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Physical Factors Affecting Fingerprint Development: A Review

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Abstract: ***Fingerprints are one of the most valuable pieces of evidence found at crime scenes because of their individuality, making them highly unique. The credibility of fingerprints to solve crimes makes it a critical tool in the field of forensics and law. This paper outlines different well-known methods for developing fingerprints that are used in forensics as well as explores the physical factors that affect latent fingerprint development when using methods like ninhydrin and cyanoacrylate fuming. Ninhydrin performs optimally at 80°C to 100°C, promoting rapid chemical reactions and clear prints. Cyanoacrylate also requires controlled temperatures of 80°C to 100°C for effective polymerization. The properties of the surface also affect the development. While ninhydrin excels on porous surfaces, cyanoacrylate is more effective on nonporous ones. Factors like humidity, concentration prove to have an effect on latent fingerprint development as well. This paper aims to highlight the importance of these factors for the most effective development of fingerprints, those which are clear to analyse.***

Keywords: Development, Forensics, Latent fingerprints, Physical factors

1. Introduction

Research Question

To what extent do physical factors affect the role of different fingerprinting developing agents in fingerprint development?

Background Information

Forensic Science is the application of scientific principles and methods in the investigation and the resolution of criminal cases[1]. It uses scientific methods to analyse and identify the evidence found at the crime scene[2]. Forensic chemists use various scientific techniques to examine substances like drugs, gunshots and trace materials, including fingerprints. This investigation plays a crucial role in this field as it establishes a link between suspects and crime scenes, contributing to the pursuit of truth and justice in the face of criminal acts[3].

Fingerprints are one of the most valuablepieces of evidence found at crime scenes because of their individuality, making them highly unique. This method is highly reliable for the identification of the criminal due to the fact that no two individuals have identical fingerprints. Unlike other physical characteristics like DNA, fingerprints stay constant throughout a person's lifetime. The credibility of fingerprints to solve crimes makes it a critical tool in the field of forensics and law. Fingerprints are composed of eccrine and sebaceous components which mainly comprise of amino acids and lipids[4]. The fingerprints are formed due to sweat which is released from pores that are present on finger ridges when it touches a surface. Sweat being colourless, the impressions formed are also colourless[5]. Fingerprints are collected fromcrime scenes and then undergo a process of development, examination, comparison and identification.

There are mainly three types of fingerprints: plastic, patent and latent. Plastic fingerprints are formed when the ridges of the fingerprints come into direct contact with a soft surface, leaving a three-dimensional impression. It can be found on surfaces like paint, soap, wax or tar. They are also visible and hence, do not need to be developed. Patent fingerprints are prints which are made by blood, grease or ink and are also visible to the eye without any further processing. Unlike latent fingerprints, plastic and patent fingerprints, being visible, can be destroyed by criminals to ensure that they don't leave a trace. Latent fingerprints are the most common type and are left on the surface through natural secretions of sweat and oils from the skin. The residues of these fingerprints contain amino acids, fatty acids and salts which interact with surfaces, making the fingerprints adhere to them. While the water present in sweat evaporates, the other constituents remain. The aim to develop latent fingerprints involves finding reagents that would react with the constituents of the residue. In comparison, the third type is not visible to the naked eye and hence needs to be developed to be seen for further analysis[6].

a. Plastic Fingerprint [7] b. Patent fingerprint[8] c. Latent Fingerprint[9]

Figure I: Representative Images of Different Types of Fingerprints

Latent fingerprints can be found on different types of surfaces. They are mainly classified into two different types: porous and nonporous. Nonporous surfaces are those that do not have pores, meaning they do not absorb substances[10]. Hence, it is one of the easiest surfaces on which fingerprints can be developed. The sweat and the other components of the residue remain on the surface as a thin film which is easy to lift as well as preserve. Examples of nonporous surfaces include glass, plastic, metal and ceramics. Porous surfaces, on the other hand, have pores which allow liquids and gases to be absorbed. Examples of these include paper, cardboard and fabric among many others[11]. While non-porous surfaces allow for more distinct fingerprints to be developed, porous surfaces make it harder to visualise but makes it last longer as they absorb the fingerprint[12].

