alginate is the inert material that was used as a thickening agent for the blood enhancement chemicals in this experiment. Sodium Alginate is the sodium salt of Alginic Acid which is a naturally carboxylated water soluble polymer (Glass, 1984). Alginic Acid is located inside the cell walls, contributing to flexibility of the giant kelp and brown algae found in temperate or cold waters, typically in the oceans around California and the northern Atlantic (McHugh, 2003) (Cyber Colloids LTD, 2009).

Sodium Alginate ($(C_6H_7NaO_6)_n$ – See Fig. 10) is a polymer made up of two basic monomer units, β-D-mannopyranosyluronic acid (mannose) and α-L-gulopyranosyluronic acid (gulose), abbreviated as M and G (Glass, 1984). The number and sequence of these monomer units vary in naturally occurring alginate. Sodium Alginate is extracted from Alginic Acid via ethanol separation (it is insoluble in ethanol and ether). A paste is precipitated and then dried, leaving a white to off white powder (MW: actual average 222) (McHugh, 2003).

Sodium Alginate is water soluble and forms a viscous solution (viscosity is dependent on the specific species of algae used for extraction). Higher G residue content tends to form a more rigid solution and is commonly used in gels, while higher M residues tend to form softer gels or viscous liquids (Phillips, 1990) (Cyber Colloids LTD, 2009).

Like most polymers, Sodium Alginate increases viscosity by forming cross-links between molecules. Divalent cations are required to create these cross-links to form a gel; calcium is the most commonly used divalent cation. In distilled water, the alginate absorbs the water and forms transient cross-links between molecules. The absorbance of water is time-dependent.

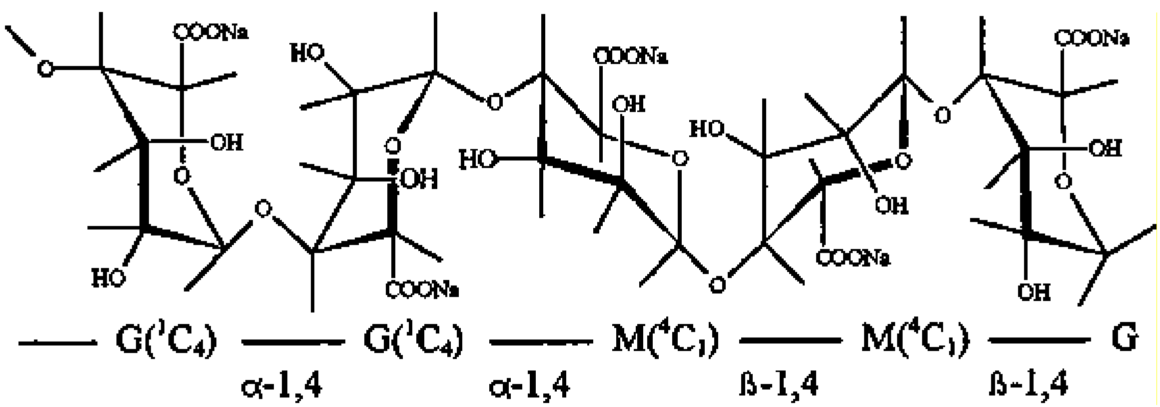

Figure 10: Chemical Structure of Sodium Alginate (Depicting M and G Residues) (FAO Corporate Document Repository)

Sodium Alginate is commonly used and is available commercially for purchase. In the textile industry Sodium Alginate is used to thicken the paste for fabric dyes. In food production, Alginate is often added to syrups, sauces, icing, and even pie fillings to create a thicker and less sticky product. Salad dressings and mayonnaises that are oil and water based often use Alginate to prevent separation. Along with thickening, Alginate can be used as a stabilizer in dairy products such as yogurt, chocolate milk, ice cream and whipped cream.

Its gelling properties can be found in artificial cherries, jellies, and restructured meats such as chicken nuggets, meatloaf, and even dog food (McHugh, 2003).

Spray Devices

The current spray apparatus used in the field is a Preval Spray Gun, an aerosol container that screws onto a glass jar that can hold up to 16oz of chemical. Tubing runs through the device into the mixture and air moves past the opening of the tube creating a vacuum which sucks the chemicals up into the internal mixing device. The pressure pushes the mixture out a small hole in the spray nozzle and a mist is extruded. The mist produced is coarse and not atomized well. The droplets are very large and cause clumping on contact (Young and Freedman, 2008).

A secondary device is a Model 250 spray gun from Badger. It is an external mixer that screws into a canister of Propel air, and a small glass jar screws onto the bottom. Small tubing runs though the device into the mixture and air moves past the opening of the tube creating a vacuum which sucks the chemicals up. External mixing allows the flow of air to be diverted over the hole and permits adjustment of vacuum strength. The smaller tube and smaller hole (about the size of a paper clip) create a better vacuum and thus atomize the mixture to a fine mist (Young and Freedman, 2008).

Justification of Study

The various problems with the current materials and methods for bloody fingerprint enhancement as previously stated are too numerous to allow effective and efficient operation at a crime scene. The low viscosity of the chemicals and the spray device and application were identified as the chief problems. The low viscosity of the chemicals caused running on angled surfaces which obscured ridge detail. This is primarily a problem on walls, ceilings, windows, and doors. The spray device produced large droplets that allowed clumping to occur on contact. These clumps gather in the furrows of the prints obscuring detail. We were commissioned by Michael Harris of the Worcester Crime Laboratory Fingerprint Unit to improve the current methodology.

Materials and Methods

Materials

Sodium Alginate (powder) was obtained from La Sanctuaire. The working chemical solution Leucocrystal Violet was obtained from the Worcester Crime Laboratory. Leucomalachite Green solid was obtained from the Worcester Crime Laboratory and prepared on site. The supplementary chemicals, including The secondary 1% Hydrogen Peroxide was prepared from 3% store-grade Hydrogen Peroxide by diluting the chemical with dH2O obtained from the laboratories in Worcester Polytechnic Institute.

100% cotton was obtained from Michael's craft store. The denim samples were cut from a pair of generic blue jeans (100% Cotton). Plastic piping, wood, glass, sheet metal (galvanized aluminum) and drywall were obtained from the Home Depot and cut into individual sample sizes. Cardboard from cereal boxes (Apple Cinnamon Cheerios and Macaroni and Cheese Boxes) was used. Blood was drawn from Mike Harris, a licensed technician and police officer at the Worcester Crime lab. He applied his blood, which contained anticoagulants, to create bloody fingerprints on each sample surface. Each Set contained one sample square of each material covered with bloody fingerprints. These Sets were set to dry for at least a day prior to staining.

The traditional spray mechanism for chemical staining, the Preval sprayer, was obtained from the Worcester Crime Lab. The Preval Sprayer uses Aeron A-70/DME (50/50) propane (21.5%), Isobutane (28.5%), and dimethylether (50%). Attached to this spray device was a 6oz jar. A second spray device, the Badger Airbrush Model 250, traditionally used for spray painting toy modeling kits, was obtained from Michael's craft store. With this spray kit, a standard 4oz bottle was used in addition to the Badger Propel air canister, which contained 1,1-difluroethane.

Conditions

Each surface was covered with fingerprints in drawn blood with test was performed in a fumehood in a laboratory at temperature which varied between 64-75°Farenheit. Indirect spraying was used to apply three coats to each surface. Direct spraying was used to apply one coat. Exact temperatures were not recorded prior to every experiment.

Sodium Alginate Base Solution

The Sodium Alginate base solution was prepared by adding 5.00 g Sodium Alginate in 0.50 L distilled water in a 1 L beaker. The mixture was stirred vigorously for two minutes with a stirring rod. The beaker was then covered with parafilm and set aside for 20 hours. This formed the sodium alginate base solution used in the remainder of the experiments.

Leucocrystal Violet

The Leucocrystal Violet solution was obtained premixed from the Worcester Crime Laboratory. The working solution contained 0.50 g of Leucocrystal Violet in 250.0 mL of 3% hydrogen peroxide and 1.85 g of sodium acetate.

Modified Leucocrystal Violet

The Sodium Alginate Base Solution was mixed with varying amounts of Leucocrystal Violet solution to determine the optimal ratio. These solutions were sprayed using a simple hand spray device onto a piece of cardboard at arm's length, held at a 90°angle to determine the ideal viscosity. For this experiment, the ratio of 3 parts Sodium Alginate: 1 part Leucocrystal Violet was chosen.

