Optimizing A Sequence of Methods for the Development of Latent Fingerprints on Thermal Paper

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Abstract

Thermal paper has been known to be a tedious substrate in latent fingerprint laboratories. Although it is considered a porous substrate, techniques that are commonly used to develop fingerprints on porous items have shown to be unsuccessful on thermal paper. A major issue is that chemicals used in these processes, as well as the common application of heat, can interact with the components of the paper, activate it, and darken the entire surface. The darkening of the paper makes the visualization of existing latent fingerprints a difficult task. Recently, numerous procedures have been created to successfully develop fingerprints on thermal paper evidence without interacting with the thermal properties. For other porous substrates, a sequence of methods may be followed to ensure that all existing fingerprints have been found. However, since thermal paper requires special techniques, a known sequence does not currently exist and laboratories may only utilize one method. If a latent fingerprint examiner solely uses one method for thermal paper evidence, they may be unaware of fingerprints that were present but failed to develop. They may also be unaware that a combination of these methods may yield better results than one method alone. The goal of this study was to determine if a sequence of current processing techniques (1,2-indanedione with zinc chloride, PDMAC® paper, muriatic acid fuming, application of heat, and ThermaNin®) could be optimized to allow an analyst to say with confidence that all existing fingerprints have been found. Nine sequences were created from the combination of the 5 methods previously mentioned. Each sequence was performed on known fingerprints that were 4 weeks, 3 weeks, 2 weeks, 1 week and 24 hours old. It was found that three out of the five techniques, 1,2-indanedione with zinc chloride, PDMAC® paper, and ThermaNin®, developed fingerprints on both the thermal and non-thermal sides of the paper. It was found that 1,2-indanedione with zinc chloride and PDMAC® paper developed the highest number of fingerprints consistently. In many cases, treatment with PDMAC® paper directly after 1,2-indanedione with zinc chloride seemed to allow visualization of additional prints and enhanced fluorescence. This modified method was then applied to real receipt samples that were treated as mock evidence. In most cases, the same results occurred after treatment with 1,2-indanedione with zinc chloride and PDMAC® paper, but there were some samples where an additional latent print was seen after PDMAC® paper treatment. Lastly, it was studied whether magnetic powder, a common starting point in latent print processing sequences, interferes with other techniques. Fingerprints were developed with either plain black magnetic powder or fluorescent magnetic powder, followed by additional processing by either 1,2-indanedione with zinc chloride, PDMAC® paper or ThermaNin®. The use of magnetic powder was shown to hinder the development abilities of these processes. In conclusion, the use of 1,2-indanedione with zinc chloride and PDMAC® paper allowed the highest number of prints to be visualized. In some cases, combining these two methods allowed previously missed fingerprints to be visualized. They worked best when other techniques were not previously used. These techniques were simple, required little preparation and could be left alone to develop while performing other tasks. The use of either of these two methods alone would be sufficient on thermal paper samples, but using them in sequence will increase the likelihood that all fingerprints present have been found.

Introduction

Thermal paper is a fine paper that is commonly used as a printing medium to print information for fax machines, automated-teller machines, retail receipts, and bus and movie tickets [1]. This type of paper consists of several different layers, each having its own unique application and property while being bonded together to form the sheet of paper [2]. It consists of a glossy (emulsion) printed side on which the desired text or image is printed. The other side of the paper can either be an additional emulsion side or a plain non-printed side [3]. Chemicals incorporated into thermal paper include leuco dyes, developers, sensitizers and stabilizers. The printing process of thermal paper does not use ink. The paper is subjected to heat in specific configurations that turn the paper black, producing the writing or imagery that was programmed to be shown [4].

The most functional layer of thermal paper is the active layer. The active layer is the top layer on which the printed image is created by the application of heat [2]. Unfortunately, this layer is what makes thermal paper so difficult to analyze in a forensic science setting. Thermal paper is considered a porous substrate in regards to latent fingerprint processing. Most often, the processing techniques for porous items involve some sort of heat application. Since heat is what activates the top layer of the thermal paper to print wording and images, applying heat during latent fingerprint processing will cause the emulsion side of the paper to darken in color. Additionally, the polar solvents used in typical porous substrate processing techniques, such as ninhydrin and DFO, can interact with the active layer, which also contributes to the darkening of the paper [5]. This darkening will hinder the contrast needed to distinguish the developed latent

fingerprint from the background. This issue has caused some laboratories to not process thermal paper evidence at all.

Several individual methods have been identified that have proven to be useful in processing latent fingerprints on this difficult substrate. The use of muriatic acid (hydrochloric acid) fuming was researched by Broniek and Knaap, after a forensic science student found that latent fingerprints had developed on receipts in an area where a custodian used the acid for cleaning [6]. Additionally, 1,2-indanedione has been shown to react with the amino acids in fingerprints and give successful results for developing latent fingerprints on thermal paper and other porous items. A study performed by Parasram showed that combining 1,2-indanedione with zinc chloride enhances the fluorescence of the developed prints [5]. Ninhydrin alternatives have also been developed, including ThermaNin® (BVDA International®). ThermaNin® is a ninhydrin hemiketal that is formed by reacting ninhydrin and 3,5,5-trimethyl-1-hexanol. It depends on the presence of water to convert it into ninhydrin and the alcohol. The ninhydrin can then react with the amino acids in the fingerprint and development can occur [5]. Moreover, research done by Armitage and Wakefield showed that a solvent-free method, a low-heat hairdryer, also yielded successful results [1]. A study performed by Scott showed that combining a source of steam with the low-heat hairdryer can enhance fingerprint development [7]. Furthermore, Arrowhead Forensics® developed PDMAC® paper, which contains Para-dimethylaminocinnamaldehyde. One simply places thermal paper evidence between the pieces of PDMAC® paper, and any latent fingerprints will reportedly develop in as little as 30 minutes [8].

The literature shows that numerous methods are available to process fingerprints on thermal paper evidence without blackening the paper. However, it has never been published whether a sequence of these known methods can be used to yield better results than an individual method alone. For other types of items that are processed for latent fingerprints, there is a sequence of methods that an analyst can work through in a particular order that helps ensure that all of the existing latent fingerprints are developed and that they are of the best quality possible. A laboratory may utilize one sole technique for thermal paper samples and therefore may be unaware that the addition of another method could make the results even better.

The first goal of this research was to determine whether a sequence of thermal paper processing techniques (hydrochloric acid, ThermaNin®, 1,2-indanedione with zinc chloride, PDMAC® paper, and a hairdryer with steam) could be optimized to ensure that all possible latent fingerprints will be developed and at a high enough quality to make comparisons possible. Additional goals of this phase were to determine if certain processing techniques inhibit each other, if these sequences work on both the thermal and non-thermal sides of the paper, and how the age of the deposited fingerprints affects the results. The next phase of the study was to determine how well the top sequence or sequences developed fingerprints on real receipts. Third, a comparison study was performed to compare the quality of development between different processes. Lastly, it was researched whether the application of magnetic powder, a common starting point in development sequences, would inhibit thermal paper processes.