Methods to Develop Latent Fingerprints

There are many ways to develop latent fingerprints. The most common ones include using ninhydrin and cyanoacrylate. Other methods include using silver nitrate, iodine fuming and powder dusting.

Powder Dusting Method

Dating back to the 19th century, the powder dusting method is used to visualise latent fingerprints on non-porous surfaces. The fine powder is applied to the fingerprint impression with either glassfibre or a camel hair brush. The method is carried out either by brushing, blowing or tapping the impression with powder. The powder sticks to the moisture and sweat present in the impression forming the ridge pattern, making the latent prints visible. The powder is usually a colour which contrasts with the surface in order to ensure its visibility. The pressure deficit mechanism causes the adhesion of powder to the fingerprint residue. In this mechanism, the properties of the sweat deposition interacting with the powder particle createconditions that lead to adhesion, ensuring the powder particles stick to the fingerprint residue. The powder particle, when wet at the bottom, sticks to the surface because the curved meniscus causes a pressure deficit within the droplet[13]. This method only works on non-porous surfaces due to the fact that the powder does not stick to the non-porous surface but instead onto the film of sweat and oil present. Moreover, the non-porous surface does not absorb sweat and oil, facilitating this method.

Iodine Fuming Method

Iodine fuming is a chemical method which is used to develop fingerprints on porous surfaces. This technique is based on the idea that crystals of iodine sublimes into a gaseous state[14].When iodine crystals are heated, they produce a purple vapour, which reacts with fatty acids and oils present in the fingerprint residues, forming a visible yellowish-browncolour.This method can also be applied on non-porous surfaces. The advantages of this method include the simplicity of carrying it out and the versatility of using it on a variety of surfaces. Fingerprints also develop quickly. Furthermore, iodine fuming develops both fresh and relatively old prints and is non-destructive. Hence, other methods can be implemented if iodine fuming does not work well.The main disadvantage of this method, however, is that the colour fades away quickly and hence, may require refuming. To overcome this issue, many techniques have been developed including the use of starch steam which produces a blue-black colour or silver foil which produces a yellow colour as a post treatment to iodine fuming[15].

Silver Nitrate Method

Using silver nitrate ($AgNO_3$) to reveal latent fingerprints has also been an early method used in forensic chemistry. This method was used on porous surfaces and hence, is not useful on surfaces that have been exposed to water[16]. It is based on the reaction of silver ions with chloride ions found in fingerprints. The reaction between silver nitrate and the chloride ions is a double displacement reaction which forms a white precipitate of silver chloride. This is relatively unstable and when it is exposed to ultraviolet radiation or sunlight, it decomposes to form silver and chlorine gas. Hence, the fingerprint is black or brown coloured after it gets reduced[17]. These reactions are shown below in equation 1. The silver colour of the fingerprints allows for easier identification of the fingerprint due to the contrast it creates with the background. Moreover, this is a relatively stable method so it does not fade over time and it can be used for visualizing old prints as well. This method is usually used as the last resort as it destroys the proteins present in the fingerprint.

$$AgNO_3 + Cl^- \longrightarrow AgCl + NO_3^-$$
$$2AgCl \longrightarrow 2Ag + Cl_2$$

