Comparison of Carbon and Iron Oxide Based Powder Suspension Formulations

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Abstract

Powder suspensions (PS) are a fingermark development technique made up of a mixture of an insoluble powder and surfactant solution. In the UK, carbon-based PS is used operationally on adhesive surfaces while iron oxide-based PS is used on flexible plastics. In NSW, Australia, only carbon-based suspensions are used due to a lack of research using iron oxide PS in an Australian context. In this research, a range of iron oxide powders and surfactant types were tested to optimise two iron oxide formulations. General observations found that thinner suspensions improved the ease of use in this technique while slightly improving the quality of developed fingermarks. The first optimised formulation involved a magnetic iron-oxide from Fisher Scientific mixed with a dilute Triton X-100 surfactant, and the other an iron-oxide nanopowder from Sigma Aldrich mixed with a 4% Tween 20 solution.

The two formulations were then compared with a pre-mixed carbon-based PS, Wet Powder. This comparison showed that the effectiveness of each formulation is heavily dependent on substrate type. Both formulations had issues with heavy background staining on different kinds of surfaces. However, Wet Powder was shown to be the most consistently effective fingermark detection technique overall, especially on adhesive tapes. Despite this, iron-oxide PS were still a highly effective fingermark development technique, notably on plastic surfaces.

Keywords

Fingermark detection, surfactant, nanoparticles, substrate, wetted fingermarks, plastic

1. Introduction

Powder suspension (PS) is a fingermark development technique made up of an insoluble powder, a surfactant and water. It is a physico-chemical detection process that involves applying the paint-like mixture to a surface or item before rinsing it with water to reveal developed fingermarks [1, 2]. This method was originally developed to detect fingermarks on the adhesive side of tape, however it has been found to detect marks on non-porous and semi-porous surfaces as well. PS is a safe, inexpensive and simple to use technique that is notably effective in difficult conditions such as marks that have been wet or aged [1, 3-6]. The Centre for Applied Science and Technology (CAST) recommends the use of different kinds of PS depending on substrate type; pre-mixed carbon-based formulations for adhesive tapes and an iron-oxide formulation that must be made fresh is recommended for other light-coloured, non-porous surfaces. Iron oxide and carbon-based PS both produce dark fingermarks and are therefore used on light-coloured surfaces, however they do not always perform equally and considerable research has been done to determine their uses and limitations [1, 5].

Due to the simplicity of the PS formulations, iron oxide PS can be easily customised using different powders and surfactants to varying degrees of effectiveness. CAST currently recommends 20g of a magnetic iron oxide from Fisher Scientific mixed with 20mL of a surfactant solution containing Triton X-100, ethylene glycol and water. Previous studies have shown that a range of iron oxide powders are effective in PS, however powders with particles predominantly ranging from a few hundred nanometres to 1 µm in diameter are optimal in this technique [1, 7, 8]. Different surfactants have also been investigated, most notably by Downham in 2017 and 2018. This research was conducted as Triton X-100 has begun to raise environmental concerns about having detrimental effects on wildlife, leading to its restriction in many countries [7, 9]. Downham found that Tween 20 may be a suitable replacement for Triton X-100 in iron oxide PS, and that both surfactants may be diluted significantly without notable effect on fingermark development [2, 7, 10]. However, further research is needed into the effect of different surfactants on iron oxide PS before the recommended formulation is altered.

PS formulations were commercialised for use on adhesive tapes. For fingermark development, two kinds of adhesive have been shown to affect development techniques;

rubber and acrylic [11, 12]. While both carbon and iron oxide PS formulations can develop marks on rubber-based adhesives, use of iron oxide suspensions on acrylic-based adhesives results in heavy background development [1, 5, 7, 12]. As it is difficult to determine the properties of a tape sample through visual observation, carbon-based PS is currently recommended for all adhesive surfaces. The application of PS on non-porous surfaces is much newer than its application on adhesive tapes, however also much broader. Iron oxide PS is recommended as carbon-based PS is less sensitive and more prone to background staining on these surfaces [1, 5, 13]. Iron oxide PS has been shown in numerous studies to also outperform other development techniques such as cyanoacrylate fuming and vacuum metal deposition on some non-porous surfaces, notably flexible plastics [14]. Other surfaces include kitchen tiles contaminated with drug and grease residues [5, 15], arson items [16, 17] and glass contaminated with sea salt spray [18].

The majority of recent research into PS formulations has been conducted in the UK, where iron oxide PS is used operationally on flexible plastics [14, 19]. In Australia however, only carbon-based PS is used and is only recommended for fingermark development on the adhesive side of tapes. Due to the success of iron oxide PS in the UK and their potential for operational use, especially on non-porous surfaces, it would be beneficial to further research iron oxide formulations in an Australian setting. This paper explores the effectiveness of various iron oxide PS formulations and compares optimised formulations to commercially available carbon-based formulations on a range of adhesive and non-adhesive surfaces.

2. Materials and Methods

2.1 General methodology

This research was completed in two stages. The first focussed on optimisation of an iron oxide PS formulation using powders and surfactants available in Australia. The second used two optimised formulas from stage 1 and compared them with a commercial carbon-based PS to determine which was more effective on a range of surfaces. Other parameters such as aged and wetted fingermarks were also tested. Ethics approval was completed through the University of Technology Sydney (ETH18-2521) and participants were required to consent to the collection of their fingermarks prior to deposition.

2.2 Substrates

A range of non-porous and adhesive surfaces were used for these experiments as shown in **Table 1**. Ceramic surfaces were cleaned prior to deposition by wiping the surface with acetone and disposable Kimtech paper wipes. Plastic surfaces were sourced unused, directly from the packaging. Tape samples were taken from the roll, with the outermost layer discarded each time samples were taken to avoid contamination. Adhesive surfaces were mounted on a clear acetate sheet to be stored after fingermark deposition and before development.

Table 1 *List of substrates used in each stage of the study*

Substrate Code	Brand	Description	Stage involving substrate
Tile	Johnson Tiles	White, glossy ceramic tiles	Optimisation/ Comparison
Plastic	J. Burrows	Resealable polyethylene plastic bags	Optimisation/ Comparison
NonAdh Tape	Duck Duct Tape	Non-adhesive side of white duct tape	Optimisation/ Comparison
AdhTape	Duck Duct Tape	Adhesive side of white duct tape (rubber-based adhesive)	Optimisation/ Comparison
Vinyl	N/A	Adhesive side of white, glossy vinyl (acrylic-based adhesive)	Comparison
Label	Avery Chemical Grade laser labels	Adhesive side of white heavy-duty labels (acrylic-based adhesive)	Comparison

2.3 Fingermark deposition

For natural fingermark deposition, donors were asked to wash their hands five minutes before the first deposition and then wait two minutes in between subsequent depositions. Donors rubbed their fingertips together before each deposition for even distribution of fingermark constituents. Fingermarks were aged in a laboratory environment with mean temperature of 19.5 ± 1 °C and mean relative humidity of 54.3 ± 15%.