Phase 1- Sequence Optimization

Materials and Methodologies

The following sequences were created for the optimization study:

Table 1: A summary of the 9 sequences created for the Phase 1 optimization study

Sequences	
1	Oven → 1,2-indanedione/Zinc Chloride→ThermaNin®
2	Hydrochloric Acid → 1,2-indanedione/ Zinc Chloride → ThermaNin®
3	Hydrochloric Acid → PDMAC® → 1,2-indanedione/ Zinc Chloride
4	Hydrochloric Acid → 1,2-indanedione/ Zinc Chloride → PDMAC®
5	1,2-indanedione/ Zinc Chloride → Hydrochloric Acid → PDMAC®
6	1,2-indanedione/ Zinc Chloride → PDMAC® → Hydrochloric Acid
7	Oven → Hydrochloric Acid
8	Oven → PDMAC®
9	Oven →ThermaNin®

The first part of the study was broken into five time periods: 4 weeks, 3 weeks, 2 weeks, 1 week and 24 hours. For each of the 9 methods within a time period, 10 pieces of unused, clean thermal paper (Gorilla Supply®) were cut into receipt-sized samples. Five pieces were reserved for processing the thermal side of the paper, while the other five were for processing the non-thermal side of the paper. Five fingerprints were deposited onto each paper sample. This was done by the volunteer rubbing their fingers on their forehead for approximately three seconds to increase the oil residues, followed by placing the fingers onto the paper with moderate pressure for about three seconds. Volunteers switched hands

approximately half way through each sample group. The thermal side fingerprints and non-thermal side fingerprints for each time period were deposited a few hours apart to allow the fingers of the volunteer to regain oil secretions. The samples for each time period group were created separately with one group created per week, starting with 4 weeks. The samples were then placed in separate boxes and stored in a shaded area within the laboratory. The deposited fingerprints were left undisturbed for the intended amount of time (4 weeks, 3 weeks, 2 weeks, 1 week or 24 hours).

A working solution of 1,2-indanedione was prepared by dissolving 1 gram of 1,2-indanedione (Reddy Chemtech®, Inc.) in 450 ml ethyl acetate (Fisher Scientific®), 50 ml of glacial acetic acid (Spectrum Chemical® Mfg. Corp.), and 639 ml of HFE-7100 (Sirchie®). A zinc chloride solution was made by dissolving 8 grams of zinc chloride (Tokyo Chemical Industry®) in 200 ml of ethanol. One ml of zinc chloride solution was added to the 1,2-indanedione solution to make a combined working solution. Samples were sprayed with solution in the fume hood, allowed to air dry, and observed under a 505 nanometer light source with an orange barrier filter.

A working solution of ThermaNin® was prepared by dissolving 2 grams of ThermaNin® crystals (BVDA International®) in 2.5 ml isopropyl alcohol (Fisher Chemicals®), 7.5 ml ethyl acetate (Fisher Scientific), and 490 ml HFE-7100 (Sirchie®). Samples were dipped into the solution and were allowed to develop for at least 48 hours in the dark.

Development with hydrochloric acid was performed by placing 25 ml of acid in a small beaker and placing that beaker into a large jar. About 3 or 4 samples at a time were placed inside the jar and taped to the rim, allowing the samples to hang suspended along

the sides of the jar. The lid was then closed on the jar, and the samples were exposed to the acid fumes until no further development occurred.

Development with PDMAC® paper (Arrowhead Forensics®) was performed by placing 5 samples at a time between 2 pieces of PDMAC® paper. The paper "sandwich" was then placed in the accompanying protective sleeve, and compressed for at least 30 minutes, which was the minimum recommended time by the manufacturer. Development was observed under a 505 nanometer light source with an orange barrier filter.

It was intended to utilize a combination of a low-heat hair-dryer with a steamer as a development technique. However, while performing quality control samples, burning of the paper occurred at a high rate. As an experiment, fingerprints were left on a piece of thermal paper and placed in a laboratory oven at 60°C for 3-5 minutes, and the results were of better quality then the hairdryer method. Therefore, the method was switched to using the oven at 60°C. Samples were placed on the oven rack at 30 second intervals. After 30 seconds, the samples were checked for development and burning. Samples that were beginning to burn were removed. If burning was starting to occur slightly, the samples were checked at shorter intervals. A sample was removed if further heating would cause significant burning.

After each step in a method, the number of fingerprints that could be visualized out of the possible 25 was recorded. A fingerprint was counted no matter what the quality. Representative photographs from each sequence were taken. Methods were evaluated by how many latent fingerprints could be visualized after each step, whether the sequence worked on both thermal and non-thermal side samples, whether a method in a sequence

inhibited the results of another, and whether results tended to improve or worsen as a sequence progressed.

Phase 1 Sequence Optimization Results

Table 2: A summary of the amount of latent prints out of 25 that were able to be developed by each step in sequence 1

Time	Step 1: Oven (# Prints) Thermal	Step 2: 1,2-indanedione/ ZnCl (# Prints) Thermal	Step 3: ThermaNin® (# Prints) Thermal	Total # Prints	Step 1: Oven (# Prints) Non-thermal	Step 2: 1,2-indanedione/ ZnCl (# Prints) Non-thermal	Step 3: ThermaNin® (# Prints) Non-thermal	Total # Prints
4 Weeks	18	4	5	18	0	24	23	24
3 Weeks	0	0	0	0	0	16	2	16
2 Weeks	11	0	8	11	0	25	18	25
1 Week	25	0	15	25	0	25	8	25
24 Hours	25	25	25	25	0	25	25	25

Table 3: A summary of the amount of latent prints out of 25 that were able to be developed by each step in sequence 2

Time	Step 1: HCl (# Prints) Thermal	Step 2: 1,2-indanedione/ ZnCl (# Prints) Thermal	Step 3: ThermaNin® (# Prints) Thermal	Total # Prints	Step 1: HCl (# Prints) Non-thermal	Step 2: 1,2-indanedione/ ZnCl (# Prints) Non-thermal	Step 3: ThermaNin® (# Prints) Non-thermal	Total # Prints
4 Weeks	25	10	7	25	0	25	24	25
3 Weeks	11	0	0	11	0	23	5	23
2 Weeks	25	0	15	25	0	25	16	25
1 Week	25	25	20	25	0	25	6	25
24 Hours	20	25	24	25	0	25	25	25

Table 4: A summary of the amount of latent prints out of 25 that were able to be developed by each step in sequence 3

