Investigating the impact of weather, for varying lengths of time, on the quality of fingerprints and comparing visualisation methods for outdoor crime scenes

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# Abstract

Currently, there is little realistic research into the impact weathering has on fingerprints. The use of wet powder suspension in destructive conditions has been shown to be effective, although the use of iron oxide suspension in weathered conditions has not been tested. This study aimed to compare the use of iron oxide suspension to more common fingerprinting techniques (black powder and aluminium powder) and investigate the impact that weathering has on fingerprints over a set amount of time. It was found that black powder provided the best quality prints, on the majority of surfaces tested, after being weathered. The only difference was with painted wood which reacted to iron oxide suspension the best. A difference was seen in quality between the start of the experiment and after 10 days of weathering, although it was not enough for it to be statistically significant so it can not be proven that the difference was down to the weather.

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1.Introduction

\*Although the terms fingerprint and fingermark have two different meanings, for the purpose of this study the term fingerprint is being used to refer to both.

# 1.1 General Background

Outdoor crime scenes are difficult to manage, with a key aspect of them being the possibility of losing evidence due to environmental factors. This is because of the impact that environmental conditions can have on evidence types, particularly fragile ones like fingerprints (National Crime Agency, n.d.). The composition of a fingerprint involves multiple substrates, each of which will react differently under different conditions (Girod, Ramotowski and Weyermann, 2012). The water-soluble aspects of a fingerprint are a prime example of this as without the influence of environmental conditions, they evaporate within a few hours of deposition, but this process can be accelerated by the influence of weathering (Home Office, 2022). The visualisation of fingerprints subject to these conditions is difficult as the common techniques used at a scene have limitations which impact their uses under these conditions (Davis & Fisher, 2015; King, Hallett and Foster, 2015). A gap has been found in the literature about the effects of weather conditions on fingerprints and the ability to use already-known techniques to enhance fingerprints subjected to realistic weather conditions. Therefore, this research is going to look into the impact caused by weathering on fingerprints and identify the best methods for fingerprints subjected to certain conditions. Staffordshire Police were interested in the outcome of this study to identify the best technique for weathered prints.

# 1.2 Materials found at outdoor crime scenes

From contact with Staffordshire Police, it was identified that the most common materials fingerprinted at outdoor crime scenes were painted wood, painted metal, window glass and uPVC (Bailey, 2023). Therefore, these are the materials used in this study.

# 1.3 Fingerprints

# 1.3.1 Importance of fingerprints

Fingerprints are classed as one of the most important evidence types because of their commonality and ability to be used for identification (Jackson & Jackson, 2017). This is why they are the main evidence type searched for at a level 1 crime scene (standard level for most volume crime) (HMICFRS, 2022; Staffordshire Police, 2024). This evidence type is held highly in court because fingerprints primarily have to be directly transferred and their uniqueness to an individual allows for conclusive outcomes (Jackson & Jackson, 2017; GOV.UK, 2022).

# 1.3.2 Prenatal development of fingerprints

Fingerprints are formed due to a thickened layer of epidermal skin, known as friction ridge skin, covering the finger (Jackson & Jackson, 2017). This skin has evolved to contain nerve endings, allowing for a greater sense of touch, and being covered in ridges for better gripping (Jackson & Jackson, 2017). The skin is a result of volar pads during pregnancy. Volar pads are growths/swellings that occur on the fingers, during the 6th week post-fertilisation (Babler 1987; LH & MG, 2017). Between weeks 10 and 11, they start to individualise and eventually disappear, leaving behind parts of a print (Babler 1987; Adamu and Taura, 2017). Differential growth in the volar pads impact the pattern produced, which is affected by stresses and their location (Kücken & Newell, 2005). At approximately 24 weeks after conception, the pattern is fully formed and remains unchanged for the rest of the individual’s life (Jackson & Jackson, 2017).

# 1.3.3 Fingerprint characteristics

A fingerprint pattern is made up of ridges and furrows, which curve in different formations to create a unique pattern on each finger (Henry, 2012). Each pattern falls into one of four main types. Loop (which is the most common, with approximately 60% of all fingerprints being one), whorl (accounts for about 35% of all fingerprints), arch (about 5% of all fingerprints have this pattern) and composite (combinations of all three) (Henry, 2012; Forensic Science Regulator, 2014; Jackson & Jackson, 2017). Each pattern is recognised by set characteristics, based on the number and location of cores, deltas and bifurcations (following the definitions published by Forensic Science Regulator, 2014).

A loop has one delta, a core and at least one of the ridges flows between the delta and the core, entering from one side, curving around and exiting from the same side (Henry, 2012; Jackson & Jackson, 2017). There are two sub-sets to this pattern, a radial loop and an ulnar loop. A radial loop is when the loop slopes in the direction of the radial bone (towards the thumb), whereas an ulnar loop is when the loop slopes towards the ulnar bone (towards the little finger) (Jackson & Jackson, 2017). A whorl consists of two deltas and at least one ridge that completely encircles the core. The UK recognises seven different types of whorls, with the main ones being plain, central pocket, twinned loop whorl and accidental whorl (with each having its own criteria) (Jackson & Jackson, 2017). Whereas arches have ridges which enter from one side, rise and fall in the centre and then exit on the other side, with no backwards turns. These are split into plain and tented arches, depending on the angle of the rising central ridges (Henry, 2012; Jackson & Jackson, 2017). Composites are the categorisation for a combination of the patterns appearing on the same finger, that has 3 or more deltas (Henry, 2012; Forensic Science Regulator, 2014).