2.4 Fingermark development

All PS formulations were applied using the same method. A wet squirrel hair fingerprint brush from Optimum Technology was loaded with PS and then gently brushed across the substrate. The suspensions were left on the substrate for approximately 15 seconds and then rinsed

with a gentle stream of tap water. Different brushes were used for each iron oxide powder and rinsed thoroughly between application of different formulations. Developed samples were left to dry overnight and photographed the next day using a Canon EOS 800D and a Canon EF-S 60mm macro lens. The Rofin Polilight PL500 was used to apply oblique white light for visual enhancement on the plastic surfaces.

2.5 Optimisation

2.5.1 Materials

Three powders (**Table 2**) were chosen to represent a range of brands and particle sizes available in Australia. Four surfactant stock solutions were also chosen and prepared as shown in **Table 3**. 100mL of each surfactant solution was prepared and stored in a sealed glass bottle in a cupboard for the duration of the study. A total of 12 different iron oxide PS combinations were made with these powder and surfactant components.

Table 2 *Iron oxide powders tested*

Supplier	Powder Reference	Powder Type	Chemical Formula	Manufactured Particle Size
Fisher Chemical	Fisher	Precipitated Magnetic Iron Oxide	Fe_3O_4	>1 µm
Chem Supply	Chem	Iron Oxide Magnetic	Fe_3O_4/ Fe_2O_3	>1 µm
Sigma Aldrich	Sigma	Iron Oxide Nanopowder	Fe_3O_4	50-100 nm

Table 3 *Surfactant solutions tested*

Surfactant Components	Surfactant Reference	Ratio/ Concentration
Triton X-100 Ethylene Glycol Water	TX	5:7:8
Tween 20 Water	T4	4% solution
Tween 20 Water	T40	40% solution
Liqui-Nox Water	LN	1:1

2.5.2 Method

Nine formulations of the same combination were created by using different powder weights and surfactant concentrations as illustrated in **Table 4**. A base ratio using five grams powder to five millilitres surfactant solution was used to reflect the ratios suggested in the CAST recommended formulation (20 g powder and 20 mL surfactant)[1]. From this reference ratio, powder weights and surfactant concentrations were reduced. Surfactants were diluted from their stock solutions by adding water as necessary.

Table 4 *Different surfactant ratios and powder weights tested for each PS formulation*

Surfactant ratio	**Powder weight (g)**		
5 mL surfactant 0 mL water	5	2.5	1.7
3 mL surfactant 2 mL water	5	2.5	1.7
1 mL surfactant 4 mL water	5	2.5	1.7

Natural fingermarks were deposited on surfaces by six donors. Each donor deposited one fingermark on every substrate sample, with a total of six fingermarks per substrate. Fingermarks were developed with PS within two hours of deposition and then stored in an enclosed cupboard to dry overnight. Each fingermark was photographed individually and graded by one assessor using the absolute CAST scale shown in **Table 5**.

Table 5 *CAST scale used for fingermark assessment [20]*

Grade	**Detail visualised**
0	No evidence of a fingermark
1	Some evidence of a fingermark
2	Less than 1/3 clear ridge detail
3	Between 1/3 and 2/3 clear ridge detail
4	Over 2/3 clear ridge detail

2.6 Comparison

The two optimised iron oxide PS formulations chosen in the previous stage were then individually compared to a pre-mixed commercial carbon-based PS 'Wet Powder Black' from Kjell Carlsson Innovation. All suspensions were applied using the same method as described in section 2.4.

2.6.1 *Method*

Natural fingermarks from five donors were deposited on six surfaces (**Table 1**) using the three middle fingers and three depletions, with a total of 9 fingermarks on each sample. Samples were then split down the centre of the middle fingermark and the left side developed using iron oxide PS and the right developed using Wet Powder as shown in **Figure 1**. Deposited fingermarks were aged for 1 day, 1 week or 1 month before development with PS. Two sets of fingermarks were deposited for each ageing period to test the effect of wetted fingermarks on this comparison. Half the samples were submerged in water for 30 minutes after fingermark deposition before being dried at room temperature and aged the same as the non-wetted samples. Both sides were then brought back together and dried for a day at room temperature before being photographed. A total of 3240 fingermarks were processed in this stage of the investigation.

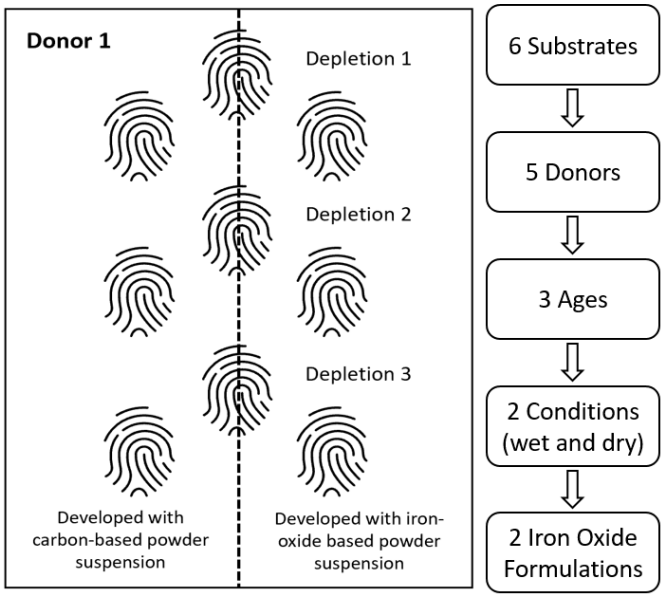

Figure 1 *Diagram of fingermark deposition and parameters tested in comparison stage of this study*

All samples were analysed by three assessors with experience in fingermark detection research using the comparative University of Canberra (UC) scale shown in **Table 6**. The median of these scores were used for data analysis.

Table 6 *Modified UC scale used for comparative fingermark assessment (technique A-Iron oxide PS, technique B- Wet Powder) [21]*

Grade	Definition
+2	Development of technique A is significantly more effective compared to technique B
+1	Development of technique A is slightly more effective compared to technique B
0	Both methods are indistinguishable in quality
-1	Development of technique B is slightly more effective compared to technique A
-2	Development of technique B is significantly more effective compared to technique A
00	No detection of the fingermark using either technique

3. Results and Discussion

3.1 Optimisation

3.1.1 Powder and surfactant type

The results of the optimisation stage showed that the greatest influence on effectiveness of these formulations was the powder/surfactant combinations rather than the ratios of surfactants and water. Initial tests used components found in the current recommended formulation (ie. Fisher iron oxide powder and Triton X-100 (TX) surfactant) as a base line to evaluate the effect that changing either the powders or surfactants had on fingermark quality. Each surfactant was first tested with the Fisher iron oxide powder. The formulation containing Liqui-Nox (LN) produced the poorest development, with the highest rates of marks rated 0 or 1 as shown in **Figure 2**.