Time	Step 1: HCl (# Prints) Thermal	Step 2: PDMAC® (# Prints) Thermal	Step 3: 1,2-indanedione/ ZnCl (# Prints) Thermal	Total # Prints	Step 1: HCl (# Prints) Non-thermal	Step 2: PDMAC® (# Prints) Non-thermal	Step 3: 1,2-indanedione/ ZnCl (# Prints) Non-thermal	Total # Prints
4 Weeks	25	0	20	25	0	0	25	25
3 Weeks	20	0	3	20	0	0	16	16
2 Weeks	25	0	25	25	0	0	25	25
1 Week	25	0	0	25	0	0	25	25
24 Hours	25	0	17	25	0	0	25	25

Table 5: A summary of the amount of latent prints out of 25 that were able to be developed by each step in sequence 4

Time	Step 1: HCl (# Prints) Thermal	Step 2: 1,2-indanedione/ ZnCl (# Prints) Thermal	Step 3: PDMAC® (# Prints) Thermal	Total # Prints	Step 1: HCl (# Prints) Non-thermal	Step 2: 1,2-indanedione/ ZnCl (# Prints) Non-thermal	Step 3: PDMAC® (# Prints) Non-thermal	Total # Prints
4 Weeks	25	25	25	25	0	25	25	25
3 Weeks	20	3	3	20	0	20	20	20
2 Weeks	25	1	1	25	0	25	25	25
1 Week	25	25	25	25	0	25	25	25
24 Hours	24	25	25	25	0	25	25	25

Table 6: A summary of the amount of latent prints out of 25 that were able to be developed by each step in sequence 5

Time	Step 1: 1,2-indanedione/ ZnCl (# Prints) Thermal	Step 2: HCl (# Prints) Thermal	Step 3: PDMAC® (# Prints) Thermal	Total # Prints	Step 1: 1,2-indanedione/ ZnCl (# Prints) Non-thermal	Step 2: HCl (# Prints) Non-thermal	Step 3: PDMAC® (# Prints) Non-thermal	Total # Prints
4 Weeks	25	4	25	25	25	0	25	25
3 Weeks	12	0	12	12	21	0	21	21
2 Weeks	25	25	25	25	25	0	25	25
1 Week	3	0	3	3	25	0	25	25
24 Hours	25	0	25	25	25	0	25	25

Table 7: A summary of the amount of latent prints out of 25 that were able to be developed by each step in sequence 6

Time	Step 1: 1,2-indanedione/ ZnCl (# Prints) Thermal	Step 2: PDMAC® (# Prints) Thermal	Step 3: HCl (# Prints) Thermal	Total # Prints	Step 1: 1,2-indanedione/ ZnCl (# Prints) Non-thermal	Step 2: PDMAC® (# Prints) Non-thermal	Step 3: HCl (# Prints) Non-thermal	Total # Prints
4 Weeks	25	25	0	25	25	25	0	25
3 Weeks	20	25	2	25	25	25	0	25
2 Weeks	13	22	0	22	25	25	0	25
1 Week	25	25	10	25	25	25	0	25
24 Hours	24	24	0	24	25	25	0	25

Table 8: A summary of the amount of latent prints out of 25 that were able to be developed by each step in sequence 7

Time	Step 1: Oven (# Prints) Thermal	Step 2: HCl (# Prints) Thermal	Total # Prints	Step 1: Oven (# Prints) Non-thermal	Step 2: HCl (# Prints) Non-thermal	Total # Prints
4 Weeks	20	20	20	0	0	0
3 Weeks	7	7	7	0	0	0
2 Weeks	11	13	13	0	0	0
1 Week	14	14	14	0	0	0
24 Hours	24	24	24	0	0	0

Table 9: A summary of the amount of latent prints out of 25 that were able to be developed by each step in sequence 8

Time	Step 1: Oven (# Prints) Thermal	Step 2: PDMAC® (# Prints) Thermal	Total # Prints	Step 1: Oven (# Prints) Non-thermal	Step 2: PDMAC® (# Prints) Non-thermal	Total # Prints
4 Weeks	8	0	8	0	0	0
3 Weeks	7	0	7	0	0	0
2 Weeks	14	0	14	0	0	0
1 Week	8	0	8	0	0	0
24 Hours	22	0	22	0	0	0

Table 10: A summary of the amount of latent prints out of 25 that were able to be developed by each step in sequence 9

Time	Step 1: Oven (# Prints) Thermal	Step 2: ThermaNin® (# Prints) Thermal	Total # Prints	Step 1: Oven (# Prints) Non-thermal	Step 2: ThermaNin® (# Prints) Non-thermal	Total # Prints
4 Weeks	13	12	13	0	0	0
3 Weeks	7	10	10	0	9	9
2 Weeks	15	15	15	0	2	2
1 Week	3	13	13	0	10	10
24 Hours	24	15	24	0	3	3

Phase 1 Sequence Evaluation

The results from Phase 1 revealed several important discoveries. First, non-thermal side fingerprints were not able to be developed with hydrochloric acid or the oven. Therefore, ThermaNin®, PDMAC® paper and 1,2-indanedione/ zinc chloride were the methods that were able to develop prints on both sides. Additionally, it was shown from sequence 3 that PDMAC® paper was unable to develop prints after hydrochloric acid processing (Table 4), as well as after oven processing from sequence 8 (Table 9). This occurred on non-thermal side samples as well, even though the two methods did not develop any prints previously. Although sequences 4 and 5 showed that prints could be visualized from PDMAC® paper processing after hydrochloric acid had been previously utilized, it was unclear whether PDMAC® development had truly occurred. This was due to the fact that in both sequences, 1,2-indanedione/ zinc chloride had also been previously applied, and PDMAC® paper fluoresced under the same wavelength as this technique.

A general trend found from these sequences was that the number of prints that could be seen did not seem to improve throughout a method, but rather remained constant or worsened. For example, the results from sequence 1 showed that for thermal samples, oven processing was able to develop a high number of prints for the majority of the samples, but this number tended to decrease after 1,2-indanedione/ zinc chloride processing. The number mainly increased again after the last ThermaNin® step (Table 2). Moreover, there did not seem to be a trend regarding the age of the print and how well a method could develop it. In some cases, a sequence was able to develop older prints better than fresher ones, which made the results somewhat inconsistent. For instance, in sequence 5, 1,2-indanedione/ zinc chloride was able to develop all 25 prints on 4 week-

old samples, but only 12 on 3 week-old samples (Table 6). This issue could have been due to variations in the deposition of the fingerprints since each age group was deposited at a different time.

Comparing individual processes, each process was able to develop prints on thermal side samples, with the number varying depending on the age of the sample and where it was placed in that particular sequence. Difficult processes were the oven and ThermaNin®. For the oven, burning was a concern. Even though prints of the same age were processed together, samples developed at very different rates. Some samples were completely discolored after the first 30 seconds in the oven, while others remained in the oven for several minutes without burning or full development. It was therefore required to constantly check the samples to see which ones needed to be removed (either due to satisfactory development or burning) or processed for more time. The black fingerprint against the white background allowed great contrast, but burning often occurred at a faster rate than print development. As can be seen in Figure 1, the grid pattern of the laboratory oven shelves often became burned into the paper as well.