Leucocrystal Violet Sample Staining

Set 1, composed of one sample of each material surface covered with dried bloody fingerprints, was photographed prior to any staining, including close-ups of several individual fingerprints. The traditional working Leucocrystal Violet stain was then applied to half of each material via a direct spray with the Preval spray canister while the material was held at a 90° angle in a fumehood. The material was then laid on a flat surface and the stained section covered with a paper towel. The Leucocrystal Violet was sprayed over the second half of the material in a sweeping motion, staining it indirectly. Each sample was then photographed.

Set 2 was stained with Leucocrystal Violet using the Badger Airbrush Model 250 and the same methods as above. Each sample was photographed. Set 3 was stained with the new Leucocrystal Violet in Sodium Alginate solution using the Badger Airbrush Model 250 and same methods as above.

Set 13 was stained with the new Leucocrystal Violet in Sodium Alginate solution using the Preval sprayer and the same methods as above.

Leucomalachite Green

Leucomalachite Green working solution was prepared immediately prior to use by adding 1.00 g of Leucomalachite Green to 100.0 mL of glacial acetic acid and 150.0 mL of distilled water.

Modified Leucomalachite Green

The new Leucomalachite Green solution was prepared by adding 1 part Leucomalachite Green working solution: 2 parts Sodium Alginate.

Leucomalachite Green Sample Staining

Set 7 was stained with the traditional Leucomalachite Green working stain and applied to half of each material, which was held at a 90° angle, via a direct spray using the Preval spray canister in a fumehood. The secondary 1% hydrogen peroxide solution was then sprayed in the same fashion with the same spray device over the stained prints. The material was then laid on a flat surface and the stained half covered with a paper towel. The Leucomalachite Green was sprayed over the second half of the material in a sweeping motion, staining it indirectly; this was repeated with the 1% hydrogen peroxide. Each sample was then photographed.

Set 8 was sprayed with Leucomalachite Green in the Badger Airbrush Model 250 using the same methods as above. Set 9 was sprayed with the new Leucomalachite Green in Sodium Alginate solution with the Preval sprayer using the same methods as above. Set 10 was sprayed using the new Leucomalachite Green in Sodium Alginate solution using the Badger Airbrush Model 250 and the same methods as above.

Results

The main goal of this experiment was to improve existing blood staining technologies for use in the field of bloody fingerprint analysis. Specifically, this project sought to improve on current chemical stains by increasing the viscosity to prevent disruption of ridge detail in bloody fingerprints due to surface porosity or angle of application, and identify an optimal means of applying these improved stains by testing several spraying devices. Surface angle, surface porosity, and various spraying devices and techniques were investigated.

Laboratory conditions were close to ideal with little dirt and dust; these experiments were not affected by the elements (rain, wind, etc).The temperature and barometric pressure were not recorded explicitly prior to every experiment since research on the use of the chemicals used suggested that slight temperature changes would not affect the results, though it was noted that the temperature fluxuated slightly between 65-75°F.

Several variables came into play in this portion of the experiment. The first variable was the surface angle to which the stain was applied. The surface angles that were investigated were 0° and 90° relative to the horizontal; these angles were most likely to produce running and dripping with the standard chemical stain.

The second variable tested was the chemical's ability to perform on surfaces of varying porosity. Leucomalachite Green and Leucocrystal Violet are most commonly used for enhancement on porous surfaces; for this reason, the majority of surfaces tested were more porous. Eight surfaces were investigated, ranging from very porous such as wood, drywall, cardboard, cotton cloth, and denim to less porous, including glass, metal, and plastic. Each surface used was clean and dry prior to the application of the fingerprints. Traditional chemical stains bead on less porous surfaces which eliminate fingerprint ridge detail; these same stains bleed into more porous materials and blur the fingerprint.

Two different chemical stains were tested: Leucomalachite Green and Leucocrystal Violet. Both are heme reagents. The iron molecule within heme creates free radical hydroxyl groups from the hydrogen peroxide in solution; this hydroxyl free radical then oxidizes the Leucomalachite Green or Leucocrystal Violet to induce a color change (see Figure 7). Each chemical was tested on each sample surface, then combined with sodium alginate to increase its viscosity and tested again.

Negative Control

Eight surfaces of varying porosity were covered in fingerprints by Michael Harris, a licensed technician and police officer at the Worcester Crime Laboratory. He applied his blood, which contained anticoagulants, to create bloody fingerprints on each sample surface and the surfaces were left to dry in a fume hood overnight. Each surface sample was photographed with no alterations to the blood (see Appendix A Figure 1 A-H). This is the negative control and represents an untouched crime scene.

The cotton and denim (both 100% cotton) (see Appendix A: Figure 1 A and B) are the most porous surfaces. The ridge detail on these surfaces is not visible due to the stitching and texture of the fabric. Wood was slightly less porous and maintained some visible ridge detail, though much was lost in the grain of the wood (see Appendix A: Figure 1 C). Cardboard maintained fairly good ridge detail (see Appendix A: Figure 1 D). Drywall absorbed much of the blood and retained little visible ridge detail (see Appendix A: Figure 1 E). Metal had very low porosity and lost most of the fingerprint detail in blurring and smearing (see Appendix A: Figure 1 F). Plastic retained little visible fingerprinting (see Appendix A: Figure 1 G). Glass retained no visible ridge detail and produced much beading and smearing (see Appendix A: Figure 1 H).

Leucocrystal Violet

Current Method

The first experiment run demonstrated traditional field testing techniques and mechanisms to produce standard stained fingerprints as they are produced currently. This test acted as a control or baseline for the experiment. Standard working (unmodified) chemical and Preval spray gun used at crime scenes was used with no modifications. This control allowed for comparison and recognition of improvements or diminishments caused by modifications or changes to the chemicals, spray device, and methods. In Figure 1 A-H, the Leucocrystal Violet was sprayed directly onto the surface at a 90° angle. In Figure 1 a-h the Leucocrystal Violet was sprayed indirectly onto the surface at a 0° angle

The cotton and denim (100% cotton) (Appendix A: Figure 2 A, B) showed no ridge detail. The texture and stitching of the fabric was more noticeable than the fingerprint. The blood and chemical both soaked into the fabric causing no running producing a print that was dark and blurry. The ridge detail was also lacking when the chemical was sprayed indirectly (Appendix A: Figure 2 a, b) showed no ridge detail also due to the texture and stitching.   The color enhancement was lighter than from the direct spray and the print was also blurry.

The wood showed no ridge detail due to the grain in the wood (see Appendix A: Figure 2 C,c). The blood and chemical soaked into the wood and caused blurring in several spots. The direct spray was heavier and spotty in the areas that did not soak up the chemical completely.

The cardboard and drywall did not have any texture that obscured the print and some ridge detail was maintained (Figure 1 D, E, d, e). The direct spray (Figure 1 D and E) caused spotty and thick droplets to form which obscured any smaller ridge characteristics. The overall swirls are still partially visible. The indirect spray (Figure 1 d and e) caused the prints to be slightly blurry.

The metal retained little visible ridge detail (see Appendix A: Figure 2 F). This was partially due to the loss of ridge detail by blood beading on the nonporous surface, and partially due to the beading caused by the chemical.

The chemical on plastic retained some ridge detail. When sprayed directly, the chemical was splotchy and heavy, making ridge detail difficult to pinpoint (see Appendix A: Figure 2 G). Indirect spraying created a lighter stain and more even coating, though ridge detail is still difficult to pinpoint (see Appendix A: Figure 2 g).

Glass produced no maintenance of ridge detail for either the direct spraying or indirect spraying (see Appendix A: Figure 2 H,h). This was partially due to the beading of the blood prior to staining and partially exaggerated by the addition of the liquid solution. In the case of direct spraying, the chemical produced a substantially thicker coating (see Appendix A: Figure 2 H). Indirect spraying left much of the blood unstained (see Appendix A: Figure 2 h).

Airbrush System

Leucocrystal Violet working solution was sprayed using the new Model 250 Airbrush directly with the material held at a 90° angle and indirectly with the material at the horizontal (0°); this constituted Set 2 (see Appendix A, Figure 3).

In general, the Leucocrystal Violet solution showed improved ridge detail maintenance, though the Leucocrystal Violet still produced a somewhat spotty stain. Running was reduced on the vertical surface, but still occurred slightly. Indirect spraying produced the best results. This test was run to observe the effects of the improved spray device relative to the old spray device and to determine whether this was responsible for the improvement in ridge detail maintenance. The new spray device proved to be somewhat beneficial to the staining procedure.