# 1.3.4 Fingerprint composition

The deposition of a fingerprint occurs because the ridges that make up the patterns are covered in pores and glands that release residue, resulting in a copy of the print pattern being made on the surface of an object when the epidermal skin touches it (Lee and Gaensslen, 2001; Girod, Ramotowski and Weyermann, 2012; Robson et al., 2022). There are multiple glands present, including eccrine, exocrine and sebaceous glands, each of which release its own compound, making fingerprints a mixture of amino acids, and organic and inorganic residues (Robson et al., 2022). Which usually also involve contaminants, as a result of touching food or cosmetics (Girod, Ramotowski and Weyermann, 2012). If a print appears incomplete after developing it could be due to low concentration of components or inhomogeneous distribution across ridges (Home Office, 2022).

# 1.4 Fingerprint visualisation methods

Most fingerprints are latent, meaning invisible to the naked eye and so they have to be enhanced before analysis (Forensic Science Regulator, 2014). There are many methods for visualising fingerprints, which vary from powders to chemical or physical developers, but only certain methods can be conducted at a scene. The method chosen is dependent on the surface type, colour, texture and condition (Defence Science and Technology Laboratory, 2022). Currently, the main technique used at scenes is powdering (Thomas, 1978; Home Office, 2006), for which the recommended guidance for choosing which powder to use on a surface is:

A diagram of different colors

Description automatically generated

Figure 1:Flowchart for powder selection (Defence Science and Technology Laboratory, 2022)

Home Office (2022) also offers guidance to scene examiners as to which recovery method should be used in each situation. This is more extensive than Figure 1, explaining the best process for each material. For the materials used in this study the Home Office (2022) recommends powder suspension as the most effective for painted surfaces with gloss, intermediate gloss and glass. It is also recommended as another option to superglue fuming for uPVC, but before this step, powdering is recommended, with black magnetic powder used for painted metal with full gloss, intermediate gloss and uPVC and aluminium powder recommended for glass

# 1.4.1 Black Powder

Black powder is one of the most common recovery methods used (Home Office, 2006). There are different types of black powder, with the most common being Carbon Black (Yamashita and French, 2011). This powder consists of granular carbon particles mixed with a binder (which changes depending on the supplier), usually containing textured particles of an irregular shape, between the size range of 5-10µm (Lee and Gaensslen, 2001; Home Office, 2006; Defence Science and Technology Laboratory, 2022; Home Office, 2022). It is known as being versatile due to its uses on many surfaces and low likelihood of causing substrate painting (Yamashita and French, 2011). It is commonly found in a crime scene examiner’s fingerprinting kit with an animal hair brush (FI at Staffordshire Police, 2024. a) and its primary use is on lighter coloured non-porous or semi-porous surfaces because it reacts with the water and oil in the residues to create a dark grey/black image (Lee and Gaensslen, 2001; Sodhi & Kaur, 2001; Home Office, 2006; Moreno *et al*., 2021; Home Office, 2020). They are also preferably imaged in situ, as they do not lift as well as other powders (Home Office, 2022).

# 1.4.2 Aluminium Powder

Aluminium powder is also a highly common powder and is believed to be one of the most sensitive on smooth surfaces (Home Office, 2006). It is classed as a flake powder because it is made up of jagged-edged flakes (around 4-10 µm in diameter) of Aluminium metal, which is coated in a thin layer of stearic acid and it also commonly found in a forensic examiner’s fingerprint kit (Home Office, 2020; Defence Science and Technology Laboratory, 2022; FI at Staffordshire Police, 2024. a). It is used on smooth, non-porous or semi-porous surfaces to visualise latent prints. However, the effectiveness of it drops considerably as the texture of the surface increases (Home Office, 2020). The metallic flakes lie flat on the surface of the material creating a highly reflective silver/grey image, that may need extra illumination to visualise (Home Office, 2006; Home Office, 2022).

# 1.4.3 Iron Oxide Suspension

A less common technique is wet powder suspension (WPS). This involves applying a suspension mixture, of a paint link consistency, to the material (Home Office, 2020; Defence Science and Technology Laboratory, 2022). There are many types of WPS, including FE3O4 (Iron Oxide), TiO2 (Titanium dioxide), ZnCO3 (Zinc Carbonate) and ZnO (Zinc Oxide). All of these produced good quality results against fingerprints exposed to natural conditions and the latter three produced good results against prints exposed to destructive conditions (Haque et al., 1989; Dhall & Kapoor, 2016). The method used in this study is Iron Oxide, which is classified as a small particle reagent (SPR), meaning the fine particles within the solution adhere to oily or fatty components within the print (Bumbrah, 2016). The components of Iron oxide suspension have changed multiple times throughout the years, but each one produces a black fingerprint. (Trapecar, 2012; Defence Science and Technology Laboratory, 2022). It is used on non-porous or semi-porous materials for latent or bloodied fingerprints but can also be used on wet surfaces or surfaces that have been subject to moderate heat (Home Office, 2020)

# 1.5 ACE-V System

The ACE-V system is an examination process for fingerprints, to determine or exclude a common source. The system comprises of four stages (analysis, comparison, evaluation and verification) (Jackson & Jackson, 2017; Trapečar, Jankovič and Murtič, 2022).

## 1.5.1 Analysis

This stage involves analysing the mark and questioning if it is suitable for comparison by assessing the quantity and quality of ridge detail present (Chapman and Hicklin, 2017; Jackson & Jackson, 2017). This is done by grading the print 0-5 based on level 1, 2 and 3 detail, which is split into four categories (quantity of print, quantity of friction ridges, continuity of ridges and level of contrast), to get a total score out of 20 (SWGFAST, 2013; Fieldhouse and Gwinnett, 2016). From which, the print is deemed suitable for comparison or not. If satisfied as suitable then the print will move on to the next stage, but if not then it is classified as insufficient and the examination ends (SWGFAST, 2013; Jackson & Jackson, 2017).

# 1.5.2 Comparison

The fingerprint is then compared side-by-side to known prints, either from suspects or the closest matches from a fingerprint database to find similarities or discrepancies (Chapman and Hicklin, 2017; Jackson & Jackson, 2017). These are compared at all levels of detail (SWGFAST, 2013).