Equation 1: Silver Nitrate Method Mechanism

Cyanoacrylate (Superglue) Fuming Method

A famous method that is used by forensic scientists to develop fingerprints is using cyanoacrylate, commonly known as superglue fuming. This method is presently very popular in forensic chemistry and itis mainly used on non-porous surfaces. It is based on the idea of polymerized cyanoacrylate ester being deposited on fingerprint residues[18]. The gaseous cyanoacrylate fumes react with the amino acids, fatty acids and proteins present in the sweat residue to form a white solid material. The method to develop the fingerprint using cyanoacrylate involves fumes of cyanoacrylate ester monomers reacting with anions present in the residue of the fingerprint. This leads to propagation where monomers react with more and form a polymer of cyanoacrylate molecules[19]. This process is done in a fuming chamber to prevent the contact of oxygen, which would otherwise inhibit the process. Since this reaction forms a white compound, it is not very visible on many surfaces. To enhance its visibility, the fingerprint undergoes post-treatment where it is coloured using dyes or fluorescent light sources[20]. The developed impressions last longer due to the plasticization of the print which prevents damage to the mark. This method makes the fingerprint semi-permanent so that it could either be dusted or tape lifted without getting disrupted. Superglue fuming possesses a variety of advantages making it a popular method currently. Firstly, cyanoacrylate fuming is highly sensitive to amino acids and other components present in the residue, allowing for the development of clear and detailed prints. Moreover, this method is efficient and non-destructive and does not damage any other trace evidence that is present. This allows for the fingerprint to be used to find various pieces of evidence. Another advantage that this method has is that it is a quick process as the boiling point for cyanoacrylate is around 54°C to 56°C and hence only takes a few minutes for the latent fingerprint to develop. However, it is vital to ensure that the residue is not over fumed with superglue as this could result in frosty prints which lack details and make them difficult to differentiate[21].

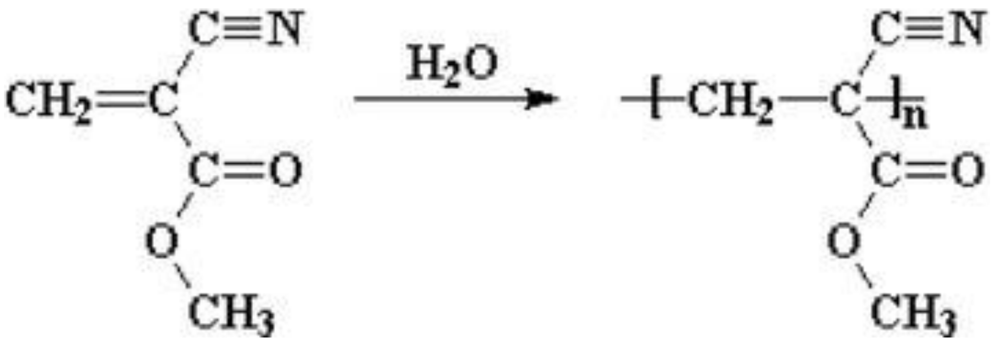

Figure 2: Polymerization of Cyanoacrylate [22]

Ninhydrin Method

Ninhydrin is one of the most famous fingerprint developing techniques used in the forensics field. It is a white crystalline solid that reacts with the α-amino acids to produce a purple colour known as Ruhemann's purple[23]. Ninhydrin has two carbonyl groups and one hydrindantin group. The amino acids are present in the sweat residue of the fingerprints. The ninhydrin reagent is used mainly on porous surfaces, meaning the water gets absorbed leaving behind the amino acids as solid materials. The reaction between ninhydrin and amino acids is a very slow reaction, and hence is sped up using heat or moisture. This is done through ninhydrin chambers which provide a hot and humid environment for the reaction to occur.Moreover, due to the stability of amino acids, ninhydrin is able to develop relatively old fingerprints as well. The reaction in this method involves the nucleophilic attack of the amine group in amino acids on the carbonyl group on ninhydrin. This forms a Schiff base, which are compounds that have a double bond linking carbon and nitrogen atoms. This is not directly visible but when the compound is heated, it undergoes a series of dehydration reactions and rearrangements to form Ruhemann's purple. This reaction is shown below in *Figure 2.*Using ninhydrin as a reagent offers several advantages, making it one of the most popular methods in the field. One of the major advantages of ninhydrin is that the reaction is highly sensitive and can react with small amounts of amino acids, allowing for the development of clear and detailed fingerprints. However, the disadvantage to this method is that ninhydrin fades as Ruhemann's purple degrades due to the exposure to light and oxygen[24]. To resolve some of the limitations that ninhydrin has, analogues were synthesized [25]. Analogues are compounds that are structurally related to ninhydrin that undergo similar reactions with amino acids. Examples include DFO,5-methylthioninhydrin and 1,2-indandione. These are shown below in *Figure 4.* However, these were not able to replace ninhydrin completely. One reason for this is that ninhydrin is a non-specific reagent and can react well with all the 14 types of amino acids present in fingerprint residues, unlike the analogue [26].

