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The Discovery of Forensics Chemistry Latent Fingerprints: An Article Review

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Abstract

Forensic chemistry distinguishes itself from other branches of chemical sciences by the necessity to cater to the requirements of both the scientific and legal communities. Its research, application, and presentation are uniquely geared towards meeting the needs of these two domains. Consequently, forensic chemistry research is inherently practical and derived, emphasizing metrology (the science of measurement) and validation. Forensic chemistry has evolved beyond its initial analytical origins and now encompasses a broader range of chemical sciences. As the field expands, established forensic practices are being reevaluated, extending beyond drug analysis and toxicology to encompass diverse areas such as combustion chemistry, materials science, and pattern evidence. Chemistry has been used more and more to help with criminal investigations and forensic chemistry has become an important topic of study for students at all levels of education. The excitement of carrying out chemical tests is increased with the chance to explore a criminal incident. Both educators and students are consistently intrigued by the prominence of chemistry in crime scene investigations depicted in television shows. Fingerprint analysis, a key component of forensic science, has been adapted for every educational level. From elementary school students creating fingerprints with ink to the exciting (and messy) activity of revealing latent fingerprints through dusting, educators have found engaging ways to incorporate forensic science lessons. Superglue, readily available commercially, allows anyone interested to show its capabilities for detecting latent prints. Forensic science or forensic chemistry courses in high school and postsecondary education often include experiments involving the revelation of latent fingerprints. Latent fingerprints are formed when a person touches a surface, leaving behind a nearly transparent chemical residue that mirrors their unique skin ridge patterns. Latent fingerprints are likely to be left on surfaces every time you contact or grab them. To improve the contrast between the fingerprint residue and the surface it has been applied on, many methods have been established. Abundant and resilient, latent prints are unintentionally left behind on the surfaces you touch daily. Specialized techniques can reveal many of these latent prints, highlighting their potential significance in forensic investigations.

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Introduction

A fleshy pad called the volar pad, which is situated at the tips of your fingers, allows you to firmly grip surfaces. Within this pad, intricate patterns are formed by the skin ridges, resulting in unique fingerprints for each individual. While the pattern itself does not reveal specific information like race, gender, or age, its uniqueness allows for identification and matching. The significance of fingerprints as identifying marks has been recognized since ancient times when they were even used as seals.

The fingerprints are readily noticeable to the naked eye when you press your fingertips against a soft surface or leave a colorful material from your volar pad behind. However, when you touch anything, a little coating of transparent chemical residue from your volar pads is transferred in the shape of your distinctive skin ridges, leaving behind latent fingerprints. In fact, it's possible that latent fingerprints are left behind every time your hands contact or hold something. The contrast between the fingerprint residue and the surface has been improved via the development of several approaches, improving visibility. Latent prints are surprisingly prevalent and robust. You unknowingly leave hundreds of latent prints on the surfaces you touch each day, even if you're not aware of it. Specialized methods can be used to reveal many of these prints.

The fingerprints usage in criminal investigations has been documented for over a century. If a latent fingerprint of yours is discovered at a crime scene, it proves that you were there at some point. Similarly, finding your fingerprint on a firearm implies that you handled it once.

In essence, latent prints can link physical evidence to the perpetrator of a crime. Despite the advancements in DNA analysis, fingerprints continue to hold significance due to their ability to provide quick and cost-effective individual identification, comparable to that of DNA. In many jurisdictions, obtaining a court order is often necessary for DNA collection, whereas fingerprints are routinely taken at the time of arrest for most crimes. Law enforcement agencies maintain comprehensive searchable fingerprint databases, and fingerprints possess the unique capability to distinguish between individuals even when their DNA profiles are identical.