The cotton and denim (100% cotton) produced little to no ridge detail (see Appendix A: Figure 2 A,a,B,b). The weave of the fabric overwhelmed much of the ridge detail in the fingerprints. For cotton, the stain was not dark enough or contrasting enough to produce good fingerprint detail (see Appendix A: Figure 3 B,b). Indirect spraying on both cotton and denim failed to darkly stained the fingerprint (see Appendix A: Figure 3 a,b).

Staining with wood maintained some ridge detail, though some was also lost due to the integration of the chemical into the grain of the wood (see Appendix A: Figure 3 C,c). Indirect application maintained the best ridge detail, despite running opposite the grain of the wood (see Appendix A: Figure 3 c).

Cardboard produced little ridge detail (see Appendix A: Figure 3 D,d). Much of the chemical and blood were absorbed into this porous surface. In the case of direct spray, the spotting was approximately the same as indirect spraying (see Appendix A: Figure 3 D,d).

Drywall produced good ridge detail (see Appendix A: Figure 3 E,e). Spraying directly produced good contrast on the ridges (see Appendix A: Figure 3 E). Indirect spraying maintained some ridge detail but it was less obvious; the contrast was lighter, making observation of ridge detail more difficult (see Appendix A: Figure 3 e).

Metal produced little maintenance of ridge detail (see Appendix A: Figure 3 F,f). This was partially due to the blood beading on the nonporous surface, and partially to the addition of the liquid chemical (sprayed). Some ridge detail was maintained and the chemical was only somewhat splotchy on the indirect application (see Appendix A: Figure 3 e).

Plastic maintained good ridge detail, especially in the case of indirect spraying (see Appendix A: Figure 3 G,g). Direct spraying produced a thick and heavy fingerprint, obscuring nearly all ridge detail (see Appendix A: Figure 3 G). Indirect spraying produced a somewhat less splotchy appearance and maintained some visible ridge detail (see Appendix A: Figure 3 g).

Glass retained little to no ridge detail (see Appendix A: Figure 3 H,h). Partially due to the blood beading and partially due to the addition of new liquid chemical (sprayed), these fingerprints have no characteristics for identification. Indirect versus direct spraying had little effect on fingerprint contrast.

Sodium Alginate Addition

In this experiment, Sodium Alginate was used as a thickening reagent to increase the viscosity of the chemical stains. We observed this increased viscosity further emphasized ridge detail from staining and prevented physical disruption f the chemical after it dried. This is especially beneficial in the case of fingerprints on surfaces at extreme angles, such as ceilings or walls. After the Sodium Alginate solidified, we observed the formation of a protective cover that prevented physical disruption of the fingerprint.

Leucocrystal Violet and Sodium Alginate were then mixed in varying ratios in order to determine which produced the optimal viscosity: thick enough to stick to surfaces at angles between 0° and 180° without running, but thin enough to be sprayed using conventional spay devices. The ideal viscosity was determined to be 3 parts Sodium Alginate: 1 part Leucocrystal Violet. This new solution was then tested with the Preval Spray Gun both directly and indirection (see Appendix A, Figure 4). When sprayed both directly and indirectly, the modified chemical failed to run.

Cotton and denim (100% cotton) produced little ridge detail (see Appendix A, Figure 4A,a,B,b). Most of it was obscured by the weave of the fabric. Spraying indirectly produced less staining and contrast than direct spraying. Directly spraying created a thick splotchy appearance, as the chemical appeared to sit on the top of the surface rather than soak in (see Appendix A, Figure 4B).

Wood produced little ridge detail (see Appendix A, Figure 4C,c). The chemical created a more splotchy appearance when sprayed directly since it didn't soak into this surface especially well, most likely due to the increased viscosity (see Appendix A, Figure 4C). Spraying indirectly produced little ridge detail and less splotching (see Appendix A, Figure 4c).

Cardboard produced little to no ridge detail (see Appendix A, Figure 4D,d). Spraying directly produced some beading on the surface of the cardboard (see Appendix A, Figure 4D). Spraying indirectly failed to produce substantial ridge contrast (see Appendix A, Figure 4d).

Drywall showed some maintenance of ridge detail (see Appendix A, Figure 4E,e). Spraying directly produced a thicker, splotching effect, with the chemical joining into rather large globs on the surface of the material (see Appendix A, Figure E). Spraying indirectly maintained good ridge detail, demonstrating a lighter contrast and substantially reduced globbing (see Appendix A, Figure 4e).

Metal produced little to no ridge detail (see Appendix A, Figure 4F,f). Spraying directly produced much more contrast but little ridge detail (see Appendix A, Figure 4F). Spraying indirectly produced too little contrast to be easily visible (see Appendix A, Figure 4f).

Plastic produced some ridge detail (see Appendix A, Figure 4G,g). Unfortunately, these pictures are too blurry to observe the positive effects of this modification. Direct spraying produced good contrast with some residual globbing (see Appendix A, Figure 4G). Indirect spraying created better ridge detail though the contrast was less obvious (see Appendix A, Figure 4g).

Glass retained little to no ridge detail (see Appendix A, Figure 4H,h). Partially due to the blood beading and partially due to the addition of new liquid chemical (sprayed), these fingerprints have no characteristics for identification. Indirect versus direct spraying had little effect on fingerprint contrast.

Airbrush System and Sodium Alginate

Leucocrystal Violet and Sodium Alginate were then mixed in varying ratios in order to determine which produced the optimal viscosity: thick enough to stick to surfaces at angles between 0° and 180° without running, but thin enough to be sprayed using conventional spay devices. The ideal viscosity was determined to be 3 parts Sodium Alginate: 1 part Leucocrystal Violet. This new solution was then tested with the Airbrush Model 250 spray device on each sample material both directly at a 90° angle and indirectly at a 0° angle.

Cotton and Denim (100% cotton) failed to produce any discernable ridge detail (see Appendix A, Figure 5). The weave of the fabric overwhelmed any ridge detail. The contrast with denim, especially in the case of indirect spraying, failed to produce a contrast color dark enough to make ridge detail visible (see Appendix A, Figure 5 B,b).

Wood produced little to no ridge detail (see Appendix A, Figure 5 C,c). This is partially due to the fact that the fingerprints stained were very dark and had little ridge detail to begin with. In addition, this surface is highly porous. No beading of the chemical on top of the surface was observed.

Cardboard produced some chemical ridge detail maintenance (see Appendix A, Figure 5D,d). Spraying directly produced some ridge detail though the contrast was not optimal (see Appendix A, Figure 5D). This is likely partially due to the fact that the chosen blood fingerprint contained less heme than that chosen for the indirect spray. Spraying indirectly showed no improvement over spraying directly (see Appendix A, Figure 5D,d).

Drywall produced no visible ridge detail (see Appendix A, Figure 5E,e). Most of the chemical was absorbed. Additionally, contrast was low on this surface.

Metal produced little observable ridge detail (see Appendix A, Figure 5F,f). This is likely due to the blood's beading on contact with the surface rather than any addition by the chemical.

Plastic produced excellent improvement in both the experiments run spraying directly and those run spraying indirectly (see Appendix A, Figure 5G,g). Spraying directly produced some clumping and a darker contrast, though significant ridge detail was maintained. Spraying indirectly produced the best fingerprint, with smaller ridge characteristics visible and a strong maintenance of ridge detail (see Appendix A, Figure 5g).

Glass retained no ridge detail (see Appendix A, Figure 5H,h). This is partially due to the blood's beading on the glass. Addition of spraying chemical did not improve contrast or enhance ridge detail (see Appendix A, Figure 5H,h).

Leucomalachite Green

Current Method

Appendix A Figure 6 is representative of the staining capacity of Leucomalachite Green in the field and acts as a control or baseline for the experiment. The unmodified chemical and Preval spray device used currently at crime scenes were used with no modifications. This control allows for comparison and recognition of improvements or diminishments caused by modifications or changes to the chemicals, spray device, and methods. In Figure 6 A-H the Leucomalachite Green was sprayed directly onto the surface at a 90° angle. In Figure 1 a-h the Leucomalachite Green was sprayed indirectly onto the surface at a 0° angle

The cotton and denim (100% cotton) (Appendix A: Figure 6 A and B) showed no ridge detail. The texture and stitching of the fabric was more noticeable than the fingerprint. The blue of the denim made it difficult to see the green color change of the Leucomalachite Green. The blood and chemical both soaked into the fabric causing no running however the print was blurry. The cotton and denim (100% cotton) (Appendix A: Figure 1 a and b) showed no ridge detail also due to the texture and stitching. The color enhancement was difficult to see on the denim due to the blue fabric.