# 1.5.3 Evaluation

An evaluation of the information recovered from the previous two stages is then conducted and a final conclusion will be expressed in a report outcome. The outcomes can be either be an exclusion (prints are sufficient quality but not consistent and so determined to be not made by the same person), Identification (prints are determined to be from the same person) or inconclusive (not possible to reach a conclusion) (Jackson & Jackson, 2017; Trapečar, Jankovič and Murtič, 2022).

# 1.5.4 Verification

In this stage, the conclusion reached by the original examiner is checked by at least two independent fingerprint experts. For this, the ACE process is repeated and if the conclusions match then it provides validity and safeguards against errors. If not then a discussion is had between all the experts and a mutual conclusion is reached (Jackson & Jackson, 2017; GOV.UK, n.d.).

# 1.6 Persistence of fingerprints

Examiners are not always able to attend a scene immediately so how a fingerprint persists on a surface is important. Over time the substrate and composition of a print can change and the environment in which a fingerprint is in will contribute to the speed at which this happens (Home Office, 2022). Especially if it is in destructive conditions (such as outside in the rain, buried in soil or submerged in snow). If a print is found in these conditions, then recovery is not usually attempted because of this (Deans, 2006), but it has been shown that enhancement of prints like this could be possible as long as the correct technique is used (Wood & James, 2009). The specific details of the environment will change how quickly the fingerprint deteriorates, including the level of exposure and order in which it is exposed to certain conditions (Home Office, 2022). Even if the fingerprint is recovered soon after deposition, the material on which it is deposited could still have an effect. Depending on the porosity of the surface, the water-soluble components of the fingerprint might evaporate quicker so the print will shrink more in a shorter amount of time (Home Office, 2022). The materials in this study are all non-porous, but environmental factors and the ageing of the print can still have an effect on it (Home Office, 2022).

# 1.6.1 Effects of weathering

According to the Oxford English Dictionary (n.d.), weathering is the change (wear away, discolour) that occurs as a result of atmospheric action (the weather). Met Office (n.d. a) recognise that there are multiple types of weather conditions (ranging from rain and thunderstorms to snow and ice to sunny weather). Each of these are also affected by temperature, humidity, wind speed and cloudiness (Met Office, n.d. a). This creates many different combinations of weather conditions that can happen within a day. Depending on the time of year, certain weather conditions can be expected more than others and weather forecasts provide information about what weather conditions might occur in the next few days (Met Office n.d. b; Met Office n.d. c). For fingerprints on surfaces, exposed to these conditions each change could have an impact on the quality of the fingerprint remaining. Fingerprints exposed to different conditions in a different order or for different amounts of time will change how much the print is affected (Home Office, 2022). The presence of low temperatures can cause fatty acids to melt or volatile constituents to be driven off leaving organic compounds or inorganic salts. Whereas high temperatures can result in compounds breaking down and evaporating, leaving only inorganic salts. These changes will have an impact on which visualisation method is best as it will depend on what compounds within the print the technique reacts with/adheres to (Home Office, 2022). It should be noted, that this study is being carried out in the UK where the weather does not reach exceeding high temperatures often. The average weather conditions seen throughout a year in the UK are explained by Beck et al. (2023) and Met Office (n.d. d). On the other hand, the presence of water can remove water-soluble substances and exposure to high humidity can have similar effects as moisture is drawn to the material and print (Home Office, 2022). Humidity is also a concern for indoor substrates as it can reach high levels indoors if not ventilated correctly, causing an increase in moisture that could have the same effects seen outdoors (Seppänen & Kurnitski, 2009; Home Office, 2022). Weather conditions may not only affect the fingerprint, it can also affect the substrate, causing corrosion, oxidation, melting or distortion (Moncmanová, 2007; Home Office, 2022).

# 1.6.2 Ageing of prints

Even without the addition of weathering, the quality of a print can change over time due to ageing. This is due to surface interactions, oxidative mechanisms and decomposition (Cadd et al., 2015). The solubility of the fingerprint components will determine the extent of the impact that ageing has on the fingerprint within a space of time (Home Office, 2022). In eccrine prints water will evaporate first (within minutes), followed by the volatile components (within days/weeks). This causes the ridges to become brittle and topographically irregular. Eventually leaving the print to dry out with organic compounds and inorganic salts remaining (Cadd et al., 2015; Home Office, 2022). Whereas with sebaceous prints some constituents are lost within a short period of time (days) and others may persist for many years (Home Office, 2022). A fingerprint can lose nearly 98% of its original weight within 72 hours of deposition (Cadd et al., 2015).

# 1.7 Literature Review

Fingerprint research is an important area because of the weight fingerprint evidence has on a case (Jackson and Jackson, 2017). Due to this, fingerprints are commonly searched for at a crime scene, but as a fragile evidence type many factors can influence the quality of a fingerprint recovered by the time the scene is attended by examiners (Home Office, 2020). Outdoor scenes are particularly vulnerable to this as the evidence is subject to the open elements. For a while, these were viewed as impossible scenes and visualisation was not attempted, but it has been shown that if the right technique is used then fingerprints can still be recovered (Wood & James, 2009; National Crime Agency, n.d.). This has led to techniques being developed to allow for fingerprints subjected to destructive conditions (such as being subjected to the weather, submerged in water or involved in a fire) to possibly still be recovered (Deans, 2006; Dhall & Kapoor, 2016). However, not all of these techniques are applicable to a real-life crime scene (Davis & Fisher, 2015; King, Hallett and Foster, 2015; Bailey, 2024). The key themes discussed in this literature review are current enhancement techniques and issues faced with weathered fingerprints, possible solutions to these issues, making a fingerprint study realistic and where the gaps are in research.