Chemical methods employed for revealing latent prints can be classified into two categories: those that rely on chemical reactions and those that leverage intermolecular forces for adhesion. The key objective of these techniques is to generate a significant contrast between the fingerprint residue and the surface, ensuring effective detection of the latent print. The ideal method should be simple, cost-effective, sensitive, and reliable. Durability is desirable, but photographed images can preserve revealed prints. Some techniques are nondestructive, allowing for sequential analysis of a print using different methods. In addition to the variety of surfaces on which prints may be deposited, environmental conditions may also pose challenges. The quantity of fingerprint residue can also vary significantly (Figure 1).

Figure 1. Latent Fingerprints.

Developing fingerprints latent using traditional methods

Method of powder dusting

The powder dusting method, utilized for latent fingerprint development on nonporous surfaces, has a long history and remains widely employed. Since the late 19th century, this technique has been in use. When fingerprint powder is dusting, it adheres mechanically or physically to aqueous or oily components in the latent fingerprint residues (Datta, et al, 2001). Crime scenes typically utilize regular powder, metallic powder, and fluorescent powder (Sodhi & Kaur, 2001). Regular powders consist of resinous polymer materials (such as starch, kaolin, rosin, and silica gel) for adhesion and colorants (such as bronze flake, aluminumflake, and dolomite powder) to enhance contrast. Magnetic powders typically contain magnetic particles as carriers and nonmagnetic colorants (including carbon black powder, bronze flake, aluminumflake, and fluorescent powder) as developers. MacDonell et al. first reported the use of magnetic powders for latent fingerprint development in 1961 (MacDonell, 1961). The use of fluorescent powders emerged in the late 20th century, coinciding with the utilization of lasers for the visualization of latent fingerprints. In 1977, the fluorescent powder coumarin-6 was first introduced alongside an argon ion laser for the development of latent fingerprints (Dalrymple, et al, 1977). Fingerprint powders containing fluorescent dyes such as acridine yellow, acridine orange, crystal violet, Nile blue, Rhodamine B, and Rhodamine 6G became widely employed. These powders were applied in combination with forensic light sources and suitable barrier filters for enhanced visualization. Fluorescent powders are highly advantageous when it comes to detecting fingerprints on surfaces that possess intricate background colors or textures. This is because identifying prints developed by non-fluorescent powders can be difficult, particularly on surfaces that have multiple colors.

The powder application process for latent fingerprints involves careful brushing, which is a simple, efficient, and cost-effective method. The powder dusting approach quickly produces discernable fingerprints on even and impermeable surfaces. Nevertheless, this method has some restrictions. It can potentially pose health hazards at crime scenes, and there is a concern about the potential transfer of DNA samples via fingerprint brushes (Figure 2).

Figure 2. Powder of the fingerprint.

Fuming with cyanoacrylate

When dealing with nonporous surfaces for developing latent fingerprints, law enforcement agencies rely heavily on the Cyanoacrylate fuming method known as Super Blue fuming method. Its invention dates back to the latter part of 20th century (Datta, et al, 2001). The procedure commences by introducing vaporized cyanoacrylate ester monomers to latent fingerprint residues through which rapid polymerization occurs. The initiated bonding effectively takes place between vapors present in it and residue initiators including water and acid. The introduced monomers then react with the remaining monomers in the vapor, resulting in the formation of a durable, white-colored polymer that covers the raised papillary ridges (Datta, et al, 2001). In order to reduce fuming time, cyanoacrylate ester monomers can be volatilized by a variety of techniques, including fume circulation, rapid heat evaporation, rapid chemical evaporation, and rapid vacuum evaporation.

Latent fingerprints that have been treated with cyanoacrylate fuming are fully formed and can be seen as a white matrix that appears three-dimensional. These fingerprints may not have enough contrast which could make them difficult to see. A frequently used method typically includes applying fingerprint powders, particularly fluorescent ones, to the fumed fingerprints. Latent fingerprints can be developed on nearly any nonporous substrate using the cyanoacrylate fuming method. On the other hand, this approach comes with certain health and safety concerns. The skin, eyes, and mucous membranes might suffer serious harm from cyanoacrylate esters in liquid form and their vapors (Fung, et al, 2011). An extremely poisonous gas called hydrogen cyanide can also be produced when heating cyanoacrylate ester monomers or polymers (Li, et al, 2013) (Figure 3).