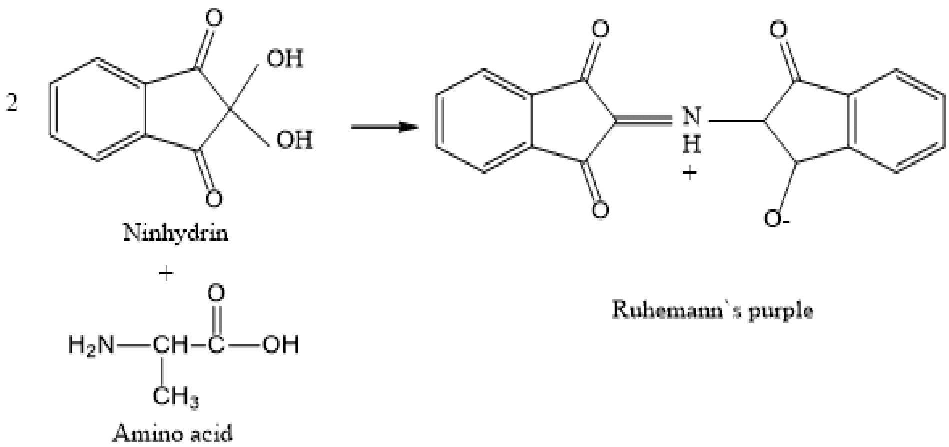

Figure 3: Formation of Ruhemann's Purple [27]

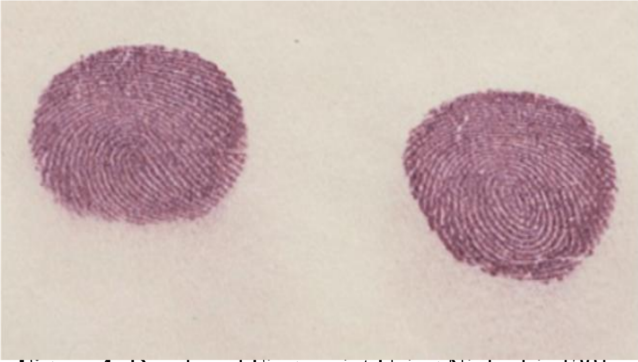

Figure 4: Developed Fingerprint Using Ninhydrin [28]

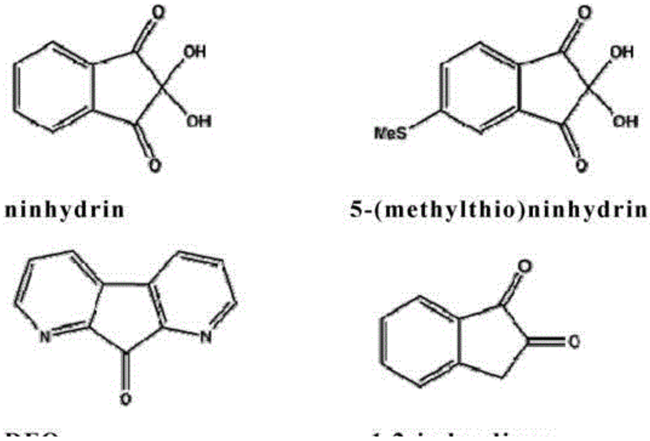

Figure 5: Ninhydrin and its Analogues [29]

2. Discussion

Physical Factors Affecting Development of Latent Fingerprints

There are many factors that affect the development of latent fingerprints when using the methods mentioned above. This includes temperature, the amount of sweat residue present and humidity. These factors affect the visibility and the clarity of the fingerprints that develop as they influence the reaction mechanism and it is important to optimise these conditions to achieve the best possible results in terms of print clarity, contrast, and visibility.