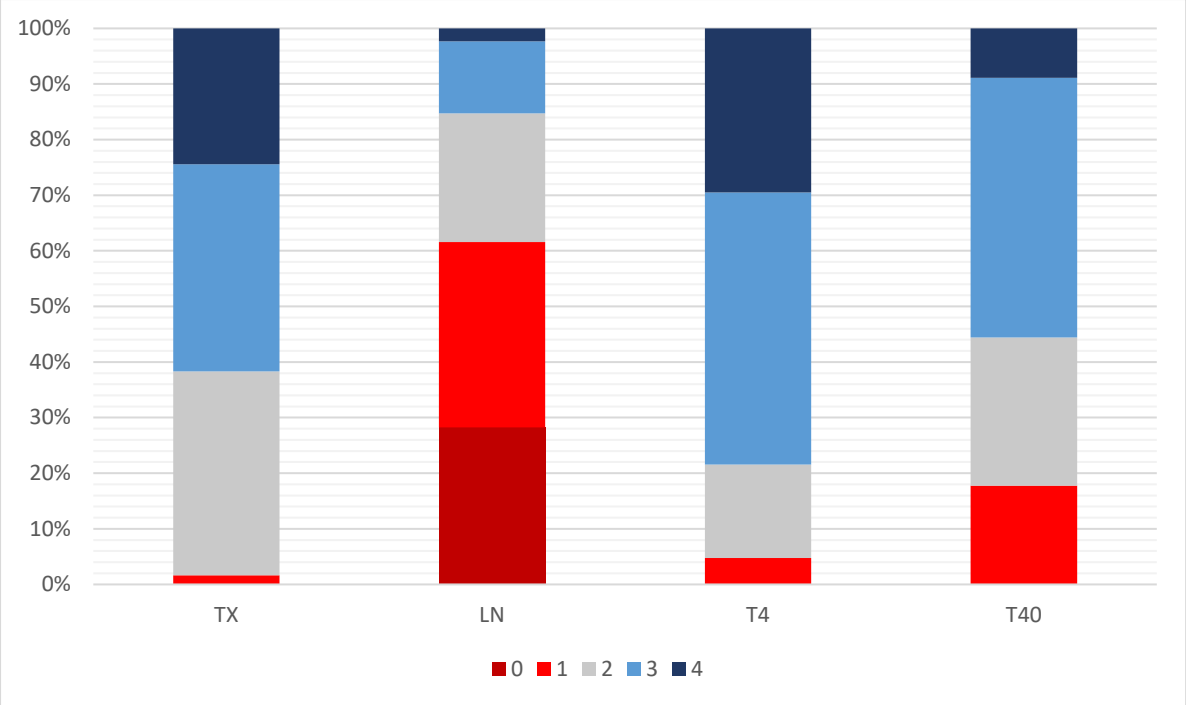

Figure 2 *Comparison of all surfactants using Fisher iron oxide powder*

From these results, the two Tween 20 surfactants could be directly compared. The more dilute surfactant (T4) produced marks of superior quality to the T40. T4 also consumed less resources and was easier to apply, therefore it was considered preferential to T40 for further optimisation. Similar results were observed when these surfactants were used with other powders.

All powders were able to successfully develop fingermarks with TX and T4 surfactants, however as illustrated in **Figure 3** the iron oxide from Chem supply was the least effective. As such, it was not considered for the comparison stage. Generally, formulations made with T4 surfactant were the most effective for all powders. This is likely due to the thinner surfactant (T4) improving consistency of the formulation and making it less likely to damage fingermark residue during application. Studies by Downham in 2018 have shown that Tween 20 is highly effective when used in PS formulations, and thinner suspensions have the added advantage of easier application which is consistent with the results of this study [7].

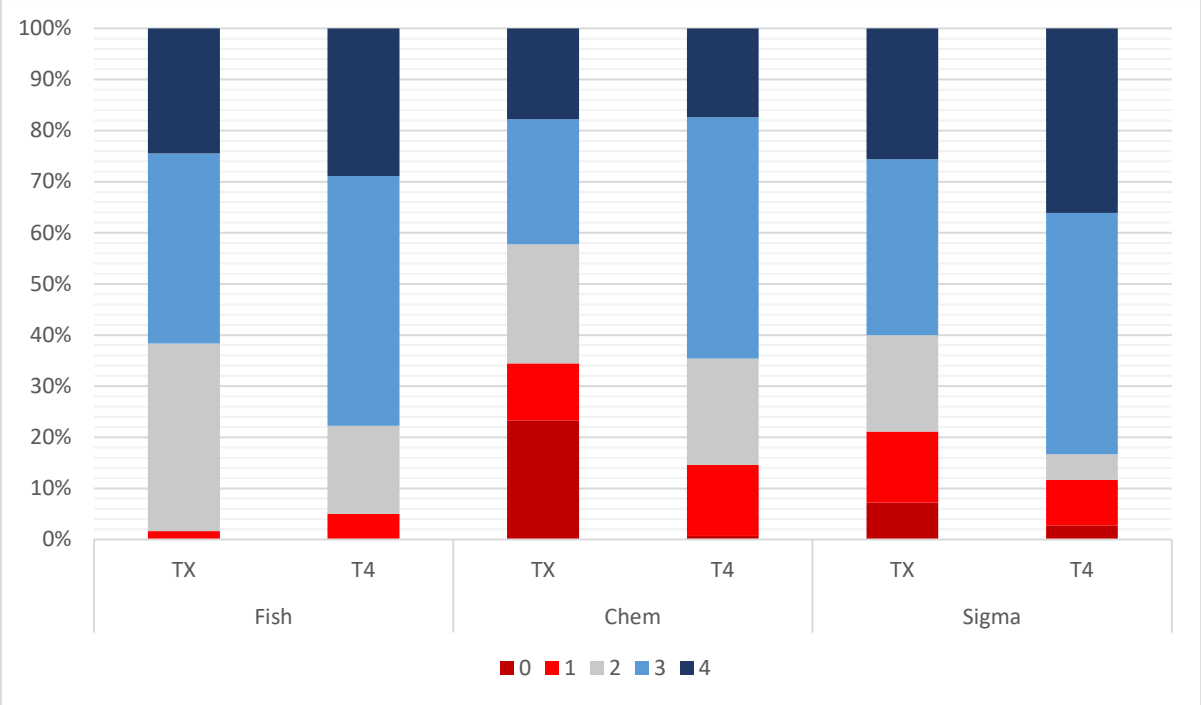

Figure 3 *Comparison of PS formulations made from three iron oxide powders (Fisher, Chem and Sigma) and two surfactants (TX and T4)*

Formulations made with the Fisher powder had the fewest number of fingermarks rated 0 or 1, suggesting it was highly effective in visualising fingermarks. The Sigma/T4 formulation yielded the highest number of developed marks rated 3 or 4 (83%) suggesting it highly effective in visualising fingermark residue. The Fisher and Sigma powders were both able to develop high quality fingermarks with TX or T4, however the fingermarks were visualised differently. Despite both dry powders being visually black, only the Sigma powder produced black fingermarks in PS while the Fisher powder produced brown ones, providing less contrast on light coloured surfaces. This was particularly important on the plastic surface, as both formulations produced high quality ridge detail however the Fisher formulation required oblique lighting to be visualised (**Figure 4**).

Figure 4 *Fingermarks developed on plastic using Fisher/TX (left) with oblique lighting to increase contrast and Sigma/T4 (right) without additional lighting. Shows difference in colour of treated marks*

From these results, two iron oxide formulations were chosen. First, the Fisher/TX formulation was selected as these components are used in the CAST recommended formulation, and it had the lowest instance of marks rated 0 or 1. The Sigma/T4 was also chosen due to the high quality of marks (rated 3 or 4) produced with this formulation.