Figure 3. Fingerprinting with Superglue and Cyanocrylate Fuming

Method of Silver Nitrate

Latent fingerprints on porous surfaces have long been developed using silver nitrate. Since the late 19th century, this method has been used (Datta, et al, 2001). Silver chloride is formed when silver nitrate reacts with chloride in fingerprint residues. The silver ions in the chloride make the stains black when exposed to light, reducing them to elemental silver and making it possible to see the fingerprints. To create fingerprints on porous materials like paper and wood, silver nitrate solution was first used. A group of researchers led by Trozzi (11) later introduced an innovative technique that utilizes an ethanol-based 3% silver nitrate solution for developing latent fingerprints on water-repellent surfaces like waxed paper. Through their experimentation, they found that ethanol helps reduce the NaCl dissolution rate in fingerprint residues resulting in improved surface wetness and quicker evaporation

Under typical indoor lighting conditions, the transformation of silver chloride into elemental silver through photo-reduction occurs at a slow rate. However, the process can be expedited when exposed to ultraviolet (UV) lights, with the effectiveness of the reaction being inversely proportional to the wavelength. Shorter wavelengths, such as 254 nm, yield more favorable results compared to longer wavelengths like 365 nm. The silver nitrate method is a straightforward and efficient approach to develop latent fingerprints on standard porous surfaces and specific water-repellent materials. It is advisable to use this method for latent fingerprints that are no older than one week. The primary limitation of the silver nitrate method is the possible decrement in contrast caused by background stains as shown in Figure 4.

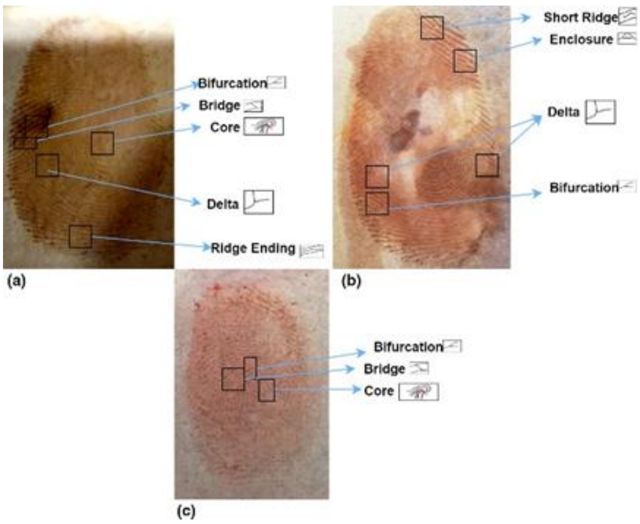

Figure 4. The use of silver nitrate in the development of latent fingerprints.

Method of Ninhydrin

The ninhydrin method is a widely utilized technique for enhancing latent fingerprints on porous surfaces, including paper, cardboard, raw wood, and plasterboard. Its inception can be traced back to the mid-20th century (Datta, et al, 2001; Oden & Hofsten, 1954). This method involves the interaction between ninhydrin and the amino acids found in the fingerprint residues, resulting in the creation of a distinctively colored substance called Ruhemann's purple, which brings the latent fingerprints into view (Datta, et al, 2001). The amino acids present in porous substrates like paper remain embedded and stable over time, without significant migration, making them ideal targets for the development of aged fingerprints (Girod, et al, 2012). Hence, the ninhydrin technique is specifically fabricated to facilitate the enhancement of aged fingerprints.