Ninhydrin

The ninhydrin method is the most effective method used on porous surfaces, hence making it a very popular method that is used. It produced durable prints and can be used on a variety of surfaces. It has been used in forensics for decades. Below are the key factors that affect fingerprint development using ninhydrin.

Effect of Temperature

Temperature plays a critical role in the ninhydrin method for fingerprint development. It affects the rate of chemical reactions, the intensity of colour development, and the overall quality of the developed fingerprints.Through various experiments, it is concluded that the optimal temperature range for ninhydrin development is typically between 80°C and 100°C. To investigate the optimal working temperature for the ninhydrin method, an experiment was conducted where ninhydrin was prepared by mixing acetone with ninhydrin crystals. This was then sprayed over each fingerprint sample and placed in either the refrigerator or a hot air oven at different temperatures. The results of this experiment revealed the positive correlation between temperature and rate of development as well as clarity of the ridges [30]. This is because temperature directly affects the rate of chemical reactions, following the principle of reaction kinetics. As temperature increases, the kinetic energy of molecules also increases, leading to more frequent and energetic collisions between reactant molecules. This results in a higher reaction rate, with more rapid formation of the desired compounds. In the case of the ninhydrin method, higher temperatures,between 80°C and 100°C, [31][32]accelerate the formation of Ruhemann's purple, allowing latent fingerprints to become visible in a shorter time frame. Moreover, such temperatures during the ninhydrin development process can enhance the sensitivity and contrast of the developed fingerprints. The increased reaction rate facilitates the interaction between ninhydrin and amino acids, resulting in more pronounced colour development. This can be particularly advantageous for aged or faint latent prints, making them more visible and easier to photograph or document. While controlled temperature is beneficial for optimal ninhydrin development, variations in temperature can introduce challenges. Fluctuations in temperature outside the recommended range may lead to inconsistent or uneven colour development. Rapid evaporation of the ninhydrin solution due to higher temperatures than the optimal range can result in uneven distribution of the reagent, potentially leading to incomplete or distorted fingerprint patterns [33]. Conversely, lower temperatures within the optimal range might slow down the chemical reactions, requiring longer exposure times for satisfactory colour development [34]. In colder environments, this may necessitate extended heating periods during the post-treatment process to achieve the desired level of contrast.

Effect of Surface

The effectiveness of the ninhydrin technique is intricately linked to the properties of the substrate or surface on which the fingerprints are deposited. The interaction between the surface and ninhydrin plays a pivotal role in determining the quality, visibility, and durability of the developed prints. The porosity of a surface significantly influences the success of fingerprint development using ninhydrin. Porous surfaces, such as paper, cardboard, and untreated wood, possess small openings or pores that allow the sweat and oil residues from the ridges of the fingers to be absorbed into the material [35]. This absorption creates a suitable environment for the reaction between ninhydrin and amino acids, resulting in the formation of the characteristic purple or blue-coloured compound known as Ruhemann's purple. The presence of pores on the surface enhances the accessibility of the ninhydrin solution to the amino acids, facilitating efficient chemical reactions and leading to pronounced colour development. The developed prints on porous surfaces tend to be clearer, more detailed, and longer-lasting due to the secure anchoring of the chemical compounds within the substrate. The chemical composition of the surface can also influence the ninhydrin development process. Different surfaces may contain varying levels of contaminants, residues, or impurities that can interfere with or enhance the chemical reactions between ninhydrin and amino acids. For instance, the presence of acidic or alkaline substances on the surface can modify the pH conditions and impact the reaction kinetics, ultimately affecting the colour development and contrast of the prints. The physical texture and characteristics of the surface can also impact ninhydrin development. Surfaces with intricate textures, crevices, or roughness may pose challenges in terms of even distribution of the ninhydrin solution and consistent colour development [36]. These surface irregularities may result in uneven coloration or incomplete visualization of latent prints. Smooth and uniform surfaces, on the other hand, tend to yield more reliable and consistent results, as the ninhydrin solution can be evenly applied and distributed.