As the CAST recommended iron-oxide formulation contains the same powder and surfactant type as the Fisher/TX formulation, this combination has been previously studied and shown to be effective. In a paper detailing the 2009 pseudo-operational trial performed by CAST which used this iron-oxide PS, Downham noted that the particle size of the Fisher powder was critical to its success [14]. The authors cited another paper by Jones *et al.* who found that iron-oxide particles with a diameter between 0.2 and 1 µm were adhering to the fingermark residue despite the presence of larger particles in the solution [8]. This led to CAST suggesting that an iron-oxide consisting mostly of particles outside this range would be less effective for fingermark development. However, the success of the nanopowder in these results shows that particles with a diameter smaller than the recommended range can still be effective.

3.1.2 Powder and surfactant ratio

The different powder weights and surfactant ratios of these two formulations were then analysed in more depth. As illustrated in **Figures 5 and 6**, changing these ratios did not have an observable impact on the effectiveness of the formulations.

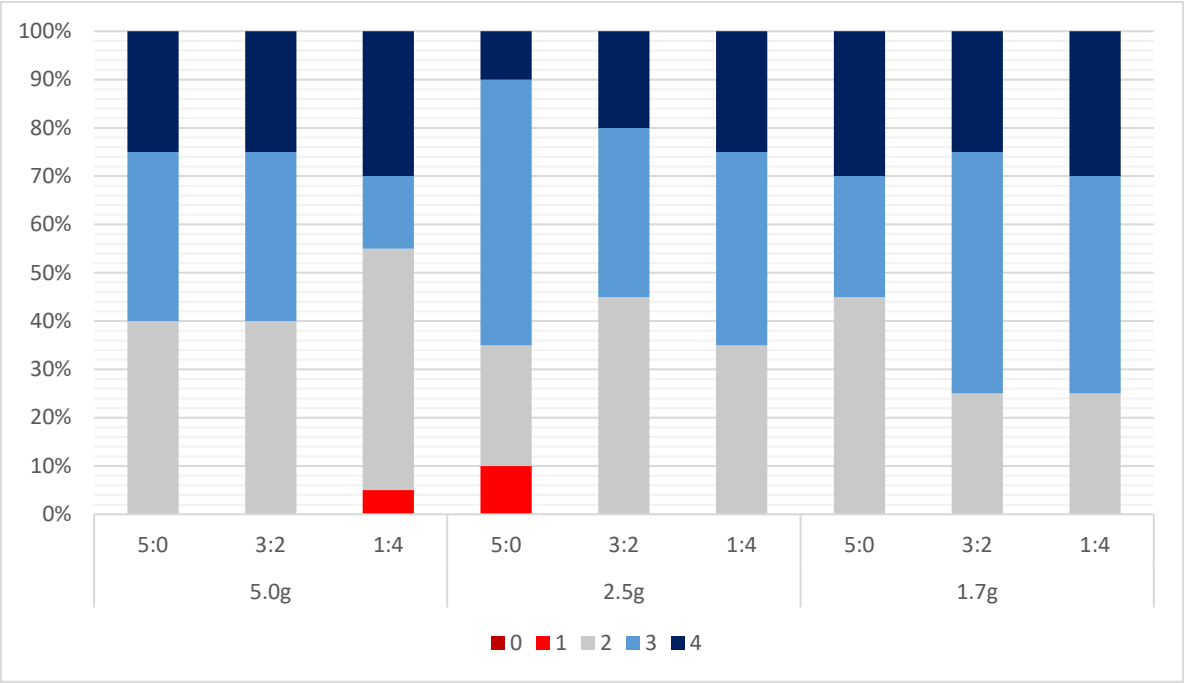

Figure 5 *Comparison of powder weight and surfactant ratio in Fisher/TX PS formulation*

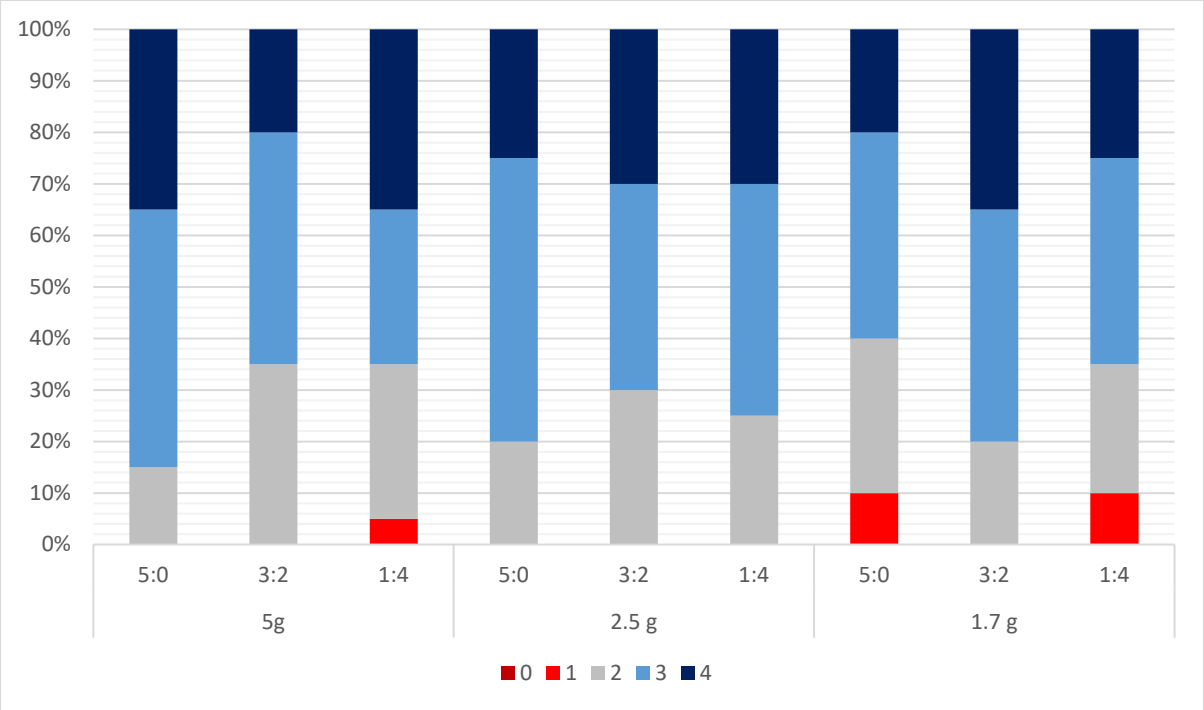

Figure 6 *Comparison of powder weight and surfactant ratio in Sigma/T4 PS formulation*

The greatest impact these variables had on the formulations was the ease of application. Thicker suspensions (using more powder and more concentrated surfactants) were difficult to apply and sometimes led to streaking on the fingermarks due to the suspension drying very quickly. This also made them difficult to wash off, as well as consume more resources. Due to this, both optimised formulations were made with 1.7 g of iron oxide powder, only one third of the recommended ratio. As the T4 surfactant was already significantly more dilute than the TX, the optimised surfactant ratios were not the same for both formulations. The final optimised formulations are outlined in **Table 8**.