As stated by the Home Office (2006) 50% of fingerprint identifications come from powdering at a scene. This is because aluminium powder and black powder are the two main visualisation techniques carried by examiners, as both are located in their fingerprinting kit (FI at Staffordshire Police, 2024. a). The Home Office (2006) surveyed examiners to see which powders were most commonly used at a scene and aluminium powder was the most common with 95%. Even though these methods are used often, they do have their disadvantages. Davis & Fisher (2015) and King, Hallett and Foster (2015) highlight the fact that powders do not work well on textured or wet surfaces. This is because the texture of the surface makes it difficult to see the ridge details and so another step needs to be done after to allow for full recovery and analysis of the print (Davis & Fisher, 2015; King, Hallett and Foster, 2015). Another issue with powders is that they are unable to be used on wet surfaces, powders clump and smudge when exposed to moisture and the brushes clump with powder (FI at Staffordshire Police, 2023). Due to these issues, other methods have been tested for enhancing fingerprints in difficult conditions.

One such technique is WPS, Dhall & Kapoor (2016) identify this as a suitable alternative. After testing three different WPS formulas in destructive conditions, it was found that all three worked, to different efficiencies. This idea is supported by the Home Office (2022) publishing that powder suspensions will remain effective when exposed to water and low temperatures, which covers two of the weather conditions mentioned in section 1.6.1. Many other pieces of literature agree with using some form of WPS or SPR in destructive conditions. Wood & James (2009) found SPR to be the best method on plastic in the presence of water and Polimeni et al. (2004) tested SPR on plastic, glass and metal which were submerged in water, and found that the technique worked on all materials. However, Madkour et al. (2017) compared SPR to black powder and cyanoacrylate fuming with fingerprints that had been exposed to fresh water and salt water. It was found that cyanoacrylate fuming was the best method, for both fresh water and salt water. Although many studies have found WPS to be a useful method, it is still not commonly used at scenes. Staffordshire Police mentioned that they have tried it before at a scene, but due to the amount of mess it created they did not continue to use it (Bailey, 2024).

This highlights an issue seen in fingerprint research, which is that many studies are lab-based and not carried out in realistic conditions, which can lead to impractical solutions. This is recognised by Sears et al. (2012) who acknowledges the lack of standardisation in fingerprint research. One aspect highlighted is the use of unrealistic fingerprints in research (fingerprints which have unnatural quantities of components), stating that groomed fingerprints should only be used in the initial testing of a method to determine which constituents the technique interacts with or determine the appearance of the reaction, but should not be used for testing past this (Sears et al., 2012). Instead, they recommend using natural fingerprints that are created as a result of carrying out normal routines rather than the donor wiping their forehead or using fingerprint reference pads. An example of a natural fingerprint depletion is shown by Pitera et al. (2018)

Currently, some research has been conducted into different techniques for recovering fingerprints that have been subject to destructive environments and WPS has been identified as a useful technique for these scenarios. However, not all materials commonly fingerprinted at outdoor crime scenes have been used in this research and no research was also found investigating the use of WPS for weathered prints, that have been left outside in a natural environment and not subject to specific destructive conditions. There is also a lack of research on the effects of weathering and ageing on fingerprints and how different weather conditions will impact the quality of enhancement and how the compositions change as a result. Iron Oxide has also not been used in any of the studies found about destructive conditions. Therefore, this research is going to look into the use of Iron Oxide suspension for fingerprint recovery from naturally weathered materials, for varying lengths of time and compare this technique to black powder and aluminium powder.

# 1.8 Aims and Objectives

This research aims to investigate the effect of weathering on fingerprints for a select amount of time and to determine the best visualisation method for fingerprints on different weathered surfaces.

The objectives of this research are to:

* Conduct a realistic study on the effect of weathering on fingerprints.
* Producing recommendations on whether Iron Oxide suspension is worth using at a crime scene.
* Identifying if any of the techniques tested are useful in recovering fingerprints from weathered surfaces.

# 1.9 Hypotheses

# 1.9.1 Impact of weather over period of time

Alternative hypothesis: The weather will have a significant difference on the quality of the fingerprints.

Null hypothesis: The weather will not have a significant difference on the quality of the fingerprints.

# 1.9.2 Best visualisation technique for each material

* Iron oxide will be the best visualisation technique on the majority of the materials.

2. Methodology

# 2.1 Preliminary Study

# 2.1.1 Selected fingerprints from depletion series

The researcher’s hands were washed 30 minutes before attending the laboratory, then normal activities were continued until the lab was attended. Once in the lab, three rows of five glass slides were placed horizontally on the bench. The researcher’s hands were then rubbed together and a depletion series of 10 prints was deposited across five of the slides (the same finger was used for all prints, right index finger, with two prints being placed on each slide). This was repeated for the other two rows, with the researcher’s hands being rubbed together before each set of 10, and each set of resulting marks were visualised with one of the following techniques:

* Black Powder: A Scene safe pure squirrel brush was dipped into a pot of black powder and then tapped on the side of the pot to remove excess powder. The material was then lightly brushed with the brush, until ridge detail was able to be seen or until it was evident that no fingerprint was present, whilst ensuring not to overpower the mark.
* Aluminium Powder: A fibreglass Zephyr brush was dipped into a pot of Aluminium powder and then tapped on the side of the pot to remove excess powder. The material was then lightly brushed with the brush, until ridge detail was able to be seen or until it was evident that no fingerprint was present, whilst ensuring not to overpower the mark.
* Iron Oxide Suspension: A suitable brush was dipped into a pot of Iron Oxide Suspension and then painted onto the material. It was then left for 1 minute, before being rinsed with lightly flowing water.

All of the prints were then graded, using the method outlined in section 1.5.1 of the introduction and further examined visually to determine which prints showed the most change within the depletion series.

# 2.1.2 Fingerprint reference pads

Two rows of five microscope slides were laid out, with the microscope slides placed horizontally. Sebaceous oils were then applied to the researcher’s finger using a sebaceous oil secretions fingerprint pad. A depletion series of 10 marks was deposited on one row of the microscope slides. With another finger, an amino acid-based reference pad was used and then a depletion series of 10 was deposited on the remaining row of glass slides. All marks were visualised with black powder, using the same method as previously stated and all of the marks were graded.