Precise control of the reaction conditions is essential to achieve optimal outcomes in the ninhydrin method: (i) maintaining a pH level above 4, preferably within the range of 4.5-5.2; (ii) creating a high-humidity environment between 50% and 80% since water plays a vital role as a reactant; and (iii) ensuring that the treated fingerprints are kept cool and shielded from light to prevent the degradation of Ruhemann's purple caused by oxygen and light exposure. Heat or steam treatment is commonly employed to expedite the ninhydrin reaction. However, it is important to note that high temperatures can result in significant discoloration of the background, resulting in reduced sensitivity and contrast in the development process.

For the purpose of revealing latent fingerprints on paper and other porous surfaces, the ninhydrin technique is frequently utilized due to its simplicity, effectiveness, and low toxicity (Sodhi & Kaur, 2001). It is particularly suitable for developing aged latent fingerprints. As a result of the relatively strict reaction conditions, achieving optimal outcomes requires skill and experience.

1, 8 Diazafluoren-9-one Technique

The DFO technique, which involves using 1,8-diazafluoren-9-one, is a valuable and efficient method for revealing hidden fingerprints on a range of absorbent materials, due to its exceptional sensitivity. The DFO method, which was suggested in the later part of the 20th century (Datta, et al, 2001; Pounds, et al, 1990; Grigg, et al, 1990), operates in a similar manner to the ninhydrin method by employing DFO to react with the amino acids present in fingerprint residues. This reaction leads to the creation of a subtle red or pink-colored product. Under green light, this product displays strong fluorescence, enabling the visualization of latent fingerprints [5, 6]. In contrast to the ninhydrin method, the DFO reaction for fingerprint development typically necessitates a low-humidity, high-temperature environment. Fingerprints that are not visible to the naked eye, when developed employing the DFO technique, can be easily identified without any additional treatment to produce fluorescence at lower temperatures, with ambient room temperature being sufficient. The DFO method generally yields a higher number of identifiable fingerprints compared to the ninhydrin method. Subsequent application of ninhydrin following DFO treatment offers an avenue for additional development by generating Ruhemann's purple. This can be attributed to the possibility that DFO might not undergo complete reaction with all the amino acids present in the fingerprint residue, thus leaving certain amino acids available for reaction with ninhydrin. The concomitant employment of DFO and ninhydrin techniques enhances the sensitivity of the developmental process beyond that achievable by either methodology in isolation. Therefore, the current recommended development sequence involves using DFO before ninhydrin on porous surfaces.

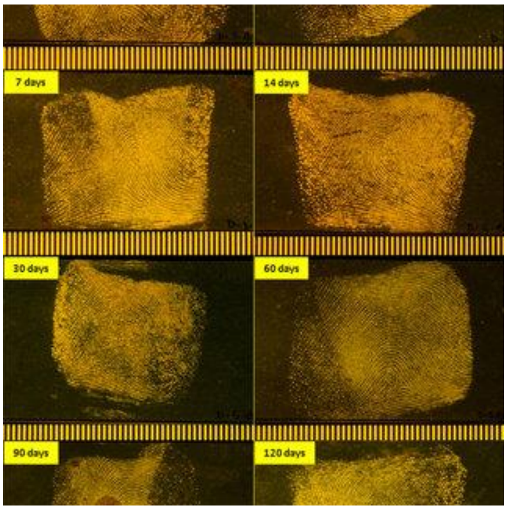

Figure 5. Latent fingerprint enhancement using 1,8-diazafluoren-9-one solutions.

Subsequent application of ninhydrin following DFO treatment offers an avenue for additional development by generating Ruhemann's purple. This can be attributed to the possibility that DFO might not undergo a complete reaction with all the amino acids present in the fingerprint residue, thus leaving certain amino acids available for reaction with ninhydrin.

Small Particle Reagents procedure

The small particle reagent method, invented in the late 20th century (Datta, et al, 2001), is an efficient technique for developing latent fingerprints in specific cases. The efficacy of this method is predicated upon the interplay between fine particles and the fingerprint's oily or fatty residues. These particles, when dispersed within a treatment solution, exhibit an affinity for the residue, facilitating the visual manifestation of the latent print (Datta, et al, 2001).