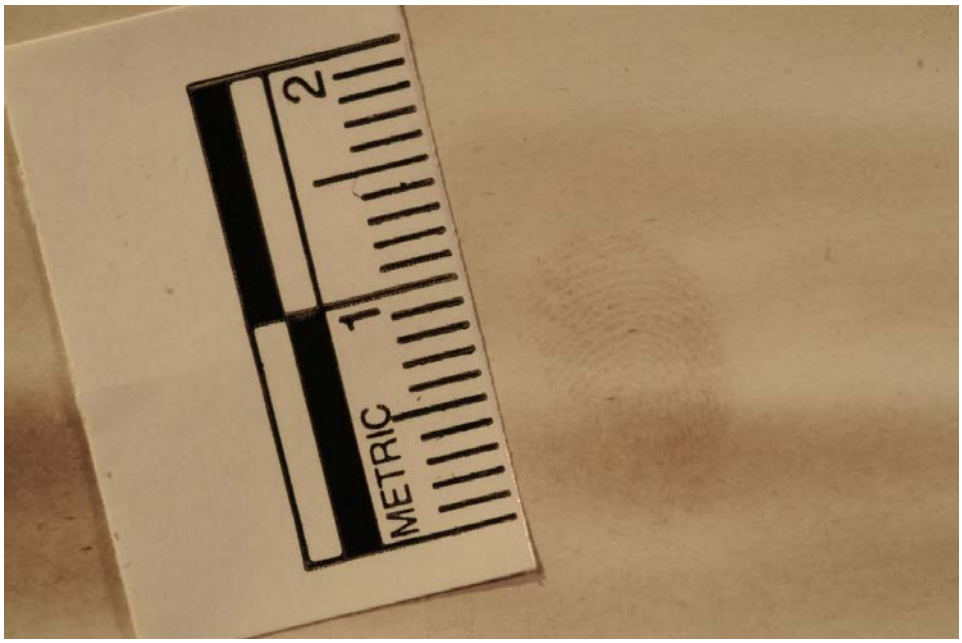

Figure 1: A latent print developed by the oven method on 1-week old thermal side sample

For ThermaNin®, the crystals did not dissolve well in solution, and thus required constant heating and stirring before use. The solution became increasingly difficult to work with each day after initially preparing it. The samples at times got residue on them from dipping them into the solution. Development also took several days. It was difficult to see development on thermal samples, especially for sequences where 1,2-indanedione/ zinc chloride had been previously applied because it caused the thermal side to discolor and darkened the background (Figure 2). Development was more successful on the non-thermal side (Figure 3).

Figure 2: An overall photograph of 24-hour fingerprints that were processed with the oven, 1,2-indanedione/zinc chloride and lastly ThermaNin®

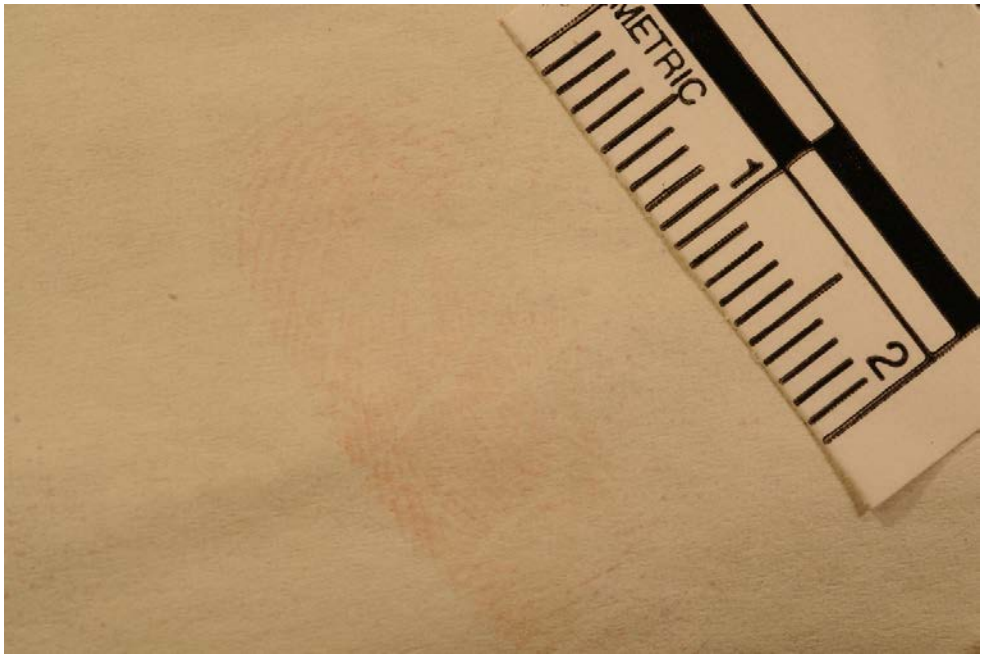

Figure 3: Latent fingerprint developed with ThermaNin® on 2-week-old non-thermal sample

Processes that were able to consistently develop a high amount of fingerprints were hydrochloric acid, 1,2-indanedione/ zinc chloride, and PDMAC® paper. Hydrochloric acid was able to develop at least 20 out of 25 fingerprints on thermal side samples 14 out of 15 times for sequences where it was the first step (sequences 2, 3 and 4). For sequences where hydrochloric acid was not the initial process, it was not as successful at developing prints. For these sequences, the previous processes (1,2-indanedione/ zinc chloride and the oven) tended to darken the paper background, which provided little contrast for the resulting green-colored print development. Although this technique was able to develop a high amount of prints, the resulting prints were often faint, making ridge detail difficult to see (Figures 4A and 4B). The developed prints also faded quickly.