# 2.2 Main Study

Multiple pieces of painted metal, painted wood, window glass and uPVC were collected (resulting in an equivalent of at least 200cmx75cm of each material). These materials were left outside to weather from the point of collection and were known as the weathered materials. Each material was placed in the orientation it would normally be found in (the painted wood was a door, which was placed vertically, the uPVC was placed horizontally like it would be found as a windowsill and the window glass was placed vertically). The only exception to this was the painted metal, which was part of a car. Due to how it had been removed from the car, it was misshapen and so laid flat on the ground, meaning some sections were weathered vertically and some were weathered horizontally.

New versions of each material were also collected (which were a minimum of 105cmx45cm) and kept inside (becoming the non-weathered materials). The weathered materials were then split into 75 rectangular sections, measuring at least 7cmx3cm, using a black POSCA pen. Whereas the non-weathered materials were split into 15 sections of the same dimensions, using the same method. Each section was then labelled with a key corresponding to which visualisation method would be used and how long the marks would be left. This was randomly assigned, other than with the Iron oxide sections where sections near the edge or at the end of a row were chosen, to avoid contamination into other sections through rinsing the suspension off. The key used was BP for black powder, AP for aluminium powder and IO for Iron Oxide suspension. The letters were then followed by either 0, 1, 3, 7 or 10 signifying how many days they were left weathering for (e.g. BP3= Black powder, 3 days). On the weathered materials, there were five of each section per material, whereas the non-weathered materials only had one of each section.

All of the fingerprints were deposited on the same day. The method used for deposition was the same as the method used in section 2.1.1 up to the point of deposition. The researcher’s hands were rubbed together, but only prints 1,4,7 and 10 from the depletion series were placed in a section (due to the results explained in section 3.1.1), whilst all other prints were placed in an area outside the test zone to allow for only the selected marks to be analysed. This was repeated for every section on all materials, with the researcher’s hands being rubbed together between each section, resulting in four prints being in each section.

Once done the day 0 prints were visualised on the same day. They were visualised following the technique they were assigned through labelling, using the methods previously described in section 2.1.1. After visualisation, each print was photographed using a Samsung Galaxy S21 via the camera app using the 1x camera for section photos and the 3x camera for close-up photos of each print (photos are shown in Appendix 1). The prints were then graded using the analysis stage of the ACE-V grading system, explained in section 1.5.1. The rest of the prints were then visualised on their dedicated days (after they had been left for their assigned amount of time), using the same method. The obtained data was examined in Excel (tables shown in Appendix 2) before selected variables were compared in SPSS using Mann-Whitney U and Sign tests.

# 3. Results and discussion

# 3.1 Preliminary Study Results and Discussion

# 3.1.1 Preliminary study 2.1.1

From the preliminary study explained in section 2.1.1, the following results were gathered.

Table 1:Grades from preliminary study 2.1.1

|  |  |  |  |
| --- | --- | --- | --- |
|  | Iron Oxide | Black Powder | Aluminium Powder |
| Print 1 | 18 | 20 | 20 |
| Print 2 | 20 | 20 | 20 |
| Print 3 | 17 | 15 | 20 |
| Print 4 | 18 | 15 | 20 |
| Print 5 | 16 | N/A | 20 |
| Print 6 | 12 | N/A | 18 |
| Print 7 | 17 | 16 | 19 |
| Print 8 | 14 | 18 | 20 |
| Print 9 | 14 | 15 | 19 |
| Print 10 | 15 | 12 | 17 |

\*Prints 5 and 6 were discounted from the grading as they were overlapping with an accidental print that had been deposited on their earlier.

Based on the results shown in Table 1 and the visual examination carried out in the lab, it was decided that fingerprints 1, 4, 7 and 10 were going to be used for analysis. Due to the difficulty in identifying where the most change occurred, it was decided that marks at equal intervals within the series would be chosen to allow for representation of the series as a whole, without having to examine all 10 fingerprints. Prints 1 and 10 were included to allow for each end of the scale to be analysed and act as extremes at either end. Prints 4 and 7 were then chosen to represent the middle of the series at equal intervals. No studies were found that report findings on this information, although Sears et al. (2012) highlights the importance of using a depletion series, to look at the sensitivity of a technique, and advises using a pre-experiment to establish where differences are shown within a series for testing on non-porous surfaces.

During this study, the method for the depletion of marks was also tested to ensure it worked before the main study. The results of this indicated that the depletion method was fit for purpose as it allowed multiple sets of prints to be deposited without affecting the grade based on which set was deposited first. A similar method has previously been used by Pitera et al. (2018), where participants carried out normal activities after washing their hands, for a set amount of time, before depletion. They also rubbed their hands together to ensure even distribution of secretions.

# 3.1.2 Preliminary study 2.1.2

From the preliminary study 2.1.2, Appendix 1 was created. Figures 2, 3 and 4, shown below, are part of Appendix 1.

A group of test tubes with numbers

Description automatically generated with medium confidence

Figure 2:Depletion series of 10 prints, deposited using an amino-acid reference pad and visualised with black powder

A close-up of a paper with a fingerprint

Description automatically generated

Figure 3:Depletion series of 10 prints, deposited using a sebaceous oils reference pad and visualised with black powder

A close-up of a notebook

Description automatically generated

Figure 4: Depletion series of 10 prints, deposited naturally and visualised with black powder

Figures 2 and 3 show the prints which were a result of using a reference pad before deposition, whereas Figure 4 shows naturally deposited prints, all of which were visualised using black powder. From these Figures, the effect of the reference pad can be seen. The prints in Figure 4 lose quality over the depletion series and end on a low-contrast print. Whereas the prints in Figures 2 and 3 stay more consistent throughout the series. Even though they lose some quality, it is not to the same extent as seen in Figure 4 as shown by the high contrast prints present at the end of Figures 2 and 3’s depletion series. Due to this, it was decided that fingerprint reference pads were not going to be used in the study because they provided unrealistic prints and minimised the point of analysing a depletion series. This is agreed with by ref Steiner, Moret & Roux (2020) who did not recommend the use of fingerprint pads in studies because of the difference observed between them and natural fingerprints (concentrations of the target compounds being too high). Sears et al. (2012) comes to the same conclusion, as explained in in the literature review (section 1.7).