Table 7 *Optimised iron oxide PS formulations*

Iron-Oxide Powder	Powder Weight	Surfactant Solution	Surfactant (mL)	Water (mL)
Fisher Chemical Precipitated Magnetic Iron-Oxide	1.7 g	Triton X-100 and ethylene glycol	1	4
Sigma Iron-Oxide Nanopowder	1.7 g	Tween 20 4%	3	2

Few studies have investigated the effect of reducing powder weight and diluting surfactant solutions on PS. The most significant was conducted by Downham in 2017 and 2018, finding that both Triton X-100 and Tween 20 may be diluted in PS without significant effect on developed fingermark quality [10]. Authors have also observed that thinner suspensions are easier to apply and wash off substrates. One study by Ferguson in 2013 into the acquisition of fingermarks on food found that halving the recommended powder weight and substituting surfactant solutions for distilled water entirely was more effective [6]. This study noted the shelf life of these formulations were very short and had to be used immediately, which would affect the feasibility of these formulations to be used operationally. These results are all consistent with the observations made during this investigation.

3.2 Comparison

This stage of the study compared the two optimised iron oxide PS formulations in **Table 8** to a commercial carbon-based PS, Wet Powder, on a range of different surfaces. The most significant variable that affected this comparison was substrate type, notably between the adhesive and non-adhesive surfaces. The two iron oxide formulations behaved differently on

many surfaces, so the results of both comparisons were analysed separately. For both comparisons however, there was no trend in depletion number affecting the quality of developed marks. For the purpose of clarity, all donor scores have been combined in the subsequent analysis. While expected donor variability was observed, the differences between donors were consistent for each comparison.

3.2.1 *Fisher/ TX results*

This comparison showed a clear difference between effectiveness of each formulation on adhesive and non-adhesive surfaces (**Figure 7**). Represented by the high number of negative scores on the graph below, Wet Powder was more effective on the three adhesive surfaces and non-adhesive side of tape. The Fisher/TX formulation was more effective on the tile and plastic surfaces. On the adhesive surfaces, the formulations also performed differently on the acrylic-based adhesives (vinyl and label) and rubber-based adhesive (tape). The Wet Powder was considerably more effective on the acrylic-based adhesives and only moderately more effective on the rubber-based tape. This difference was due to the heavy background development caused by Fisher/TX formulation on the acrylic-based surfaces (**Figure 8**). The results of this comparison on adhesive tape are consistent with literature. It is well documented that a limitation of iron-oxide PS is the heavy background development produced on acrylic-based adhesives [5, 7, 11]. As duct tape contains a natural rubber-based adhesive, the staining was not observed on this substrate [22]. In general, studies show that carbon-based suspensions are the most effective method for fingermark development on adhesive tapes [11, 22]. This is reflected in the results of this study.

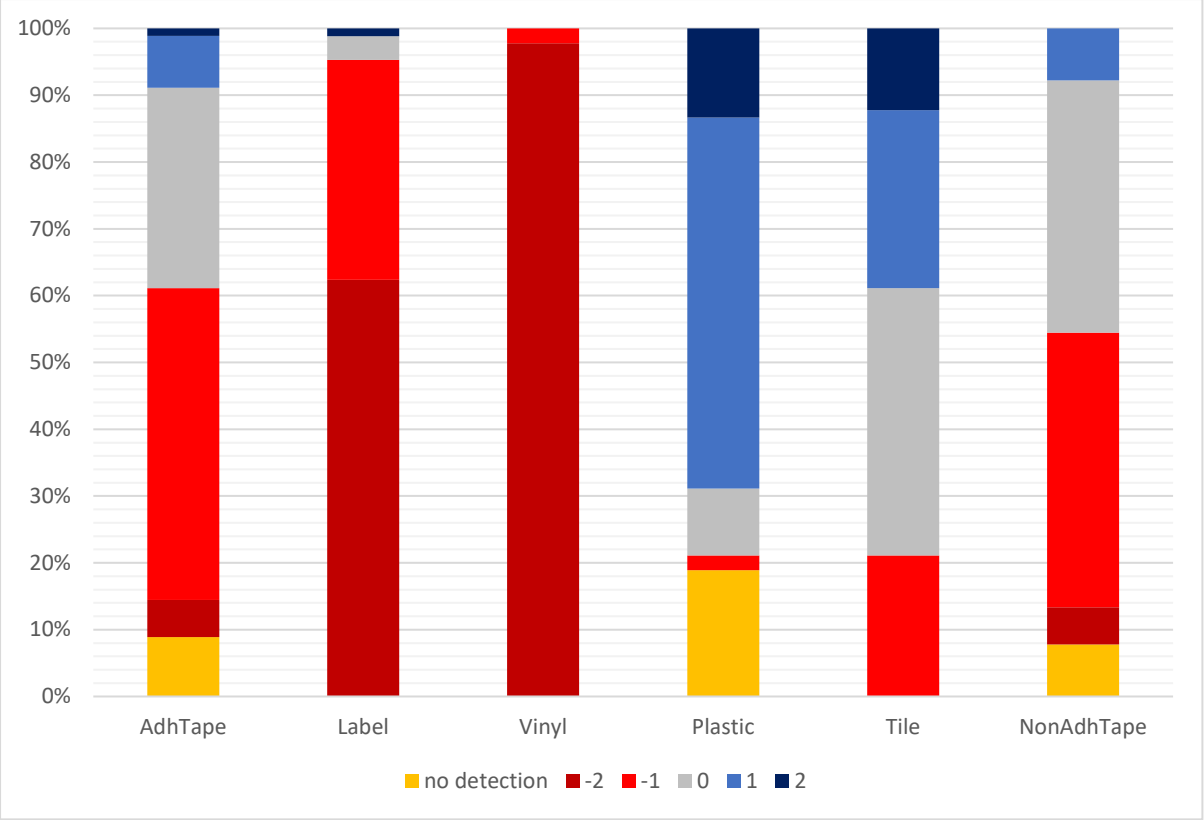

Figure 7 *Comparison of Fisher/TX and Wet Powder by substrate (AdhTape, Label and Vinyl = adhesive, Plastic, Tile and NonAdhTape = non-adhesive)*