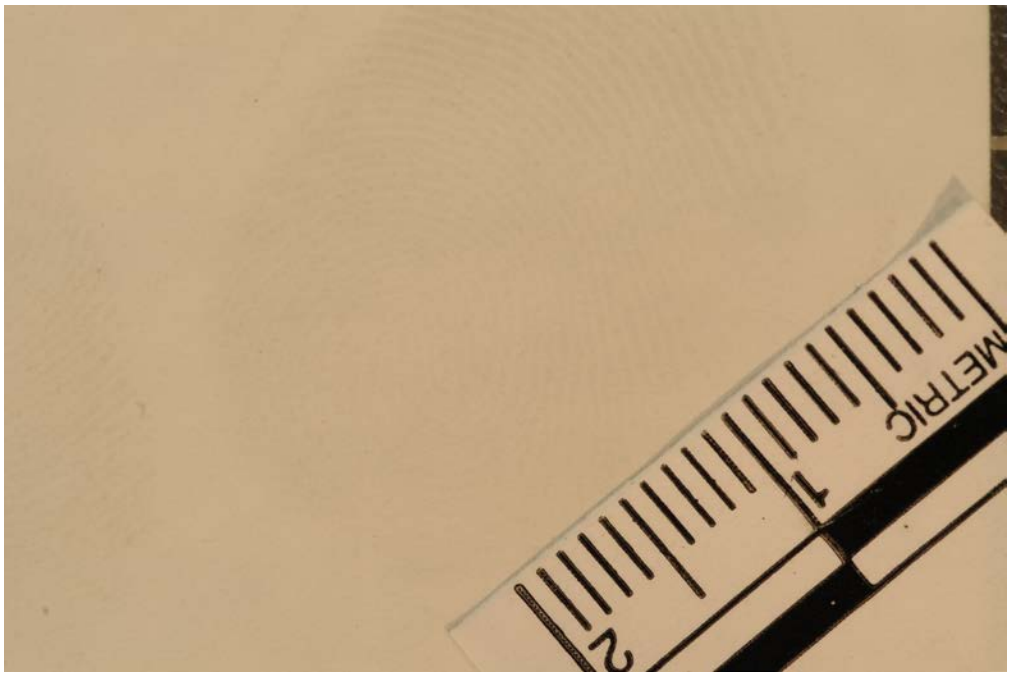

Figure 4A: Latent fingerprint developed with hydrochloric acid on 3-week-old thermal side sample

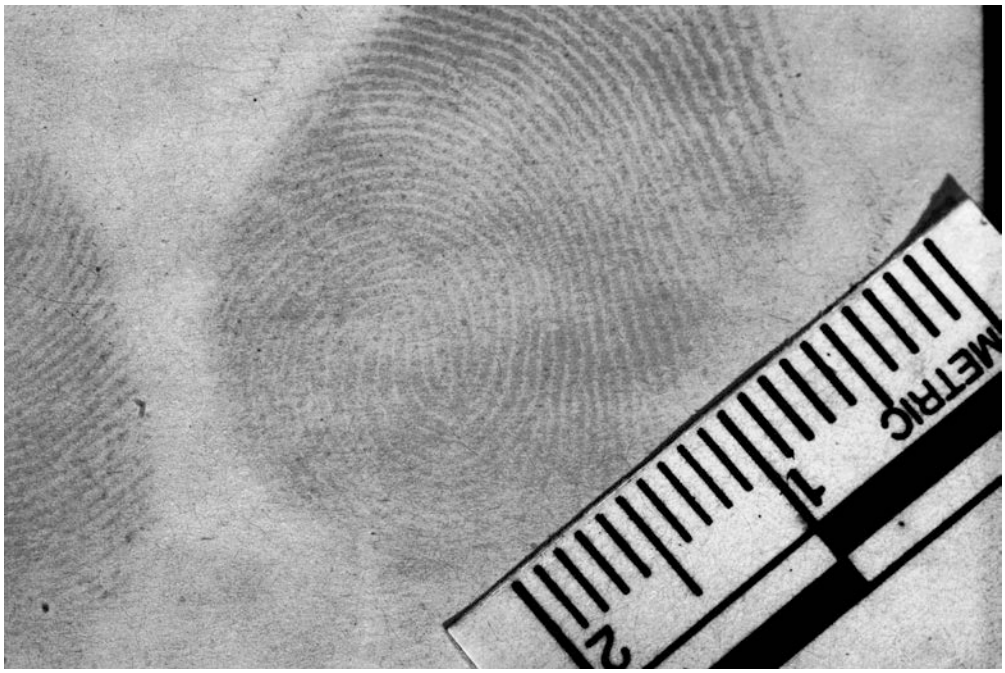

Figure 4B: Photoshop enhancement of developed fingerprint from Figure 4A

1,2-indanedione/ zinc chloride and PDMAC® paper were fluorescent techniques, which made the fingerprints easier to visualize. These two methods worked on both thermal and non-thermal side prints.

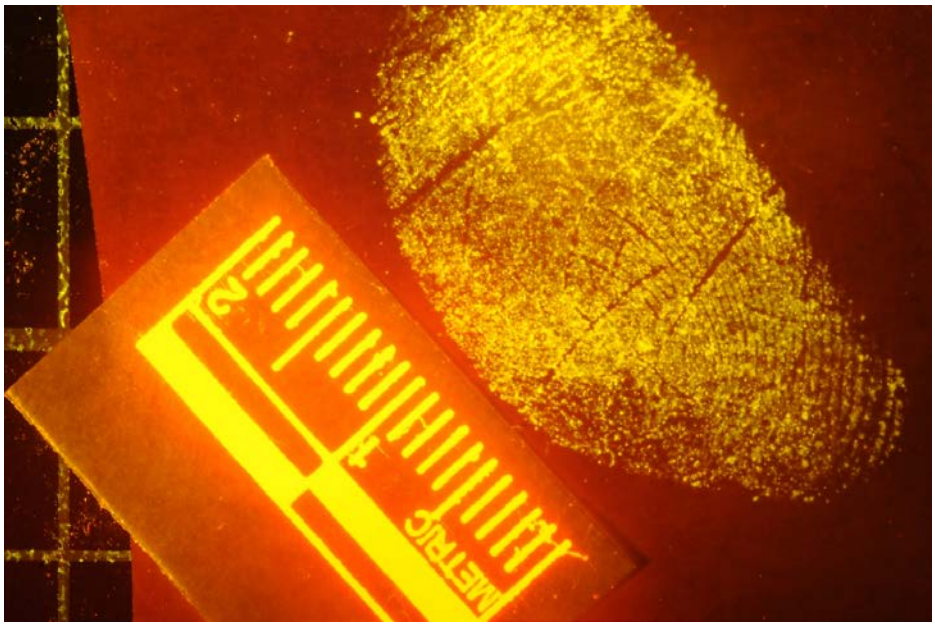

Figure 5: A close-up photograph of a 1-week-old thermal side latent print developed with 1,2-indanedione/ zinc chloride in sequence 4