The wood in Figure 6 C and c showed no ridge detail due to the grain in the wood. The blood and chemical soaked into the pores in the wood and caused blurring in several spots. The cardboard and drywall did not show fingerprints with much detail (Appendix A: Figure 6 D, E, d, e). The direct spray (Appendix A: Figure 6 D and E) caused the cardboard and drywall to become soaked over the print area due to the hydrogen peroxide that had to be sprayed after the initial Leucomalachite Green spray. Both chemicals were watery and caused the darkened area around each print. The overall swirls are still partially visible. The indirect spray (Appendix A: Figure 6 d and e) also caused the cardboard to be soaked around the print because it was so thin. The drywall being thicker did not have that problem with the indirect spray; however both prints were slightly blurry.

The metal in Figure 6 F and f were difficult to photograph and the green was difficult to see. The chemical beaded at both spray angles due to the multiple layers added by the 2 separate chemicals. The direct spray caused some running and made the print blurry.

The plastic and glass from the direct spray (Appendix A: Figure 6 G and H) ran almost instantly on contact. The separate sprays obliterated any prints on those surfaces. There was no adhesion to the surfaces as they were very smooth. The indirect spray (Figure 6 g and h)l kept the prints intact. Very little, if any ridge detail was maintained, although there was some shape and slight swirl patterns visible where the droplets were not too heavy. The chemical spotted a lot instead of running.

Airbrush System

Traditional Leucomalachite Green was applied using the Model 250 Airbrush, first directly with the surface held at 90° (Appendix A: Figure 7 A-H), then indirectly with the material at 0 (Appendix A Figure 7 a-h). This set was run to observe the effects of the new spray device on the Leucomalachite Green chemical stain and determine whether it was responsible for any improvements.

The cotton and denim (100% cotton) (Appendix A: Figure 7 A and B) showed no ridge detail. The texture and stitching of the fabric was more noticeable than the fingerprint. The blue of the denim made it difficult to see the green color change of the Leucomalachite Green. It was not thick enough to soak into the fabric. The cotton and denim (100% cotton) (Appendix A: Figure 1 a and b) showed no ridge detail also due to the texture and stitching. The color enhancement was difficult to see on the denim due to the blue fabric. Prints that were heavy in blood (red color) were difficult to see with the Leucomalachite Green and the thin spray of the airbrush made it very difficult to see any stain at all.

The wood in Figure 7 C and c showed no ridge detail due to the grain in the wood. The blood and chemical soaked into the pores in the wood and caused blurring in several spots. The cardboard did not show fingerprints with any detail retained (Appendix A: Figure 6 D and d). Even though the spray mist was very fine, both sprays caused the cardboard l to become soaked over the print area due to the hydrogen peroxide that had to be sprayed after the initial Leucomalachite Green spray. Both chemicals were watery and caused the darkened area around each print.

The drywall in Figure 7 E and e managed to retain some basic ridge patterns. Some smaller ridge detail was noticeable with the direct spray and the color was vivid. The indirect spray showed little color change and was more spotted green in areas.

The metal in Figure 7 F and f were difficult to photograph. The chemical beaded at both spray angles due to the multiple layers added by the 2 separate chemicals. The direct spray was thin enough that no running occurred.

The plastic and glass from the direct spray (Figure 7 G and H) ran on contact but only after the second coat. The overall shape of the print was still maintained on the plastic. The print was no longer intact after the hydrogen peroxide spray on the glass. There was little adhesion to the surfaces as they were very smooth. The indirect spray (Appendix A: Figure 7 g and h) kept the prints intact. Some minor ridge detail was maintained on the plastic but the spray spotted. The glass had a very light green color change and was a bit difficult to see. It beaded on the edge of the print and the actual print was very spotty.

Addition of Sodium Alginate

The Leucomalachite Green was modified by adding 2 parts Sodium Alginate: 1 part Leucomalachite Green because a 3:1 ratio was too viscous to spray with either device. The Preval sprayer with the Sodium Alginate modified Leucomalachite Green is see in Appendix A Figure 8. Figure 8 A-H depicts the direct spray with the surface held at 90° and Figure 8 a-h depicts the indirect spray with the material at 0°.

The cotton and denim (100% cotton) (Appendix A: Figure 8 A and B) showed no ridge detail. The texture and stitching of the fabric was more noticeable than the fingerprint. The blue of the denim made it difficult to see the green color change of the Leucomalachite Green. The chemical was much thicker and it did not soak into the fabric as much, leaving a decent stain. The indirect spray (Appendix A: Figure 8 a and b) caused little color change. The lack of soaking into the fabric made the stain difficult to see.

The wood in Figure 8 C and c showed no ridge detail due to the grain in the wood. The print became very dark with light green spotting. The chemical stuck to the surface rather than being soaked into the wood, but the print was blurry.

The cardboard did not show much retained ridge detail (Appendix A: Figure 8 D and d). The green color was spotted over both prints. The modified mixture stuck to the surface without soaking through even with the secondary hydrogen peroxide application.

The drywall (Appendix A: Figure 8 E and e) maintained ridge detail. There was little spotting and the green was well covered over the print. The color was faint, but the detail was still noticeable and the color contrasted with the drywall enough to observe detail.

The metal in Figure 8 F and f were difficult to photograph. No beading or running occurred but no detail was seen. The green areas in the prints were very spotty and the print was blurred in some areas of heavier application.

The direct spray on the plastic (Appendix A: Figure 8 G) maintained decent ridge detail. The color change was faint, but there was enough to draw out some patterns. There was no spotting or running. There was better detail in the areas of the print with less (red) blood, although color change and detail was seen in the heaver print areas. Indirect spray (Figure 8 g) allowed for more basic ridge patterns to be identified. The color was very faint and difficult to see. No running or spotting occurred.

The glass did not show any ridge detail (Appendix A: Figure 8 H and h). There was some beading, but no running occurred at either angle. It was very difficult to see the color change. The areas with less blood provided a better color change.

Airbrush System and Sodium Alginate

The modified Leucomalachite Green was sprayed with the Model 250 airbrush. Appendix A Figure 9 depicts both chemical modification with Sodium Alginate and the alternative spray device. Figure 9 A-H depicts the direct spray with the surface held at 90° and Figure 9 a-h depicts the indirect spray with the material at 0°.

The cotton and denim (100% cotton) (Appendix A: Figure 9 A and B) showed no ridge detail. The texture and stitching of the fabric was more noticeable than the fingerprint. The chemical was much thicker and it did not soak into the fabric as much, leaving a decent stain. The blue from the denim made the color hard to see. The airbrush was able to spray the modified chemical effectively and a darker stain occurred. The indirect spray (Appendix A: Figure 9 a and b) had better color. The chemical stuck to the surface of the fabric and made the print more noticeable. No detail was seen because the stitching and texture was more noticeable. The blue denim made the green difficult to see.

The wood in Figure 9 C and c showed no ridge detail due to the grain in the wood. The green was more visible in the direct spray. Some spotting occurred but there was not detail to obscure. The indirect spray also spotted a little. There was blurring where the pores in the grain were.

The cardboard did not show much retained ridge detail (Appendix A: Figure 9 D and d). The direct spray (Appendix A: Figure 9 D) soaked into the cardboard, and some dark green color was visible. There was blurring and some spotting. The indirect spray (Appendix A: Figure 9 d) showed minimal color change except from some green spotting.

The drywall (Appendix A: Figure 9 E and e) maintained ridge detail. Some spotting occurred from the direct spray (Appendix A: Figure 9 E). Some basic ridge patterns were visible. The indirect spray (Appendix A: Figure 9 e) showed very little spotting and a faint color change, but the lighter print ridges became more noticeable. Moderate detail was seen over the entire print.

The metal in Figure 8 F and f were difficult to photograph. No beading or running occurred but no detail was seen. There was some spotting of green and the overall color change was faint and difficult to see.

The plastic (Appendix A: Figure 9 G and g) maintained decent ridge detail. There was no spotting or running. There was better detail in the areas of the print with less (red) blood, although color change and detail was seen in the heaver print areas. The overall color change was dark enough to see most patterns.

The glass did not show any ridge detail (Appendix A: Figure 8 H and h). There was some beading, but no running occurred at either angle. It was difficult to see the print, but some color was seen. There was little effect on the heavy blood areas.

Discussion

An initial set of each material was observed to determine the capacity for blood to leave ridge detail on surfaces of varying porosity (see Appendix A: Figure 1). Denim, cotton, and glass showed the lowest ridge detail (see Appendix A: Figure 1 A,B,H). Metal showed some ridge detail, though the print seems blurred due to the blood beading on the surface (see Appendix A: Figure 1F). Wood showed little detail maintenance due to the graining (see Appendix A: Figure 1C). Cardboard, drywall, and plastic maintained the most easily viewed ridge detail (see Appendix A: Figure 1D,E,G).