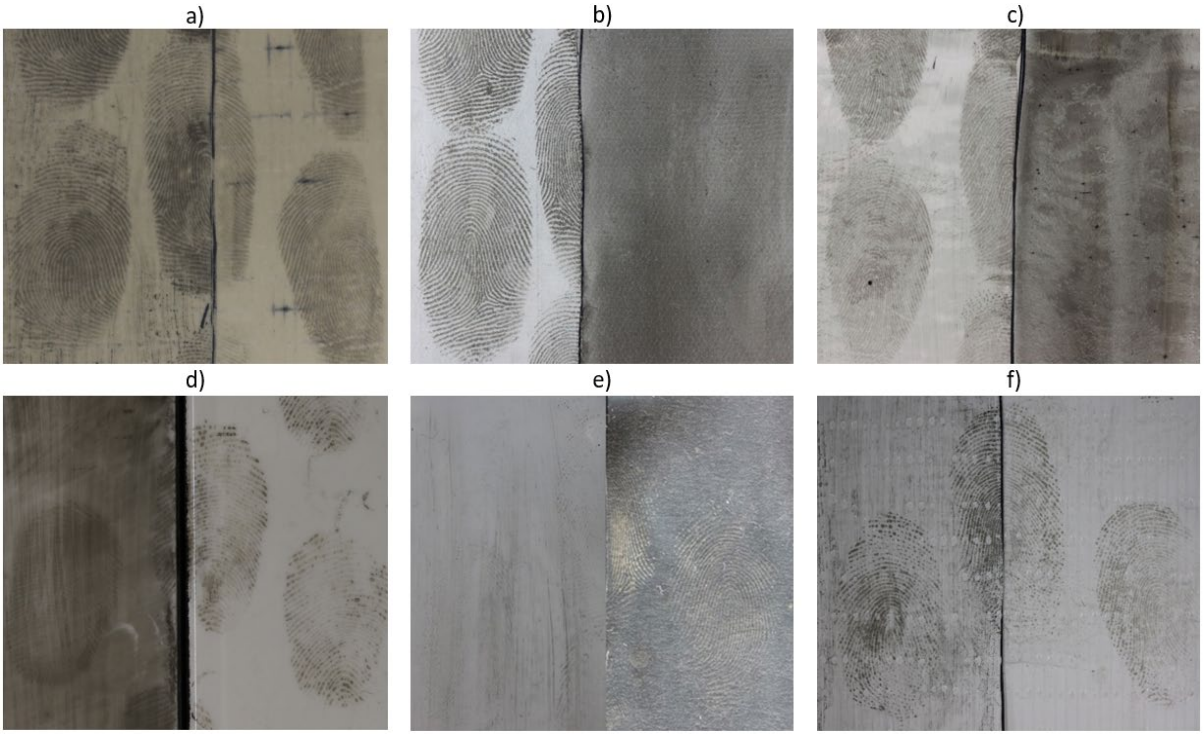

Figure 8 *Representative images of comparison between Fisher/TX (right) and Wet Powder (left) by substrate a) AdhTape b) Vinyl c) Label d) Tile e) Plastic (oblique lighting applied to right side) f) NonAdhTape*

On non-porous surfaces, there were fewer samples rated +2 or -2, suggesting that neither technique was overwhelmingly more effective on a particular surface. Plastic and tile were the only surfaces on which iron oxide PS was more effective. On these surfaces, the Wet Powder was prone to background development that greatly reduced contrast of developed marks. On plastic, oblique lighting was required to visualise marks developed with Fisher/TX as the lighter brown colour of the marks reduced contrast.

The cause of heavy background development using Wet Powder on light-coloured plastics was investigated by Bacon in 2013 [13]. This study found that many light-coloured surfaces contain titania pigment which may lead to overdevelopment when treated using carbon-based PS. Jones *et al*. showed that iron-oxide based PS did not produce the same overdevelopment on the light-coloured plastics studied [8]. As titania can be used in ceramic tiles to create a white colour [23], this could explain the heavy background development that was produced using Wet Powder. As the studies from Bacon and Jones were performed on plastic surfaces, they can only be used as a suggestion as to why this overdevelopment may occur on other surfaces. No published investigations into the cause of background development on other surfaces using carbon-based PS have been performed.

3.2.2 *Sigma/ T4 results*

The comparison between Sigma/T4 and Wet Powder differed from the previous one, as there were no clear trends observed between adhesive and non-adhesive surfaces and a higher number of samples were rated '0', suggesting both techniques performed more equally (**Figure 9**). This difference is largely due to differences in background development compared to the Fisher/TX formulation.

Notably, the Sigma/T4 iron oxide formulation did not develop background staining on the label adhesive and produced equal or better-quality marks than the Wet Powder on this surface, despite it being an acrylic-based adhesive (**Figure 10**). Heavy background development using the Sigma/T4 was only observed on the vinyl adhesive, which diverges from the results of previous literature. Spectra produced by FTIR analysis on vinyl and label adhesive surfaces had a very high degree of similarity, suggesting the adhesives had the same chemical composition. Despite this, the Sigma/T4 formulation behaved very differently on each surface indicating that there are some components involved with the detection process

within the adhesives that differ from each other. The difference is likely due to surface morphology and physical characteristics, which has been shown to influence effectiveness of PS formulations [7, 8].

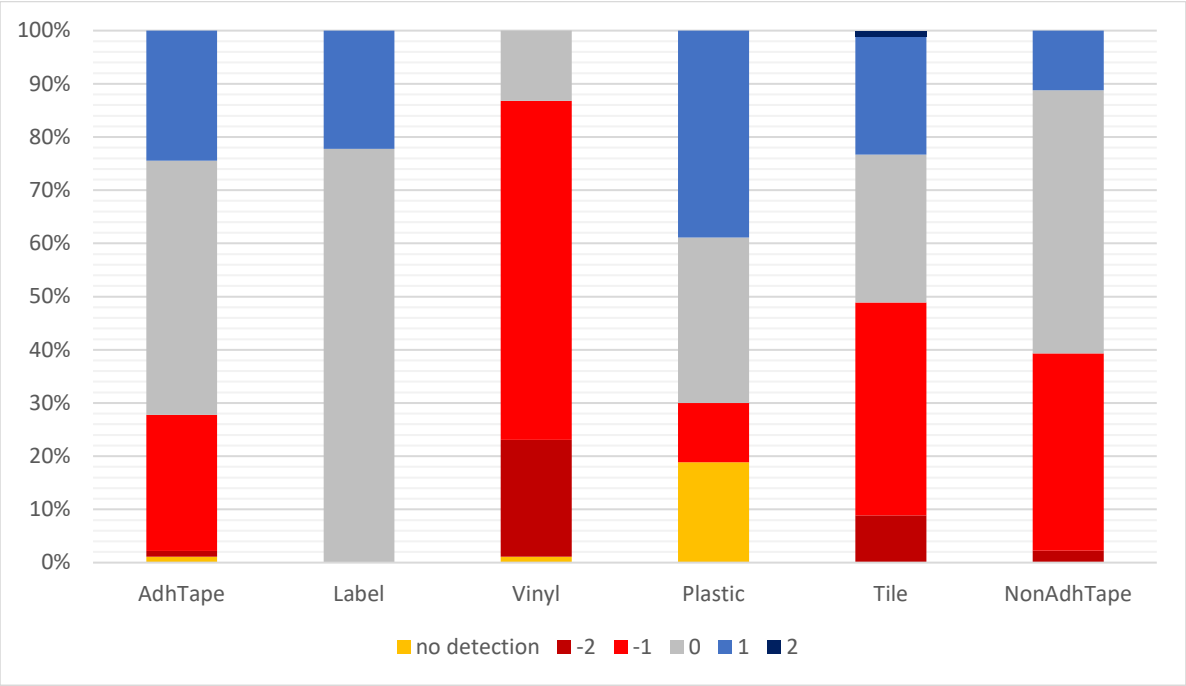

Figure 9 *Comparison of Sigma/T4 and Wet Powder by substrate (AdhTape, Label and Vinyl = adhesive, Plastic, Tile and NonAdhTape = non-adhesive)*