The small particle reagent is formulated as a suspension, comprising fine particles, a surfactant, and water. Conventional and fluorescent powders are commonly utilized in this method, with surfactants such as sodium dodecyl sulfate (SDS) being employed. The concentration of the surfactant plays a critical role, as insufficient concentration may result in haphazard particle deposition, whereas excessive concentration could lead to the inadvertent removal of fingerprint residues by water. The fine particles selectively adhere to the fatty or oily constituents present in the fingerprint residues, facilitated by the inclusion of a surfactant. This specific binding mechanism arises from the inherent stability exhibited by these components over an extended period. As a result, the small particle reagent method allows for the development of aged fingerprints. Furthermore, latent fingerprints on impermeable surfaces that have undergone prolonged exposure to wetness or immersion in water can be revealed through the application of such a technique.

For specific circumstances, the small particle reagent method complements the powder dusting method for developing fingerprints. For wet, water-immersed, aged fingerprints as well as porous surfaces, it is particularly useful (Datta, et al, 2001).

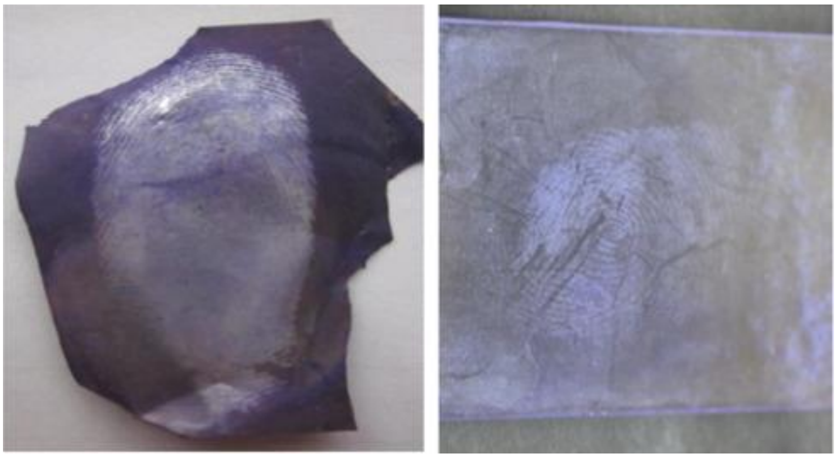

Figure 6. Crystal violet dye-based reagent for developing latent fingerprints

Gun Blue

The detection of fingerprints on brass shell casings is achieved through the application of a solution commonly referred to as "gun blue solution." This technique was initially implemented in forensic laboratories during the approximate period of 1995 (Holder, et al, 2011). Gun blue solution is an aqueous mixture comprising selenous acid and copper sulfate, which is employed for the purpose of immersing the discharged casings. Upon contact with the brass surface, a chemical transformation takes place, resulting in the generation and deposition of copper and selenium on the metal. The precise chemical reactions involved in this process can be described by the following equations, with the exception of regions containing fatty fingerprint residues (Leben & Ramotowski, 1997). Notably, the reduction reactions of both copper ions and selenous acid are facilitated in the presence of zinc (Holder, et al, 2011). Moreover, it is worth mentioning that this methodology is also applicable to nickel-plated brass and aluminum cartridges (Holder, et al, 2011).

Conclusion

In summary, the present review predominantly centers on the practical utilization of latent fingerprint development techniques. A concise survey is presented encompassing the prevailing conventional methodologies, namely powder dusting, cyanoacrylate fuming, the silver nitrate method, the ninhydrin method, the DFO method, and the small particle reagent method. Additionally, the imperative requirement for continued advancements in DNA extraction subsequent to latent print development is underscored, with the aim of fostering substantial progress in the realm of field testing.

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