# 3.2 Main Study Results and Discussion

The method conducted in section 2.2, resulted in the creation of Appendices 3-12, as well as Figure 5.

A graph of different colored dots and lines

Description automatically generated

Figure 5: Graph showing grades from all days for the weathered painted wood, visualised with Iron Oxide

Figure 5 shows the standard set of results expected from the study (other than day 1 results being higher than the day 0 results). As the depletion number and day increased, the grades of each print decreased. However, not all of the graphs showed this trend. Figure 6 is an example of one of the graphs that did not show this trend.

A group of text on a white background

Description automatically generatedA graph with a line graph

Description automatically generated

Figure 6: Graph showing grades from all days for the weathered uPVC, visualised with Iron Oxide

In this graph, only day 1 has any grades above 0. There were other graphs, similar to this, that had three or fewer trendlines (Appendices 4, 8, 9, 10, 12 and Figure 6 ) and some graphs had positive trend lines (Appendices 3, 5 and 11). The reason for these differences could be that there was more residue on the finger initially when the start of the depletion series was deposited which left more of a smudge (not allowing the ridge detail to be seen clearly). But then as the depletion series has gone on the residue has lessened, making the detail in the print clearer and so the later prints have a higher grade (Sears et al., 2012). The could have also been too few secretions on the finger when the print was deposited, resulting in a low-contrast or low-quality print (Home Office, 2020). The section chosen for that specific day or repeat could have been more weathered than other sections chosen, particularly on the painted metal where its awkward shape could have resulted in uneven weathering. Another explanation could be that more pressure was applied when depositing some prints and so more residue was left, resulting in a clearer print (Jasuja et al., 2009).

To further analyse the difference between weathered and non-weathered fingerprints and how the different visualisation methods reacted to weathered surfaces, statistical tests were carried out using SPSS.

# 3.2.1 Statistical testing

The data was tested for normality, using the Kolmogorov-Smirnov test because the data contains over 50 observations. The results of this are shown in Appendix 13, which shows a mixture of parametric and non-parametric data. Due to this, non-parametric tests were conducted as not all of the data was normally distributed.

# 3.2.1.1 Impact of weather over a period of time

For this analysis a Sign test was performed because ordinal data was collected and the observations were independent (Laerd Statistics, n.d. b). This was done with all of the day 0 weathered results and all of the day 10 weathered results (excluding visualisation technique, day of visualisation and substrate). This produced Figure 7.

A screenshot of a test results

Description automatically generated

Figure 7: Results from Sign Test comparing Day 0 grades to Day 10 grades (weathered)

Figure 7 shows that there is a statistically significant decrease between the weathered prints visualised on day 0 compared to day 10 (p= <0.001). 162 fingerprints had a lower grade on day 10 than day 0, 66 were the same grade and 12 were higher on day 10 than day 0. This suggests that weathering may have an effect on fingerprints over the course of a short period of time (10 days), which is in agreement with the Home Office (2022) as previously stated in section 1.6.1.

Comparisons were then made between the weathered fingerprints graded on each day compared to the non-weathered fingerprints for that day, based on the visualisation method. For this a Mann-Whitney U test was conducted because ordinal data was collected, the independent variables were independent groups, there was no relationship between observations and the data is non-parametric (Laerd Statistics, n.d. a). From which Appendices 14 -17 and Figures 8 and 9 were created.

A screenshot of a graph

Description automatically generated

Figure 8: Results from Mann-Whitney Test showing day 0 weathered prints compared to day 0 non-weathered prints, visualised with aluminium powder

A screenshot of a graph

Description automatically generated

Figure 9: Results from Mann-Whitney Test showing day 10 weathered prints compared to day 10 non-weathered prints, visualised with aluminium powder

The outcome from Figures 8 and 9 are the same for black powder and iron oxide, as shown in the Appendices. A Bonferroni correction was calculated to decrease the risk of type 1 error, this was done by dividing the original p-value by the number of tests conducted (0.05/8=0.00625), meaning 0.00625 is the new p-value used (Jafari & Ansari-Pour, 2018).

Each of their tests resulted in a p-value greater than 0.00625 so no statistically significant difference is seen, meaning the null hypothesis is accepted. Although all show differences in the mean rank values between weathered and non-weathered, signifying that there is a difference, it cannot be statistically proven to be due to weathering.

A Sign test was also conducted with the controls from day 0 and day 10 (excluding visualisation technique, day of visualisation and substrate). The results of which are shown in Figure 10.

A screenshot of a test results

Description automatically generated

Figure 10: Results from Sign Test comparing Day 0 grades to Day 10 grades (non-weathered)

Figure 10 shows that there is a statistically significant decrease in the grades of fingerprints visualised on the non-weathered materials from day 0 to day 10 (p= 0.001). 30 fingerprints had higher grades on day 0 than day 10, 9 had the same grades and 9 had higher grades on day 10 than day 0. This suggests that ageing or variations in the indoor climate affect the quality of fingerprints visualised. This is supported by the Home Office (2022) and Cadd et al. (2015), who highlight the impact caused by ageing and the effect that indoor climate variations have on fingerprints.