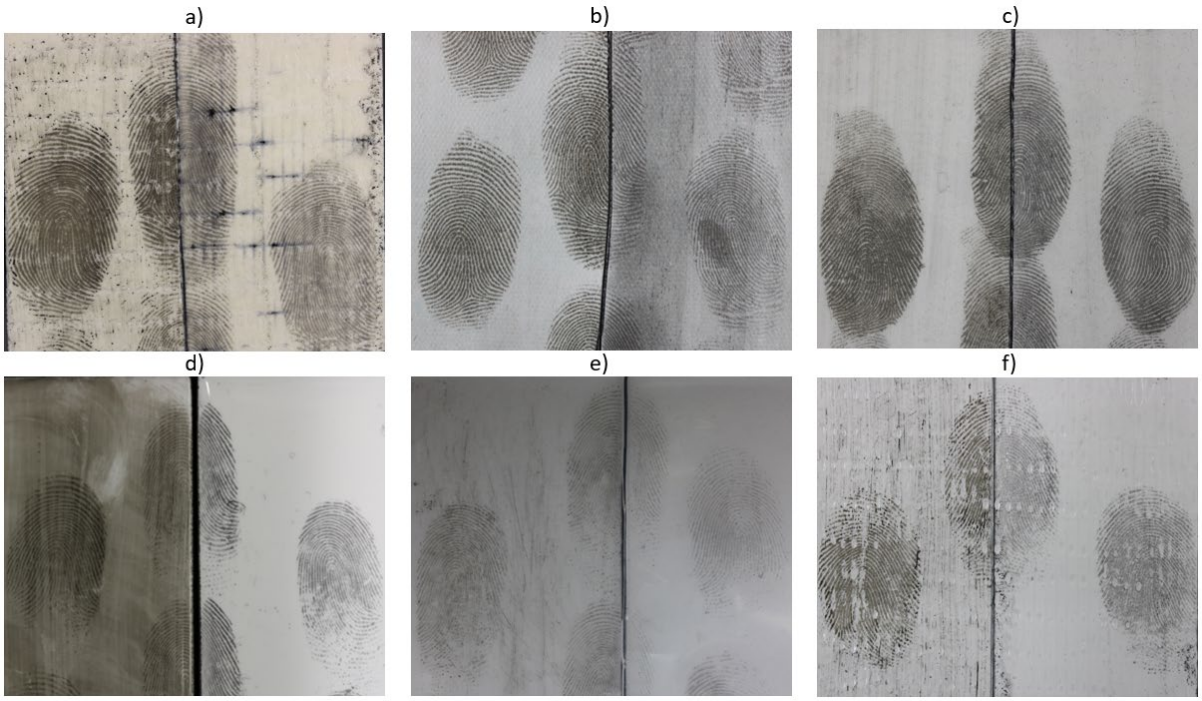

Figure 10 *Representative images of comparison between Fisher/TX (right) and Wet Powder (left) by substrate a) AdhTape b) Vinyl c) Label d) Tile e) Plastic f) NonAdhTape*

For non-porous surfaces, both PS formulations performed equally on tile and the non-adhesive side of tape, however the Sigma/T4 was moderately more effective on plastic. Little research has been done into PS involving iron-oxide nanopowders. In 2018, Downham performed a study comparing iron-oxide PS formulations [7]. The authors used a formulation with the Sigma nanopowder and Tween 20 10% surfactant solution on a small range of non-porous surfaces including ceramic tile, plastic and steel. The authors observed some inter-ridge surface development using this formulation, however also noted that the ridges developed appeared darker than those developed with the Fisher magnetic iron-oxide. This paper showed that the formulation was effective but required further testing to be validated for operational use, which is consistent with the results of this study [7].

A recent paper investigating fingermark detection techniques on compostable plastics by Illston-baggs *et al.* also used an iron-oxide nanopowder PS [24]. In the preliminary stage of this study, the CAST recommended formulation was compared to a Sigma nanopowder PS formulation mixed with 10% Tween 20, and the nanopowder demonstrated superior results. However, as these results were preliminary to the bulk of the study, details such as substrate type, number of donors and age of fingermarks are not stated. This prevents further meaningful comparison and evaluation of the two formulations. The nanopowder subsequently performed poorly compared to other enhancement sequences on the compostable plastics tested. No published work to date has investigated the use of iron oxide nanopowder PS on adhesive surfaces.

3.2.3 *Wetted and aged marks*

Similar trends were observed in both comparisons for wetted and aged marks, indicating both iron oxide formulations were similarly influenced by these variables. Overall, the quality of wetted marks was poorer and 9% more fingermarks were unable to be detected compared to those which had not been wetted. This indicates that PS is still effective on wetted surfaces and is consistent with literature. Wetting fingermarks after deposition had the greatest effect on non-adhesive surfaces. Wetting reduced the deposition of powder on fingermark ridges and subsequently contrast of developed marks on both sides of adhesive tape, tile and plastic. Notably, the heavy background development produced by Wet Powder on tiles was drastically reduced if the samples had been wet (**Figure 11**), across all ages. This is the reason

for the increase in scores rated -1 in both comparisons shown in **Figure 12**, indicating the carbon-based suspension was slightly more effective. The background development produced by iron oxide on adhesive surfaces was not reduced by wetting however. These observations suggest that the wetting process influences the deposition of powder particles, both on fingermark residue and background substrates.

A similar observation with reduction of background development with Wet Powder was seen with aged marks on tile (**Figure 11**). This has not been noted in published literature. On other surfaces, all formulations were able to detect the majority of fingermarks up to one month, and age did not seem have a significant effect on either of the comparisons. Ageing of fingermarks is known to result in general degradation of the fingermark secretions and is dependent on the surface type and ambient conditions [25-27]. As the UC scale used to grade the fingermarks for this comparison does not take into account overall fingermark quality, it is difficult to assess how each formulation was affected by age and wetting outside general visual observations. It is known that environmental factors such as wetting and ageing affects the composition of fingermark residue [26, 28, 29]. It is likely that water-soluble constituents are being affected in these processes which, in turn, is influencing the powder deposition mechanism in this technique.