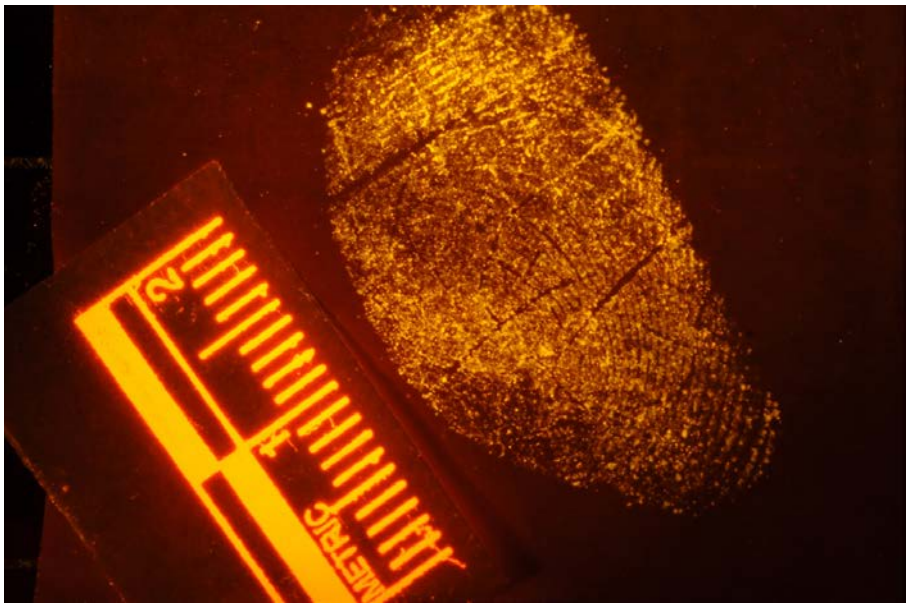

Figure 6: A close-up photograph of a 1-week-old thermal side latent print developed with PDMAC® paper in sequence 4

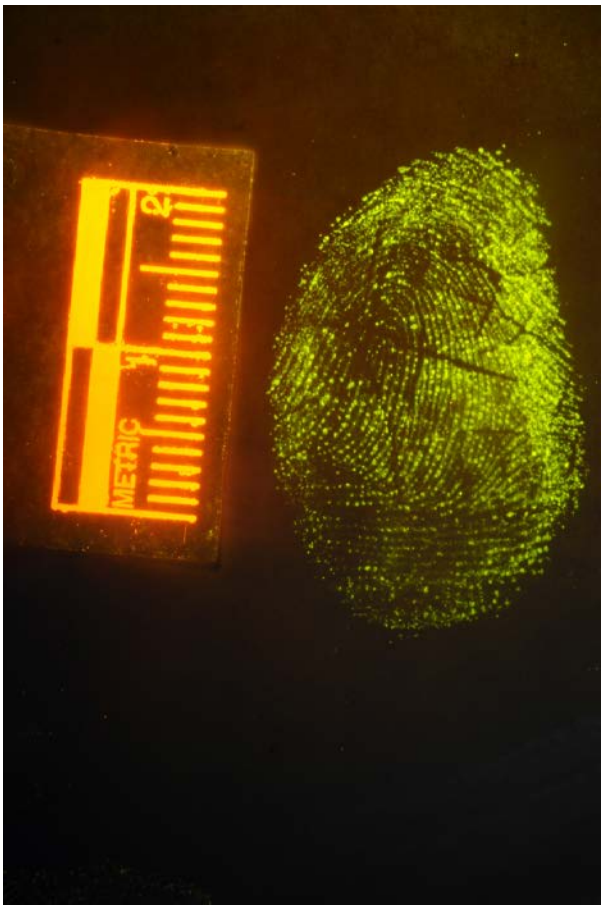

Figure 7: A close-up photograph of a 2-week-old non-thermal side latent print developed with 1,2-indanedione/ zinc chloride in sequence 5

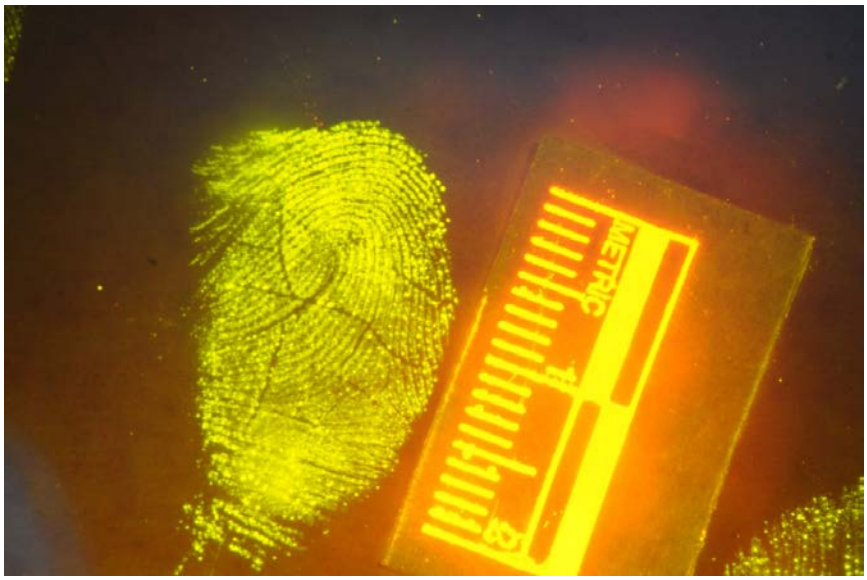

Figure 8: A close-up photograph of a 2-week-old non-thermal side latent print developed with PDMAC® paper in sequence 5

These processes tended to give the best results when they were the first steps in a sequence, versus being performed after a previous method was used. Sequences 5 and 6 had 1,2-indanedione/ zinc chloride as the first step. In sequence 5, 1,2-indanedione/ zinc chloride was able to develop at least 20 prints 60% of the time for thermal side prints and 100% of the time for non-thermal side prints (Table 6). The results from sequence 6 revealed that the technique developed at least 20 latent prints 80% of the time for thermal side prints. It was able to develop all possible fingerprints on non-thermal side samples (Table 7). The amount of latent prints visualized after PDMAC® paper processing did not change from 1,2-indanedione/ zinc chloride processing for sequence 5. Since hydrochloric acid processing was the middle step in this sequence, inhibition may have still occurred and the prints seen may have been from 1,2-indanedione/ zinc chloride fluorescence. However, sequence 6 showed that PDMAC® paper developed additional fingerprints after 1,2-indanedione/ zinc chloride processing on 3-week-old and 2-week-old thermal side prints. It was also evident that PDMAC® paper processing seemed to

enhance fluorescence in some prints after 1,2-indanedione/ zinc chloride processing (Figures 9, 10, 11 and 12).