It has been shown that weathering can impact fingerprints (as explained in the discussion points above and section 1.6.1), although it has not been proven that there is a statistically significant difference between weathered and non-weathered prints. The results found help answer the research question as to the impact of weathering on fingerprints. Even though the hypothesis stated in section 1.9 is incorrect and no statistically significant difference was found, the null hypothesis is accepted as although a difference is seen, it cannot be stated that it is caused by weathering.

# 3.2.1.2 Best visualisation technique for each material

The total number of prints developed and median score were calculated from the original grades, and then Appendices 3-12 were analysed to determine the most suitable recovery method for each material. Trendlines were used for each day of visualisation to represent how the prints changed through the depletion series. The gradient for each trendline was then calculated using the y=mx+c equation, where m is the gradient. This resulted in Appendices 18-25 and Figures 11, 12, 13 and 14.

A graph of different colored lines

Description automatically generated

Figure 11: Graph showing grades from all days for the weathered painted wood, visualised with Iron Oxide with the y=mx+c values

A graph of different colored dots and lines

Description automatically generated

Figure 12: Graph showing grades from all days for the weathered painted metal, visualised with black powder with the y=mx+c values

A group of text on a white background

Description automatically generatedA graph of different colored lines

Description automatically generated

Figure 13: Graph showing grades from all days for the weathered window glass, visualised with black powder with the y=mx+c values

A graph of different colored dots and lines

Description automatically generated

Figure 14: Graph showing grades from all days for the weathered uPVC, visualised with black powder with the y=mx+c values

Figure 11 and Appendices 18 and 19 show all of the graphs made for painted wood. These graphs represent the relationship between fingerprint grades and the day of visualisation/depletion number for each of the recovery methods. Iron oxide was identified as the best visualisation method for weathered painted wood as it produced good quality prints that steadily decreased throughout the days, with at least one print each day being able to be graded. This differs from what is shown in Appendices 18 and 19, as both black powder and aluminium powder had at least one day where no prints were visualised and both enhancement methods decreased rapidly between days and depletions. Iron oxide visualised 88% of prints on the painted wood with a median grade of 8, whereas black powder visualised 44% and aluminium powder visualised 21% and both had a median grade of 0. The use of SPR (of which iron oxide is a type) on painted wood that has been subjected to similar conditions is supported by Dhall & Kapoor (2016). However, the practical application of WPS at a crime scene is impractical, due to the amount of mess created from its use (as previously stated by Bailey, 2024 in section 1.7) and how this could contaminate or destroy other potential evidence. Figures 15, 16 and 17 are taken from Appendix 1 and show the extent of excess surface runoff from the technique.

A white door with strings on it

Description automatically generatedA drain pipe on a sidewalk

Description automatically generated with medium confidence

Figure 15: Photo showing the excess iron oxide left on the floor after use

Figure 16: Photo showing the aftermath left on the painted wood after iron oxide use

A broken white tile on a wet concrete surface

Description automatically generated

Figure 17: Photo showing the aftermath left on the floor after iron oxide use

Appendices 20 and 21 and Figure 12 represent all of the graphs made for painted metal. On this material iron oxide enhanced 26% of prints with a median score of 0, black powder visualised 61% with a median grade of 6 and aluminium powder visualised 63% with a median grade of 4.5. This was also represented in the graphs as Appendix 20 shows prints only reaching grade 13 and generally decreasing across depletions as highlighted by each day’s trendline. Whereas Appendix 21 has a wide range of grades, with the highest being 20, after day 1 the grades decrease significantly with the trendlines reaching no higher than 4. Due to this black powder was chosen as the best enhancement method for weathered painted metal as a steady decrease is seen throughout days and depletions, until day 7, represented in Figure 12. Black powder has previously been used on non-porous smooth surfaces like painted metal as stated by the Home Office (2020).

Figure 13 and Appendices 22 and 23 represent all graphs made for window glass. Figure 13 shows the graph for black powder, which was highlighted as the best recovery method for weathered window glass. It produced good-quality prints for the first two days, which decreased steadily across the depletion series. Day 3 and 10 resulted in no marks being visualised, but some results were gathered for day 7. However, for aluminium powder (Appendix 23) and iron oxide suspension, (Appendix 22) only a maximum of three days were able to be visualised with the highest grade being 16. Statistically black powder visualised 48% of prints, producing a median grade of 2, iron oxide visualised 28% of prints with a median grade of 0 and aluminium powder enhanced 21% of prints with a median grade of 0. The use of black powder on window glass has shown to be effective for fingerprint recovery as shown by Home Office (2020).

The graphs made for weathered uPVC are shown in Figure 14 and Appendices 24 and 25. Iron oxide enhanced 19% of prints with a median grade of 0 and as seen in Appendix 24 only the day 1 prints were able to be visualised. On the other hand, black powder performed the best on this material, visualising 52% of prints with a median grade of 2, but a highest grade of 20. Figure 14 shows the range of results gathered, resulting in varied degradation rates across depletion series and days. Aluminium powder had a median score of 0, enhancing 38% of prints, which is represented in Appendix 25 as no prints were visualised on days 3 and 10. Home Office (2020) agree with the finding that black powder is an effective technique on uPVC, due to its smooth, non-porous surface.

The weather experienced over the course of this study consisted of 8 days of precipitation, with an average high temperature over the 10 days of 9.5°C and an average low temperature of 2.2°C. The average humidity was 96.2%, with average wind speeds of 7.7mph and every day of the experiment was partially cloudy. Appendix 26 shows the full list of conditions experienced on each day throughout the study and all data was collected from the closest weather station to where the study was being conducted (Time and date-past weather, n.d.). These conditions would have impacted the results of the study because as mentioned previously in section 1.6 the order and level at which the occurs will change how the substrate and fingerprint are affected (Home Office, 2022). As well as having an impact on the overall outcome, specific results could have been impacted by weather conditions experienced before visualisation, for example, a lot of the prints enhanced on day 3 were unable to be graded or of low quality. This could be due to the fingerprints being subjected to 3 days of light rain and high humidity, Home Office (2022) states these factors could be detrimental to fingerprint evidence.