Leucocrystal Violet

The first experiment performed was to act as a positive control. In this experiment, a Preval spray gun was used to apply working Leucocrystal Violet to a sample of each surface, first directly at 90°, then indirectly at 0°. Addition to cotton, denim (100% cotton), wood, drywall, metal, and glass failed to produce any discernable improvement on ridge detail(see Appendix A: Figure 2 A-C,E,F,H). In general, it appears that Leucocrystal Violet produces the best results on plastic and cardboard (see Appendix A: Figure 2 G,D). Spraying indirectly produced the best ridge detail enhancement.

The second experiment tested the new spray device, a Badger Airbrush Model 250, and the traditional working Leucocrystal Violet. This new model performed poorly on cotton, denim, cardboard, metal, and glass (see Appendix A: Figure 3 A,B,D,F,H). Some detail was maintained when sprayed on plastic, drywall, and wood (see Appendix A: Figure 3 C,E,G). Spraying indirectly produced the best results for ridge detail maintenance, though the contrast was not as drastic as the samples that were sprayed directly. For plastic, drywall, and wood, this new spray device improved the ridge detail. This new spray device improved ridge detail relative to current methods used in the field. The finer spraying method produced a finer coating and helped prevent the usual globbing that is apparent in tests run with the Preval Spray Gun.

The third test was run using the Preval Spray Gun and the Leucocrystal Violet in Sodium Alginate. This test showed little improvement on cotton, denim, metal, glass, and wood (see Appendix A: Figure 4 A-C,F,H). Some improvements were visible on cardboard, drywall, and plastic (see Appendix A: Figure 4 D,E,G). The chemical was applied with a heavier splotching effect, but nonetheless still produced a somewhat improved ridge detail. This ridge detail was better than the results produced from the airbrush application device. This suggests that this chemical modification would enhance fingerprint detail and ridge characteristics in the field on cardboard, drywall, and plastic. Other surfaces were unaffected by this modification.

The fourth test run used both the new spray system (the Badger Airbrush Model 250) and the modified Leucocrystal Violet (with Sodium Alginate). This test failed to enhance ridge detail on cotton, denim, wood, drywall, metal, and glass (see Appendix A: Figure 5 A-C,E,F,H). Some improvement was seen on cardboard and substantial improvement was viewed on plastic (see Appendix A: Figure 5 D, G). Ridge detail was substantially enhanced on the plastic with both the direct and indirect application. The compilation of both modifications greatly improved both ridge detail and brought out the appearance of ridge characteristics which were previously lost in chemical splotching. In the case of plastic, these chemical improvements were optimal.

Storage

Traditional Leucocrystal Violet degrades slowly over time, retaining its ability to effectively stain for approximately one month. In high-crime areas, mixing the Leucocrystal Violet and storing prior to needing it is plausible; on lower crime areas, the Leucocrystal Violet should be mixed on-site.

Mixing Leucocrystal Violet with Sodium Alginate showed no ill effects on its capacity to stain bloody fingerprints. Ridge detail was drastically increased in plastic samples, producing a cleaner, more detailed fingerprint. The Sodium Alginate, which forms a protective covering, may slow degradation post-staining by preventing biodegradation in the case of Leucocrystal Violet. When mixed, Leucocrystal violet showed a moderate capacity for storage, though optimally the Sodium Alginate base solution should be store separate and the chemicals mixed on site.

In the case of both chemicals, indirect spraying produced the best results. Increasing the distance between the spray device and the sprayed fingerprint may produce the same results on a wall or ceiling that was produced when fingerprints were sprayed indirectly. Other experiments to be run include testing the capacity of the chemical on a ceiling (180°) to investigate whether these solutions drip.

The substantial increase in ridge detail produced by this modified chemicals will enable improved photography of ridge detail. In turn, this ridge detail will clarify other minor ridge characteristics and improve the capacity for fingerprint identification.

Leucomalachite Green

Experiment 5 tested the effect of Leucomalachite Green and the Preval spray gun as used in the field at crime scenes (see Appendix A Figure 6). Only the cardboard and drywall (Figure 6 D, d, E and e) showed any ridge detail and it was minimal. The lack of texture on these porous surfaces helped maintain this detail, but the watery chemicals caused dark spots around the prints where it soaked in. The cotton, denim and wood (Figure 6 A, a, B, b, C and c) had textures that made detail impossible to see. The non porous surfaces, metal, glass and plastic also maintained no ridge detail (Figure F, f, G, g, H, and h). There was running on contact and the prints were completely obliterated on plastic and glass. The metal had some slight texture which probably kept the print from being destroyed as on the smooth surfaces of glass and plastic. The application of two watery sprays made the enhancement on these surfaces almost nonexistent. Indirect spray prevented print obliteration and was a better application technique; however spotting occurred due to the watery nature of the substances. With the current chemical and method field use on fingerprints is not viable.

Experiment 6 tested the effect of the alternate sprayer, the Model 250 Airbrush with unmodified Leucomalachite Green. This depicts the impact of the device on the enhancement (see Appendix A Figure 7). The cotton, denim and wood all had the same outcome as experiment 4, no ridge detail (Figure A, a , B, b, C and c). The thin spray made the color faint and difficult to see. The drywall (Figure E and e) maintained the detail seen in experiment 5, but the thin spray did not soak in and no dark spot was visible. The thin nature of the cardboard (Figure D and d) still soaked the area around the print and ridge detail was obscured. The metal (Figure 7 F and f) did not produce ridge detail but the spray was thin enough to keep running from occurring. The improvement was slight, as beading occurred. Less running occurred on the plastic and glass (Figure 7 G, g, H and h) due to the thinner spray. There was lack of adhesion and the secondary hydrogen peroxide made the prints run on the smooth surface. The ridge detail on the plastic did improve with the indirect spray application but the chemical was spotty. The alternate spray device improved on the amount of running that occurred. The chemicals were still too watery to adhere well to the more non porous surfaces.

Experiment 7 tested the effect of Sodium Alginate added to Leucomalachite Green (see Appendix A Figure 8). The traditional Preval sprayer was used testing the effect of this media and viscosity change.   There was no change over the results of experiment 5 and 6 on the cotton, denim and wood (Figure 8 A, a, B, b, C and c). No ridge detail was seen but the chemical did not soak into the surfaces as much, it stuck more on the surface do to the increased viscosity. As in experiment 6, the cardboard did not retain any detail (Figure 8 D and d). The thickness of the chemical prevented soaking through to occur. The Sodium Alginate reduced the amount of spotting thus improving the ridge detail seen in experiments 5 and 6 for the drywall (Figure 8 E and e). There was no ridge detail on the metal and glass (Figure 8 F, f , H and h) as seen previously but the thicker solution better coated the surfaces and less beading and no running occurred. Improving on experiments 5 and 6, the plastic was able to retain ridge detail with direct and indirect spray (Figure 8 G and g). The adhesion to the surface was significantly increased by the increase in viscosity. The Sodium Alginate significantly improved on the running and spotting. The thicker solution allowed for better adhesion; however the Preval sprayer had a difficult time spraying the modified chemical. The overall stains were lighter and more difficult to see.

Experiment 8 tested the effect of the Sodium Alginate modification of Leucomalachite Green as well as the use of the alternate Model 250 airbrush (see Appendix A Figure 9). As seen in experiments 5, 6 and 7, the overall change in method did not improve enhancement on cotton, denim and wood (Figure A, a, B, b, C and c). The texture of these surfaces made it impossible to see any ridge detail. Since Leucomalachite Green was traditionally used for enhancement of footwear, which has less minute detail, these new changes may still be feasible. Additional tests on blood enhancement of larger detailed objects may be useful. The cardboard (Figure D and d) showed no improvement from the previous experiments. The material was too thin to prevent the two sprays from soaking the surface. The drywall had an improvement in both the direct and indirect spray (Figure E and e) over experiments 5, 6 and 7. The overall spotting was reduced, with some still occurring with direct spray, but the lighter ridges were noticeable with the indirect spray. The thinner spray and the more viscous chemical better covered the print and allowed more detail to be seen. The metal and glass (Figure F, f, H and h) also showed no improvement in ridge detail as seen in the previous experiments. The overall beading and running did improve with both changes, but was irrelevant due to the lack of detail to enhance, The overall enhancement in the plastic (Figure 9 G and g) improved with both changes compared to experiments 5, 6 and 7. Ridge detail was seen from both angles and the lighter blood areas were more noticeable due to the finer mist, and the spotting was removed with the thicker and more even coat provided by the Sodium Alginate.