Effect ofHumidity

Beyond factors like temperature and substrate, another critical variable that significantly influences the success and quality of the ninhydrin development process is humidity. Humidity, the amount of water vapor present in the air, can impact the rate of chemical reactions and the overall effectiveness of the ninhydrin method. The relationship between humidity and fingerprint development using ninhydrin is complex, as both high and low levels of humidity can influence the final outcome. While humidity can be beneficial for ninhydrin development, excessively high humidity levels can introduce challenges. In extremely humid conditions, the ninhydrin solution may absorb moisture from the air, diluting its concentration and potentially affecting the quality of the developed prints [37]. Additionally, excessive humidity can lead to prolonged drying times, as the excess moisture on the surface hinders the formation of Ruhemann's purple. Conversely, low humidity levels can also impact the effectiveness of the ninhydrin method. In dry environments, the rate of chemical reactions between ninhydrin and amino acids may slow down, requiring longer exposure times for satisfactory colour development [38]. This may extend the development process and potentially affect the overall efficiency of forensic investigations. While the ideal humidity range for ninhydrin development can vary depending on factors like temperature and specific materials, relative humidity levels between 65% and 80% [39] are generally considered optimal. Within this range, the chemical reactions between ninhydrin and the amino acids in sweat residue proceed at an efficient rate, leading to the formation of the characteristic purple or blue-coloured compound known as Ruhemann's purple [40]. Appropriate humidity levels can enhance the sensitivity and contrast of the developed fingerprints. Adequate humidity promotes efficient interaction between ninhydrin and amino acids, resulting in more pronounced colour development. This can be particularly advantageous for latent prints that are aged, faint, or present in low quantities, making them more visible and easier to photograph or document. Humidity plays a role in reaction kinetics, which describes the speed at which chemical reactions occur. In a humid environment, molecules are more likely to collide with each other due to the presence of water molecules that facilitate their movement. As a result, the frequency of successful collisions between ninhydrin and amino acids increases, leading to a higher reaction rate and more rapid colour development.

Effect of Quantity of Amino Acids Present

The intensity of colour development in ninhydrin fingerprint development is intricately tied to the quantity of amino acids available for reaction. More specifically, the presence of a larger number of amino acids, such as lysine and arginine, results in a more vibrant and pronounced coloration. When latent prints are rich in sweat residue, the reaction between ninhydrin and amino acids is robust, leading to a greater production of Ruhemann's purple and, consequently, a higher contrast and more visible fingerprint pattern [41]. Conversely, latent prints with minimal sweat residue will yield fainter colour development. The scarcity of amino acids limits the extent of the reaction and subsequently reduces the production of Ruhemann's purple. Consequently, the developed print may appear less distinct and may require careful examination and optimal lighting conditions for visualization and documentation.

Effect of Exposure to Ninhydrin

In addition to sweat residue amount, the duration of exposure to the ninhydrin solution significantly influences the intensity of colour development. The reaction between ninhydrin and amino acids is time-dependent, meaning that extending the exposure time allows more amino acids to react with the ninhydrin reagent. Longer exposure durations lead to the formation of more Ruhemann's purple, resulting in a more intense and clearly defined fingerprint pattern. The relationship between exposure duration and colour intensity follows a pattern of increasing saturation until reaching a point of diminishing returns. Initially, as exposure time increases, colour development becomes more pronounced and readily observable. However, after a certain threshold, the rate of reaction starts to slow down, and the incremental increase in colour intensity becomes less significant. Forensic experts must strike a balance between achieving optimal colour development and avoiding excessive exposure that could potentially result in overdevelopment and loss of fine details in the fingerprint.