The majority of the weathered materials responded best to black powder being used for visualisation so overall it appears to be the best technique for recovery of weathered fingerprints. The only material that responded better to another method was Painted wood, which worked best with iron oxide. This finding is in disagreement with the Home Office (2022) who state that powders may still be effective on materials that have been subjected to water, but SPR is more effective as the components within the print, which it adheres to, are not altered by the presence of water (which was the main destructive condition experience in this study). It also differs from the hypothesis stated in section 1.9 which suggested that iron oxide would be the better overall recovery method for most materials. Although as stated below, there were some limitations to this study which might have led to this outcome. This helps answer the research question as the different enhancement methods have been compared and the best visualisation method has been determined for each method and overall. The recommendations for further research in this area are to test other variations of WPS against realistic weather conditions to see if it is useful at scenes and make it more applicable to use at crime scenes. The effects of specific weather conditions need to be analysed individually to determine what effect each one has on fingerprints. Whilst conducting this study the concept of using Magneta flake on weathered materials was suggested, as it dries as it is applied and so does not smudge like other powders on wet surfaces and could also be used on textured surfaces. Research into this would be useful to determine if it would be a better method than the techniques tested in this study.

Whilst conducting this study some limitations were found with the methodology used. The fingerprints were not enhanced by an examiner, instead, experience was gained throughout the study and so the technique used for powdering could have improved, rather than the fingerprint quality. Only one colour of painted wood, painted metal and uPVC were tested so the grades would be affected by the level of contrast between the materials and the visualisation technique. This is particularly evident with the painted wood and uPVC, as both were white and so the darker visualisation methods (iron oxide and black powder) would get a higher grade for contrast. After the study had started it was realised that the non-weathered painted wood was slightly textured, this affected the black powder and aluminium powder results on this material as both powders are only effective on smooth surfaces. The fingerprints were also photographed on a mobile phone, rather than a standard camera that would be used at a crime scene and so the photos taken are not of the same quality as would be expected from an examiner. This also made it difficult to photograph on certain surfaces as the painted metal was reflective in the sun so it was hard to focus on the fingerprint details. A smaller version of the study had to be set up to redo the powdered prints for days 1,7 and 10 because on their selected days the materials were still wet, meaning the powders were unable to be used. Taking this into account might mean that black powder is not the best enhancement method for weathered fingerprints as even though the iron oxide visualised fewer prints, it was able to be used on each of the selected days (even when it was raining). A low amount of experience was had using iron oxide before the study, when rinsing the solution off the materials distilled water in a plastic bottle with the tip was used initially, but it was determined that this was too powerful as at times it would rinse through all of the iron oxide. Once this was realised the method was changed to using a water bottle. Overall the study has low reproducibility because the weather conditions experienced cannot be replicated exactly.

# 4. Conclusion

The effect of weathering on fingerprints and the best visualisation method for these conditions has been studied. It was found that whilst weathering may affect the quality of fingerprints recovered, there is not a statistically significant difference between the fingerprints graded after 10 days of weathering. Black powder was identified as the best visualisation method for weathered prints, but a repeat of the study had to be conducted to obtain all of the grades for black and aluminium powder. Further research has been suggested investigating the use of other WPS and Magneta flake to determine their effectiveness in developing weathered fingerprints.

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# Appendices

Appendix 1

[Dissertation Photos](https://staffsuniversity-my.sharepoint.com/:f:/g/personal/d013430l_student_staffs_ac_uk/Ej-0T8autQVFjJxfwQ0Wh7UBYqJ9E5ecMYmw7PI0-aZzTA?e=QyPrq1)

Appendix 2

[Main study results.xlsx](https://staffsuniversity-my.sharepoint.com/:x:/g/personal/d013430l_student_staffs_ac_uk/ES6QrV_NdN5IqVHT2OpfVqAB6J1Is6IOEgIN3qRDd0EWtw?e=voylEA)

Appendix 3

A graph of different colored dots and lines

Description automatically generated

Appendix 4

A graph of different colored dots and lines

Description automatically generated

Appendix 5

A graph of different colored dots and lines

Description automatically generated

Appendix 6

A graph of different colored dots

Description automatically generated

Appendix 7

A graph of different colored lines

Description automatically generated

Appendix 8

A graph of different colored lines

Description automatically generated

Appendix 9

A group of text on a white background

Description automatically generatedA graph of different colored lines

Description automatically generated

Appendix 10

A group of text on a white background

Description automatically generatedA graph of different colored lines

Description automatically generated

Appendix 11

A graph of different colored dots and lines

Description automatically generated

Appendix 12

A group of text on a white background

Description automatically generatedA graph of different colored dots and lines

Description automatically generated

Appendix 13

A screenshot of a table

Description automatically generated

Appendix 14

A screenshot of a graph

Description automatically generated

Appendix 15

A screenshot of a graph

Description automatically generated

Appendix 16

A screenshot of a graph

Description automatically generated

Appendix 17

A screenshot of a graph

Description automatically generated

Appendix 18

A graph of different colored dots and lines

Description automatically generated

Appendix 19

A group of text on a white background

Description automatically generatedA graph of different colored lines

Description automatically generated

Appendix 20

A graph of different colored lines

Description automatically generated

Appendix 21

A group of text on a white background

Description automatically generatedA graph of different colored lines

Description automatically generated

Appendix 22

A group of text on a white background

Description automatically generatedA graph of different colored lines

Description automatically generated

Appendix 23

A group of text on a white background

Description automatically generatedA graph of a window class

Description automatically generated

Appendix 24

A group of text on a white background

Description automatically generatedA graph with lines and dots

Description automatically generated

Appendix 25

A group of text on a white background

Description automatically generatedA graph of different colored dots and lines

Description automatically generated

Appendix 26

A screenshot of a computer

Description automatically generated