The use of Leucomalachite Green in the field for bloody fingerprint enhancement is minimal. Ridge detail was moderate to high on drywall and plastic and could be of some use. The lighter color of the stain makes the detail more difficult to see making the stain less effect than other chemicals with a darker and more noticeable color change.

Storage

Traditional Leucomalachite Green degrades quickly, usually within several hours or days. In the presence of acetic acid, as mixed with the current working solution, Leucomalachite Green's degradation is drastically accelerated; this requires that Leucomalachite Green be mixed on-site immediately prior to use. The acetic acid serves no publicly exposed purpose, and contributes to the swift degradation of Leucomalachite Green. As a result, we suggest replacing the glacial acetic acid with acetate (chemically similar) to prevent the rapid destabilization of the green dye. Given this accelerated degradation rate in response to chemicals in solution, Sodium Alginate will not protect this chemical from degradation.

The Leucomalachite Green stain was rather light. Further tests investigating the use of 2% and 3% hydrogen peroxide need to be run to determine whether this will darken the stain to improve ridge contrast.

Additional Considerations

Spray Device

The current Preval sprayer produces droplets that are much too big to distribute the chemical stains and effectively maintain ridge detail in fingerprints (see Appendix A, Figure 5A). The new chemical sprayer, the Badger airbrush Model 250, produces a finer spray which better distributes the chemical stain into a thin coating and maintains ridge detail (see Appendix A, Figure 5B). The spray is fine enough to allow for less accuracy when spraying without worry of adding too much too quickly. This is especially important since multiple coats are often applied when spraying indirectly to enhance ridge detail. However, this new spray device still has some setbacks.

The proposed airbrush sprayer, at $40 per mechanism plus the additional cost of $14 per air canister, costs a great deal more than the $6 disposable Preval spray gun. The ridge detail improvement without the modified chemical stains is not enough to warrant this drastic price increase for the Leucocrystal Violet. However, due to the Preval spray gun's inability to spray the modified Leucomalachite Green, the airbrush device proposed or one similar is necessary. In addition to the price problem, the bottle containers for the chemical on the proposed airbrush model are also miniscule compared to those for the Preval spray gun; this substantially limits the spray time and requires repeat filling. The air canisters used in the airbrush model get cold after approximately an hour; this chilling decreased the pressure of the spray device, necessitating a canister switch to continue spraying. We propose that a warming belt which would store the canister close to the body to keep it warm would be a means of avoiding this problem in the field. Alternatively, an air processor could be used for large scale or long term processing in a crime lab. Another experiment should be run to investigate the amount of chemical being used by the airbrush sprayer compared to the Preval spray gun; the cost of the airbrush tools may equivocate with the cost of chemical saved over time.

In regards to environmental risk factors, neither spray device contains CFCs and therefore neither contribute to ozone depletion. The airbrush system, being reusable, will produce less physical waste compared to the disposable Preval spray gun. In addition, the possible decreased chemical use due to the production of a finer mist may decrease the negative effects due to toxic exposure by these chemicals. More experiments are necessary to determine this aspect definitively.

We propose that another airbrush system could be used instead of the Badger model 250. The finer mist produced by the airbrush is the cause of the improvements observed with this spray device. Other airbrush models may eliminate the limitations in the current proposed system. Further testing to investigate the modified chemicals in combination with other airbrush models is necessary.

Public Use

Currently, field tests are being performed to investigate how the modified chemicals and proposed spray device function in real life situations. An area wide demonstration is to be held for representatives of local Crime Laboratories on May 7, 2009. Representatives from Worcester, Boston, the Massachusetts State Crime Lab, the Federal Bureau of Investigation and other surrounding towns have been invited to view this presentation. In addition to performing presentations to demonstrate our results, the modified Leucocrystal Violet and Leucomalachite Green are in the process of being patented.

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Appendix A.

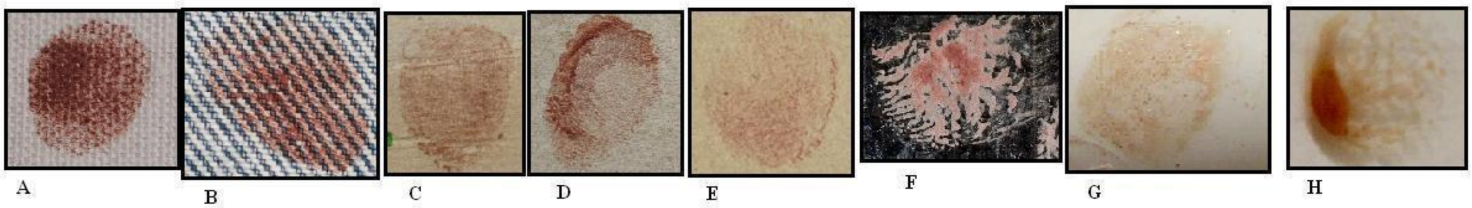
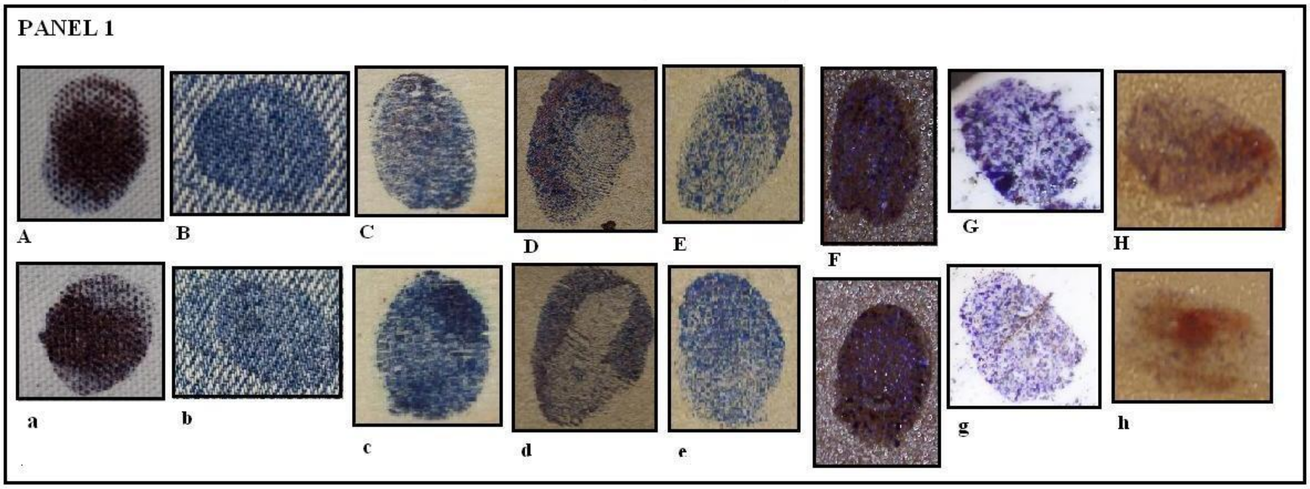