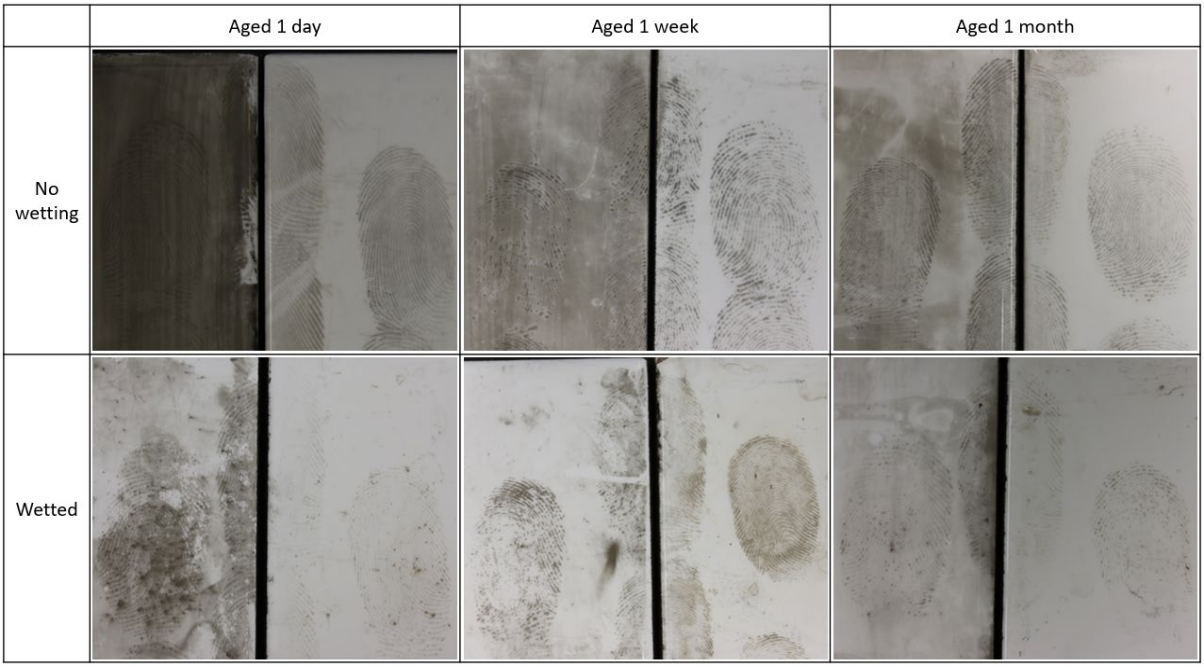

Figure 11 *Comparison of wetted and aged marks developed with Fisher/TX (right) and Wet Powder (left) on tile*

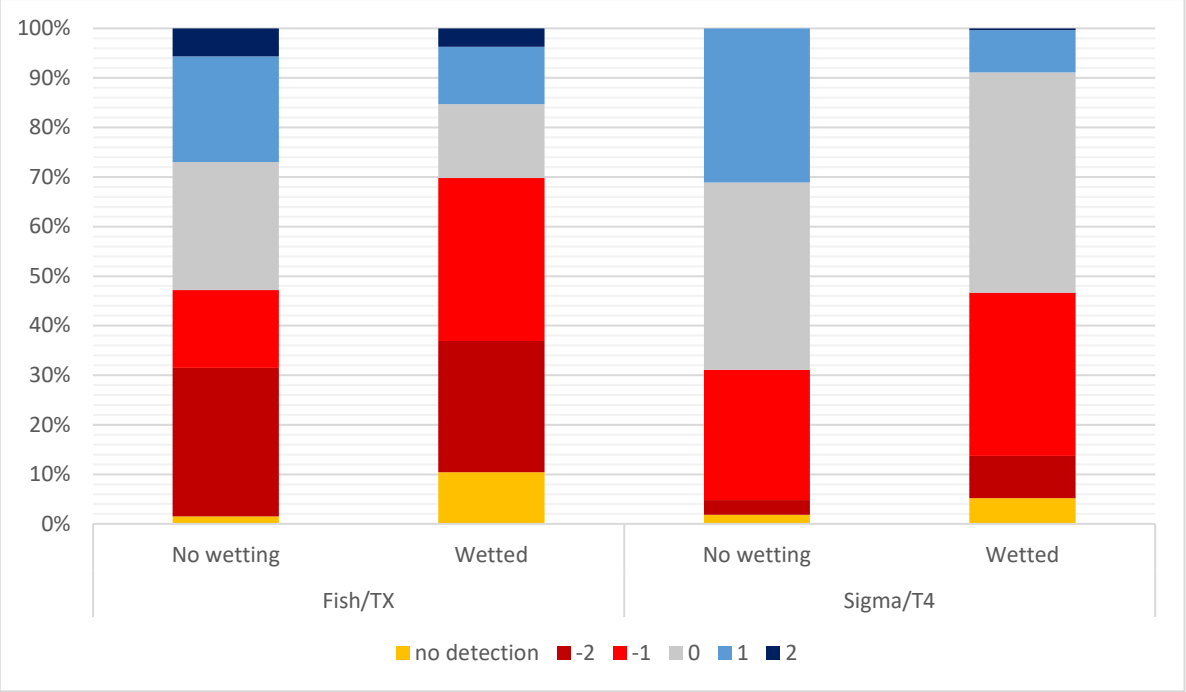

Figure 12 *Effect of wetting surfaces on comparison of two optimised iron oxide PS formulations with Wet Powder*

PS is the recommended fingermark development technique if a non-porous surface is known to have been previously wetted, as many enhancement techniques are unsuccessful on these surfaces [5, 30]. However, previous research into the effect of wetted surfaces on the effectiveness of PS is limited, with the majority of research including wetted items using white PS [30]. Within these studies, no comparisons of previously wet or dried substrates have been conducted.

In a pseudo-operational trial performed in 2009 by CAST, pre-wetted plastic surfaces were briefly investigated [14]. Of the 100 flexible plastic substrates used, 8 were known to have been pre-wetted and PS were used to detect fingermarks on these surfaces. The PS used were iron oxide and titanium dioxide-based for light and dark coloured surfaces respectively. This study demonstrated that PS were the most effective technique on wetted surfaces, however no comparison between the previously wetted or dry surfaces were made. A carbon-based suspension was not investigated in this study. The focus of these studies was on comparing PS formulations against other fingermark enhancement techniques, and it was found that PS performed very effectively. This gap in research makes it difficult to understand why both formulations interact differently with substrates that have been wet.

The results of this study have showed that iron oxide PS formulations are not superior in effectiveness enough on the tested surfaces to replace carbon-based PS in NSW. However, it was a highly effective technique on some non-porous surfaces, notably plastic. Further research comparing the optimised formulations developed in this study to other detection techniques would assist in determining the viability of using the formulations on specific surfaces. The customisability, ease of use and portability of iron oxide PS, as well as its effectiveness on wetted and aged marks makes it a valuable technique that can be further improved to increase the rate and quality of fingermark detection in Australia.

4. Conclusions

The optimisation stage of this investigation showed that the effectiveness of iron oxide PS depends heavily on powder and surfactant type and that the current recommended formulation is highly effective compared to other formulations made with compounds available in Australia. It also has a very broad range in which it can still develop high quality fingermarks and is resilient to changing surfactant concentrations and powder weights. A formulation made with iron oxide nanopowder and Tween 20 is also shown to be effective for fingermark development. Overall, thinner suspensions made with less powder and more dilute surfactants improves the ease of application as well as reducing resources used, which is useful when considering operational implications.

The comparison stage of this study was conducted with the aim to compare the performance of iron oxide and carbon-based PS formulations on a range of surfaces. It was determined that the effectiveness of all formulations depended heavily on substrate, however overall Wet Powder was the more effective and consistent fingermark detection technique on the surfaces tested. All formulations had issues with background development on specific surfaces which greatly influenced their effectiveness. On plastic, both iron oxide formulations outperformed Wet Powder, which is consistent with the CAST recommendation to use iron oxide PS on plastic surfaces in casework. Wetting the fingermarks after deposition showed that all formulations were highly effective on wetted surfaces, and influenced the interaction between PS, fingermark residue and surface especially on non-adhesive surfaces.

The two optimised iron oxide formulations did not perform the same on all substrates. Notably, the formulation containing iron oxide nanopowder prevented heavy background

development on one acrylic-based adhesive which was unexpected based on previous literature. As both formulations consisted of different powders and surfactants, it is not clear which component influenced this difference. The variability in performance of each formulation indicates that one or both of these components not only effects the interaction of the technique with fingermark residue but also with the surface. Further research into the detection mechanism of this technique and its interaction with various surface characteristics is vital to better interpret these results and to consequently aid in optimising future formulations.

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