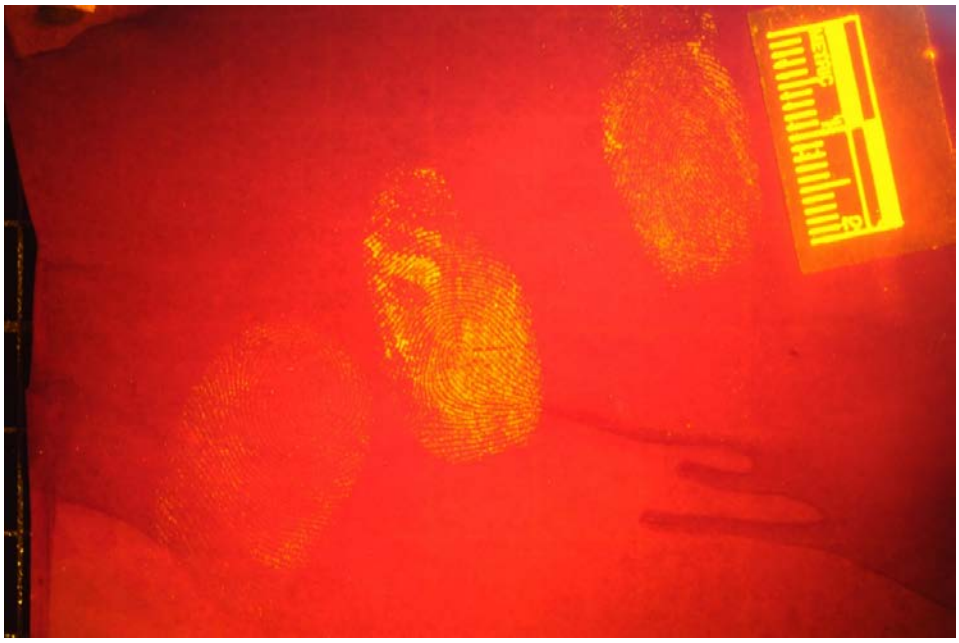

Figure 9: 1,2-indanedione/ zinc chloride development of 3-week old thermal side fingerprints

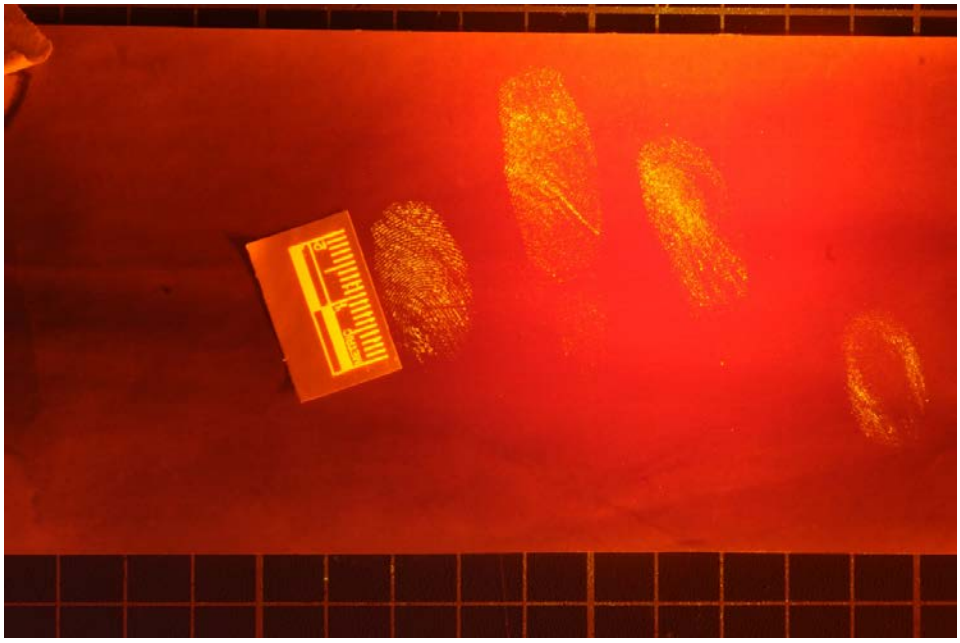

Figure 10: PDMAC® paper development of 3-week old thermal side fingerprints

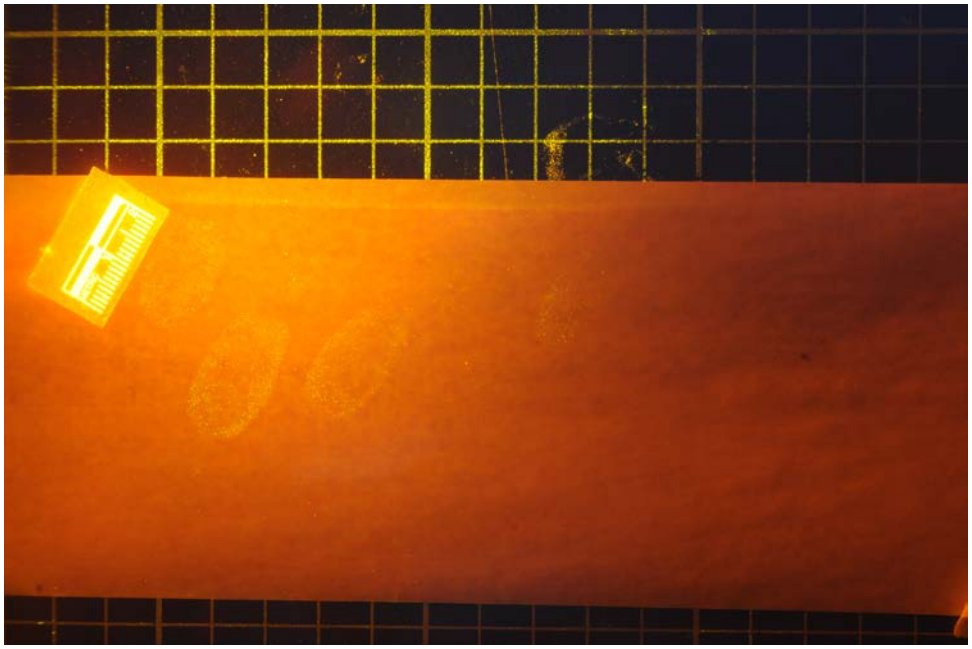

Figure 11: 1,2-indanedione/ zinc chloride development of 3-week old non-thermal side fingerprints