FIGURE1:Negative Control. Unstained Fingerprints on Various Surfaces

A. 100% Cotton
B. Denim (100% Cotton)
C. Wood
D. Cardboard
E. Drywall
F. Metal
G. Plastic
H. Glass



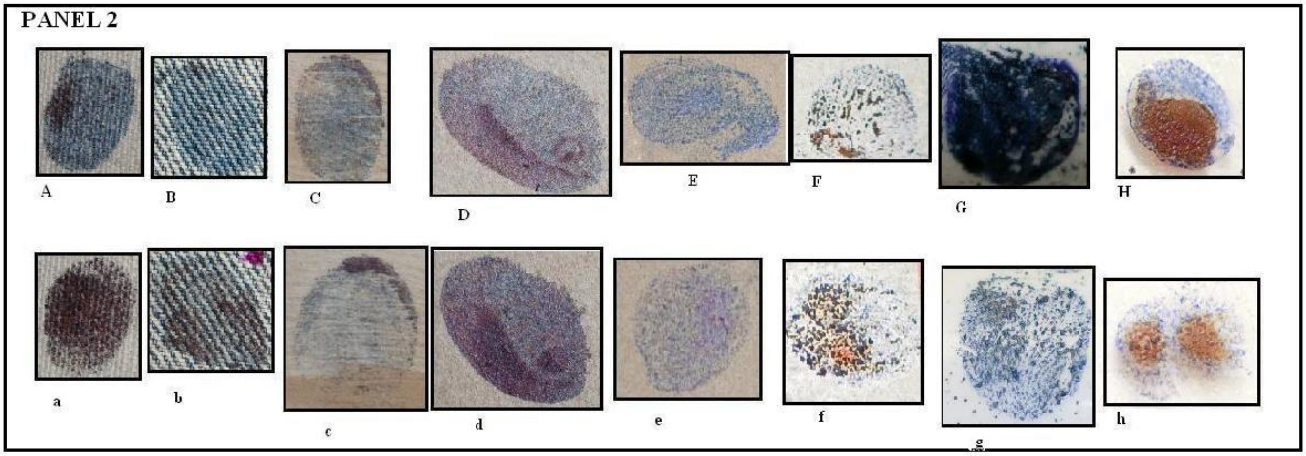
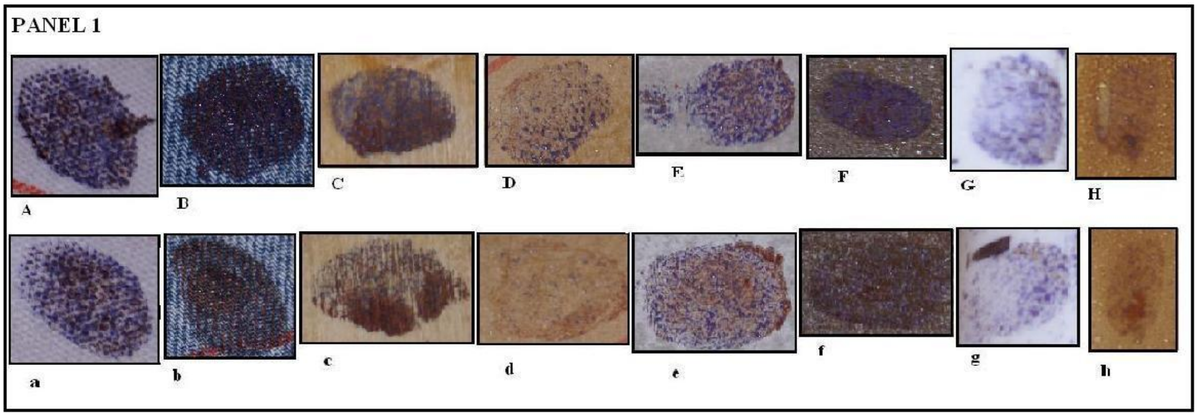


Figure 2: Current Method. Leucocrystal Violet (unmodified) using Preval Spray Gun
Figure 3: Modified Leucocrstayl Violet using Preval Spray Gun

Figures 2 & 3 use the same scheme:

Direct Spraying:
- **A. 100% Cotton**
- **B. Denim (100% Cotton)**
- **C. Wood**
- **D. Cardboard**
- **E. Drywall**
- **F. Metal**
- **G. Plastic**
- **H. Glass**

Indirect Spraying:
- **a. 100% Cotton**
- **b. Denim (100% Cotton)**
- **c. Wood**
- **d. Cardboard**
- **e. Drywall**
- **f. Metal**
- **g. Plastic**
- **h. Glass**



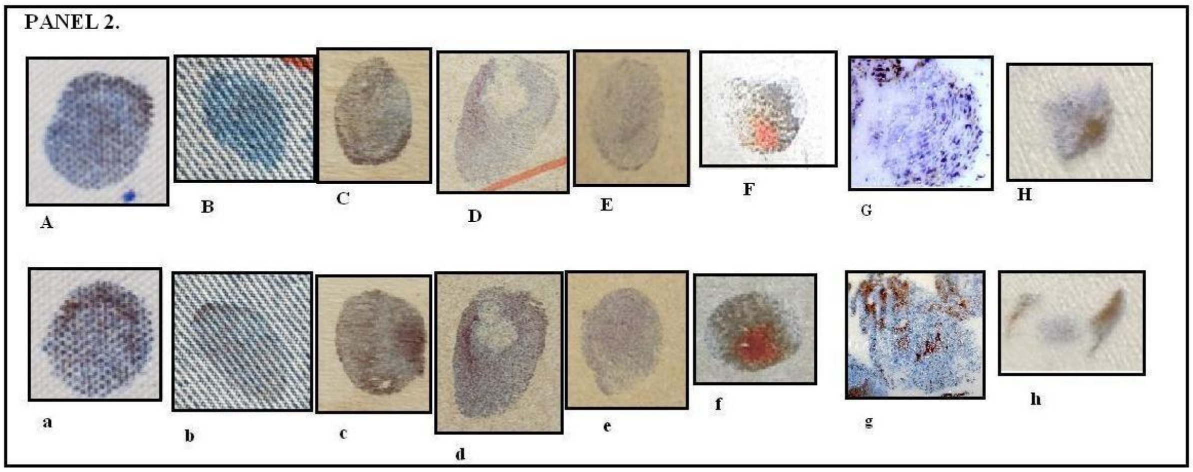


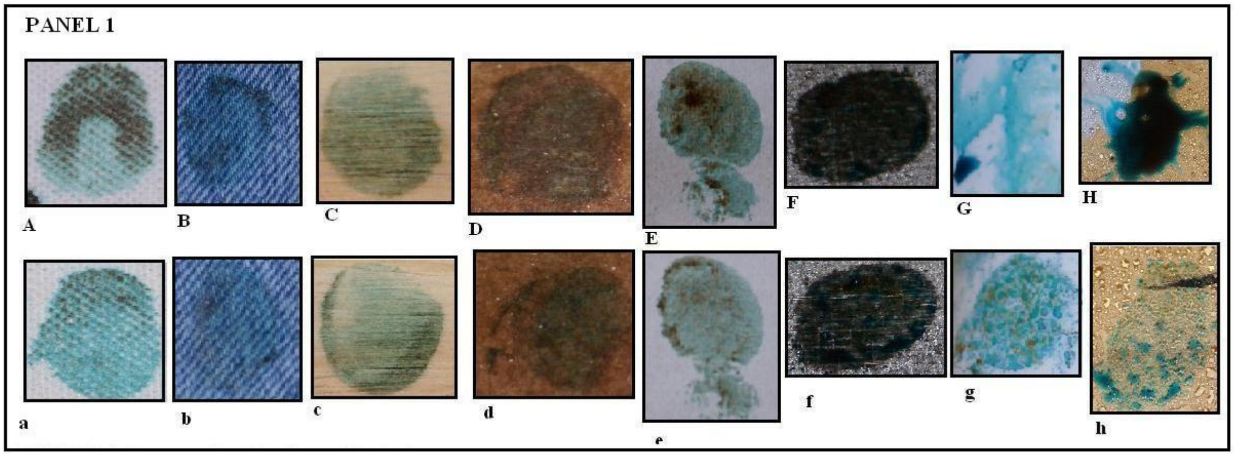
Figure 4: Modified Leucocrystal Violet using Preval Spray Gun

Figure 5: Modified Leucocrystal Violet using Airbrush System

Figure 4 and 5 use the same scheme:

Direct Spraying:
A. 100% Cotton
B. Denim (100% Cotton)
C. Wood
D. Cardboard
E. Drywall
F. Metal
G. Plastic
H. Glass

Indirect Spraying:
a. 100% Cotton
b. Denim (100% Cotton)
c. Wood
d. Cardboard
e. Drywall
f. Metal
g. Plastic
h. Glass