Cyanoacrylate

Cyanoacrylate, or superglue, fuming is favoured by forensic experts to develop fingerprints on nonporous surfaces. This method involves superglue vapours reacting with the sweat residue of the fingerprint, undergoing polymerisation and forming a white compound that sticks to ridges revealing the fingerprint. It is a very effective method because of its versatility across surfaces, non-destructive nature and its sensitivity to faint prints. Factors such as temperature, concentration and surface type can affect fingerprint development using cyanoacrylate, as outlined below.

Effect of Temperature

The cyanoacrylate fuming method involves exposing an item or surface suspected of carrying latent fingerprints to cyanoacrylate vapours. These vapours polymerize upon contact with moisture, including the moisture present in fingerprint residues, forming a white solid known as cyanoacrylate ester or "superglue." The ester adheres to the ridges of the fingerprint, rendering it visible and allowing for subsequent processing and analysis. Temperature plays a vital role in governing the kinetics of this polymerization process and, consequently, the efficiency of fingerprint development.The optimal temperature range for cyanoacrylate fuming typically falls between 80°C and 100°C [42]. Within this range, the rate of polymerization is most favourable, resulting in efficient and effective development of latent prints. At higher temperatures, the polymerization process accelerates, leading to rapid and pronounced development [43]. Conversely, temperatures below the optimal range may slow down the reaction, necessitating longer exposure times for sufficient print visualization. Elevated temperatures promote faster polymerization of cyanoacrylate vapours, leading to accelerated fingerprint development. When the temperature is increased, the kinetic energy of molecules rises, causing more frequent and energetic collisions between the cyanoacrylate vapours and fingerprint residues. This heightened collision frequency expedites the polymerization process, allowing for quicker formation and deposition of the cyanoacrylate ester onto the ridges of the latent print. This accelerated development under higher temperatures can be advantageous in scenarios where time is of the essence, such as field investigations or time-sensitive casework. However, it is essential to strike a balance, as excessively high temperatures might lead to overdevelopment, potentially obscuring fine details and reducing print clarity. In addition, fluctuations in temperature outside the optimal range can have profound effects on cyanoacrylate fuming. Drastic temperature fluctuations, especially rapid drops in temperature, can lead to condensation of moisture on the surface being fumed. This moisture can interfere with the polymerization process by diluting the cyanoacrylate vapours, affecting the adherence and quality of the developed prints. Therefore, maintaining a stable and controlled temperature environment is crucial for consistent and reliable results.

Effect of Concentration

The concentration of the cyanoacrylate solution serves as a critical determinant in the cyanoacrylate fuming process. It directly affects the rate at which polymerization occurs, which in turn affects the speed and quality of print development [44]. Cyanoacrylate molecules in higher concentrations are more abundant, increasing the likelihood of their collision with fingerprint residues. This elevated collision frequency accelerates the polymerization process, leading to rapid and pronounced development of latent prints. The optimal concentration range for cyanoacrylate fuming typically falls between 2% and 4% [45]. Within this range, the cyanoacrylate solution is sufficiently concentrated to ensure efficient polymerization and effective fingerprint development [46]. However, exceeding this range can lead to overdevelopment, where excessive polymerization occurs, potentially obscuring finer details of the fingerprint and affecting the clarity of the developed print [47]. Conversely, concentrations below the optimal range may result in insufficient development or require longer exposure times to achieve satisfactory results. The concentration of the cyanoacrylate solution has a direct impact on the clarity and level of detail visible in the developed latent prints. An appropriate concentration ensures that a visible and contrasting white deposit forms along the ridges of the fingerprint. This allows forensic experts to capture high-quality images and documentation for analysis and comparison. Higher concentrations often lead to bolder and more pronounced prints, which can be advantageous for capturing intricate ridge patterns and minutiae. However, excessive concentrations might lead to an overly thick deposit that obscures finer details, necessitating careful adjustment and optimization to achieve the desired results. Moreover, the choice of concentration is not uniform across all surfaces and materials. Different surfaces may require varying concentrations to achieve optimal development. Surface characteristics, such as porosity, chemical composition, and texture, can influence the interaction between the cyanoacrylate vapours and the fingerprint residues. Hence, it is vital that forensic experts tailor their approach based on these characteristics to ensure that the chosen concentration aligns with the specific requirements of each investigation