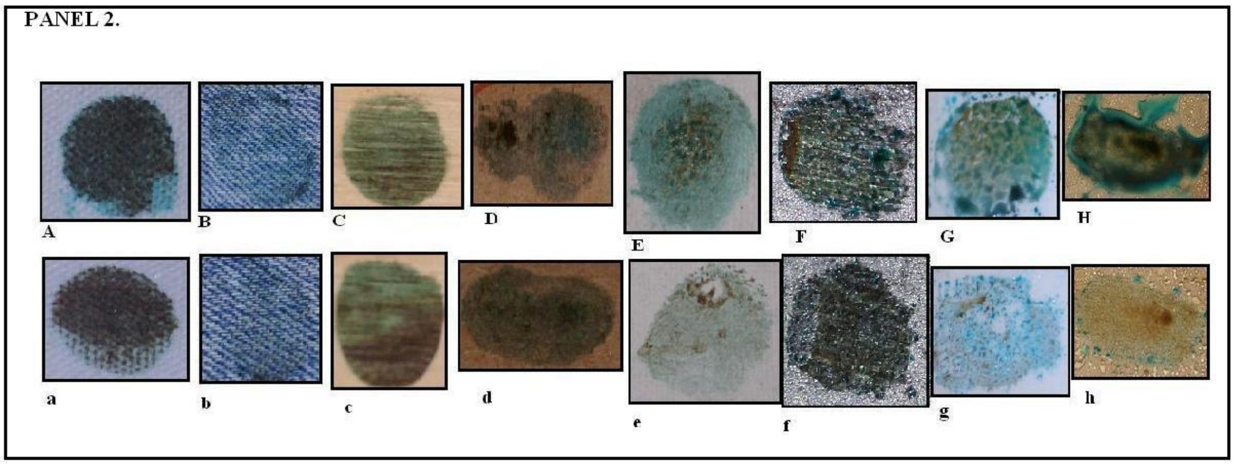


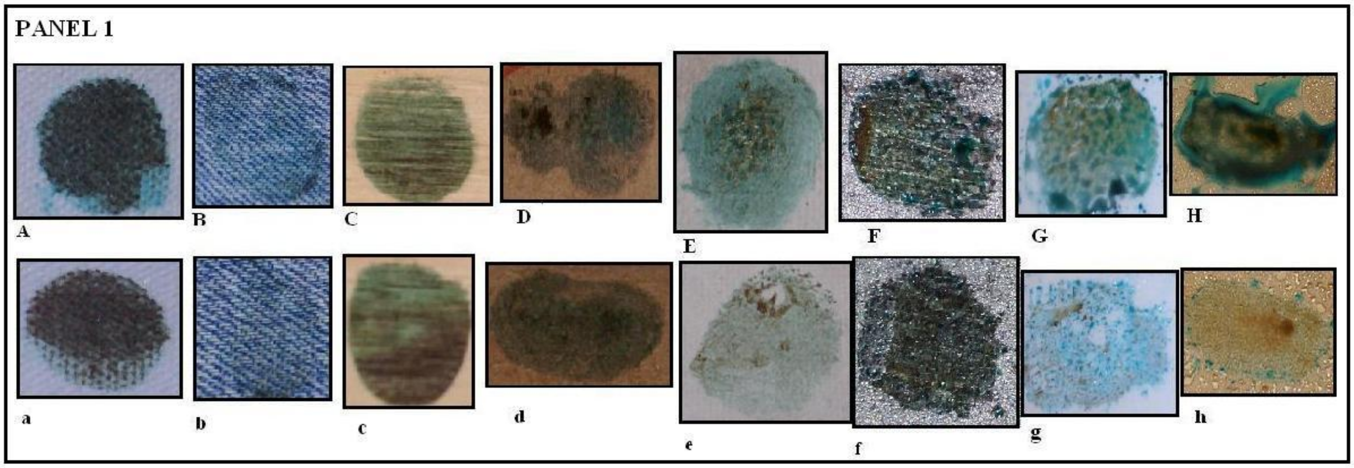
FIGURE 6: Leucomalachite Green Control.
Leucomalachite Green (unmodified) with Preval Spray Gun

FIGURE 7: Leucomalachite Green (unmodified) using Airbrush Spray System

Figure 6 and 7 use the same scheme:

Direct Spraying:
- A. 100% Cotton
- B. Denim (100% Cotton)
- C. Wood
- D. Cardboard
- E. Drywall
- F. Metal
- G. Plastic
- H. Glass

Indirect Spraying:
- a. 100% Cotton
- b. Denim (100% Cotton)
- c. Wood
- d. Cardboard
- e. Drywall
- f. Metal
- g. Plastic
- h. Glass



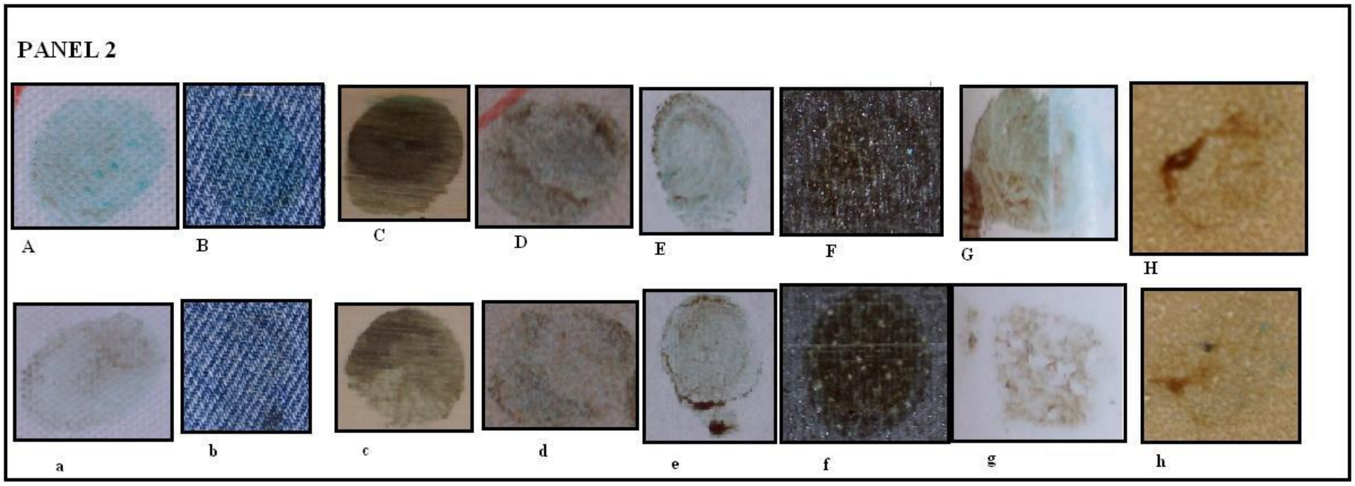


FIGURE 8: Leucomalachite Green using Preval Spray Gun

FIGURE 9: Leucomalachite Green using Airbrush Spray System

Figure 8 and 9 use the same scheme:

Direct Spraying:
- A. 100% Cotton
- B. Denim (100% Cotton)
- C. Wood
- D. Cardboard
- E. Drywall
- F. Metal
- G. Plastic
- H. Glass

Indirect Spraying:
- a. 100% Cotton
- b. Denim (100% Cotton)
- c. Wood
- d. Cardboard
- e. Drywall
- f. Metal
- g. Plastic
- h. Glass

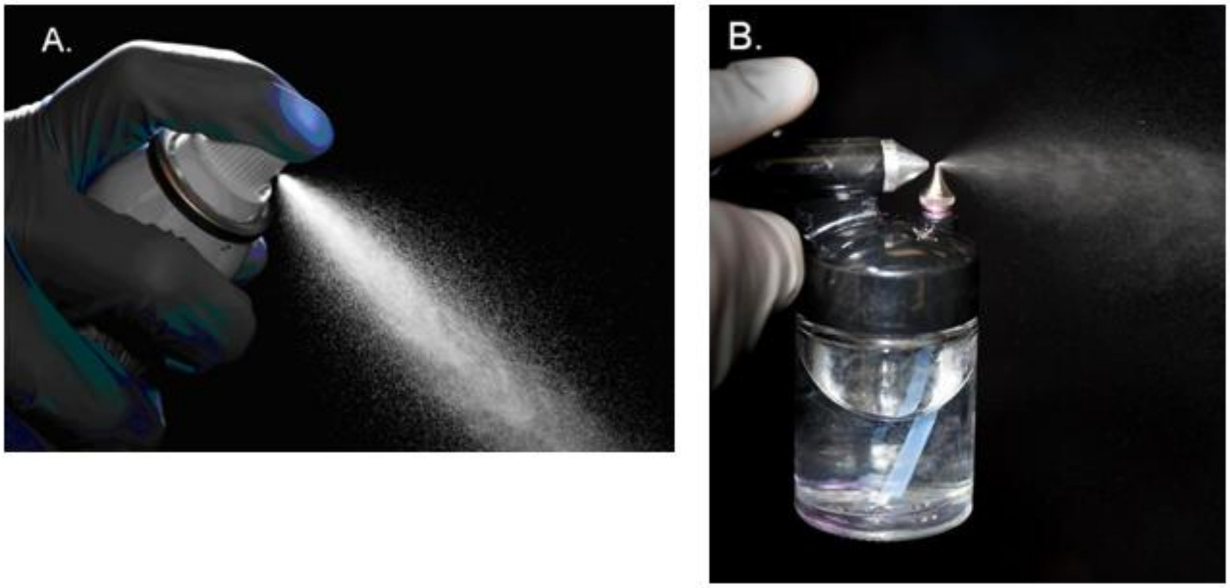


Figure 10. Preval Spray Gun (A) Close-up of Atomization; Badger Model 250 Airbrush (B) Close-up of Atomization