Effect of Surface

The success of fingerprint development using the cyanoacrylate method, commonly known as superglue fuming, is profoundly influenced by the type and characteristics of the surface on which latent prints are deposited. The interaction between cyanoacrylate vapours and the surface significantly determines the quality, visibility, and durability of the developed prints. Various surface-related factors play a pivotal role in optimizing the cyanoacrylate fuming process and achieving reliable results in forensic investigations. The porosity and permeability of the surface are critical considerations in cyanoacrylate fingerprint development. Cyanoacrylate vapours primarily adhere to the moisture in fingerprint residues. Nonporous surfaces, such as glass, metal, and plastics, offer minimal pathways for moisture penetration, allowing cyanoacrylate to polymerize and form a visible deposit on the ridges of the fingerprint [48]. In contrast, porous surfaces with numerous microscopic openings, like paper and cardboard, can absorb both the cyanoacrylate vapours and the fingerprint residues, potentially leading to less effective development. The chemical composition of the surface can impact the interaction between cyanoacrylate vapours and fingerprint residues. Some surfaces may contain chemical compounds that hinder or enhance the polymerization process. Certain contaminants or residues on the surface might interfere with cyanoacrylate polymerization, affecting the quality and clarity of the developed prints. Forensic experts must consider the surface's chemical properties and potential interactions when applying the cyanoacrylate method. Moreover, the surface texture and topography influence the even distribution of cyanoacrylate vapours and the subsequent development of latent prints. Surfaces with intricate textures, such as those with crevices or roughness, may pose challenges in achieving uniform fuming and even deposition of the cyanoacrylate ester [49]. The presence of irregularities can lead to uneven polymerization, resulting in uneven or incomplete fingerprint development. Smooth and uniform surfaces are generally more conducive to consistent and reliable cyanoacrylate fuming. The condition of the surface, including cleanliness and contamination, can impact the success of cyanoacrylate fingerprint development. Surfaces with traces of oils, grease, dirt, or other contaminants might inhibit the adhesion of cyanoacrylate vapours to the fingerprint residues, resulting in incomplete or distorted prints. Proper surface preparation, cleaning, and removal of contaminants are essential for maximizing the efficacy of the cyanoacrylate method.

3. Conclusion

In conclusion, this paper has explored the different methods of developing fingerprints while focusing on the physical factors that affect fingerprint development when using methods like ninhydrin and cyanoacrylate fuming. Various environmental factors play pivotal roles in different fingerprint development methods, each leaving its distinctive mark on the quality and efficiency of the process. Temperature, for instance, plays a significant role in both the ninhydrin and cyanoacrylate methods. The ninhydrin method thrives within the optimal range of 80°C to 100°C, where higher temperatures speed up chemical reactions, revealing clear ridge patterns and latent prints promptly. Deviations from this range, however, introduce risks of uneven development and reduced reaction rates. Cyanoacrylate fuming method uses controlled temperature environments between 80°C and 100°C to encourage efficient polymerization. Besides temperature, the nature of the substrate surfaces influences the effectiveness of both the ninhydrin and cyanoacrylate methods. For ninhydrin, porous surfaces like paper and wood enable effective reactions by absorbing sweat residues. Conversely, factors like porosity affects vapour penetration, favouring nonporous surfaces for effective development when using cyanoacrylate.The choice of cyanoacrylate concentration proves essential as well, with optimal ranges of 2% to 4% facilitating strong and clear prints. Considering humidity's role, the ninhydrin method benefits from controlled humidity levels between 60% and 80%, enhancing sensitivity and contrast in developed prints. On the other hand, cyanoacrylate fuming requires careful humidity control to prevent moisture interfering with the polymerization process. Essentially, a crucial aspect of effectively employing these fingerprint development methods for precise forensic analysis lies in understanding and effectively handling these factors. Researchers need to be cognisant before using these methods to limit errors when carrying out the development of latent fingerprints.

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