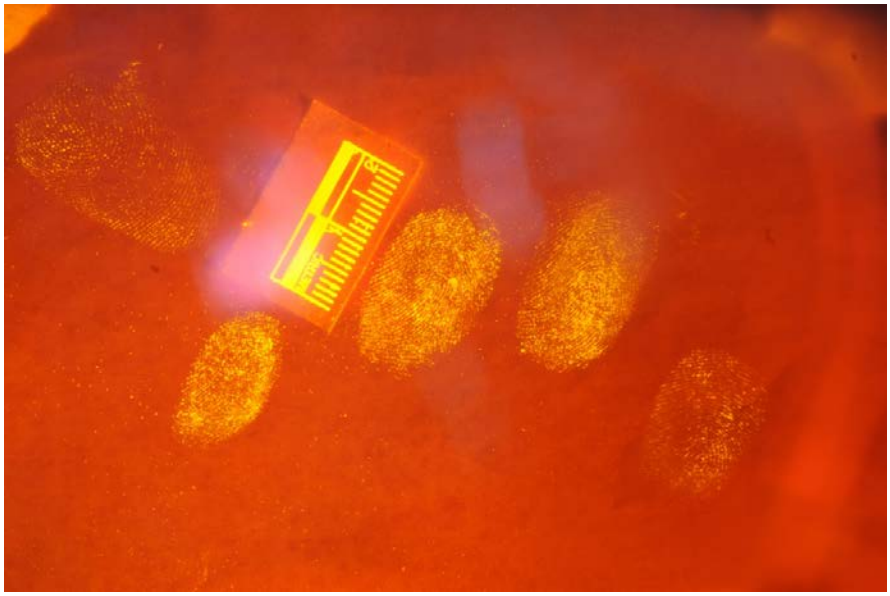

Figure 12: PDMAC® development of 3-week old non-thermal side fingerprints

If hydrochloric acid fuming was eliminated from sequence 6, it was the strongest sequence out of the 9 tested. It was able to consistently develop a high amount of latent prints on both sides of the paper, and results either remained constant or improved after each step. Therefore, the modified sequence of 1,2-indanedione/ zinc chloride followed by PDMAC® paper was taken into the next phase of the project.

Phase 2-Real Receipt Processing

Materials and Methods

Volunteers donated used receipts over a two-month period. These receipts were treated as mock evidence, so the amount of fingerprints they contained were unknown and no additional prints were deposited. 20 samples were chosen at random. Both the front and back of each receipt were processed. Sequence 6 (1,2-indanedione/ zinc chloride

followed by PDMAC® paper) was performed on each receipt, with the number of latent prints that developed recorded after each step.

Phase 2 Results

Table 11: A summary of the amount of latent prints that could be visualized on real receipts after each step in modified Sequence 6

Receipt	# Prints 1,2-Indanedione/ ZnCl Front	# Prints PDMAC® Front	# Prints 1,2-Indanedione/ ZnCl Back	# Prints PDMAC® Back
1	1	1	4	4
2	2	2	5	5
3	0	0	4	5
4	0	2	7	7
5	1	1	2	2
6	0	0	3	4
7	2	2	1	1
8	0	0	2	2
9	2	2	4	4
10	0	0	5	5
11	0	0	5	5
12	0	0	1	1
13	3	3	13	13
14	3	3	11	11
15	0	0	3	3
16	0	0	1	1
17	0	0	1	1
18	5	5	4	4
19	0	0	0	0
20	0	0	0	0

Phase 2 Real Receipt Processing Evaluation

The results from the “mock evidence” processing showed that 1,2-indanedione/ zinc chloride and PDMAC® paper generally developed the same number of fingerprints. In the cases of samples 3, 4 and 6, treatment with PDMAC® paper allowed additional prints to be seen. The fingerprints seen were generally of good fluorescence quality. Since it was unknown how many latent prints these receipts contained, it was difficult to determine how well sequence 6 worked on the samples. The main conclusion that could be drawn from this phase was that Sequence 6 was able to develop latent prints on both sides of the receipts in several cases. Only two samples out of 20 resulted in no development on either side. This situation is not uncommon in evidence processing.

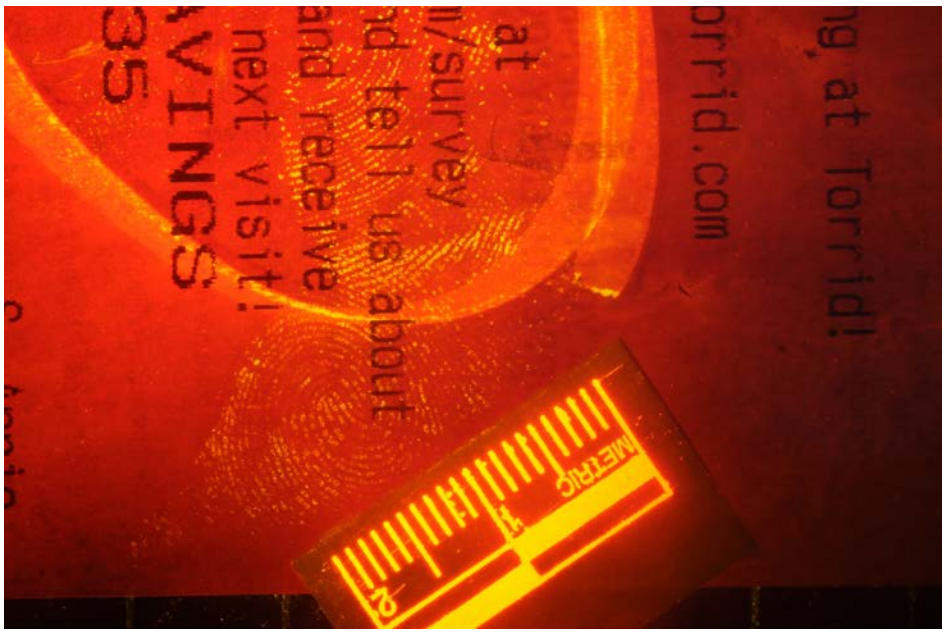

Figure 13: Latent print development that occurred after 1,2-indanedione/ zinc chloride processing on the thermal side of a real receipt

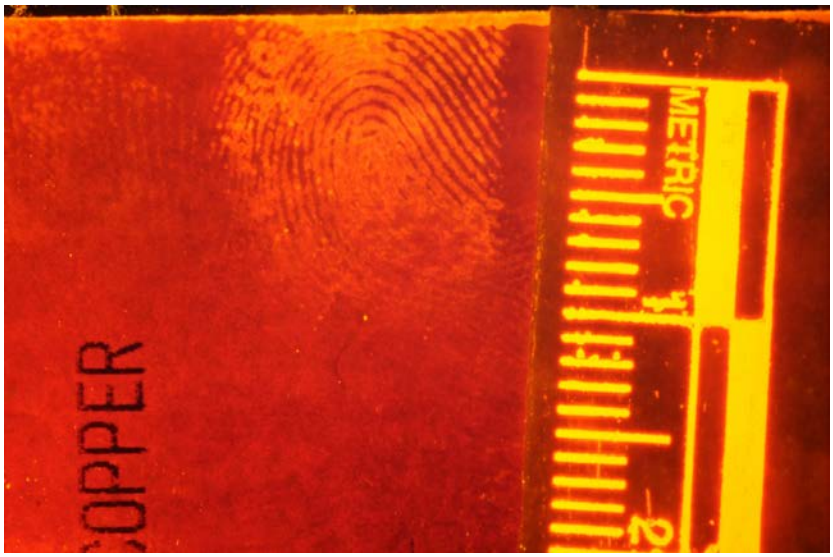

Figure 14: Latent print development that occurred after PDMAC® paper processing on the thermal side of a real receipt

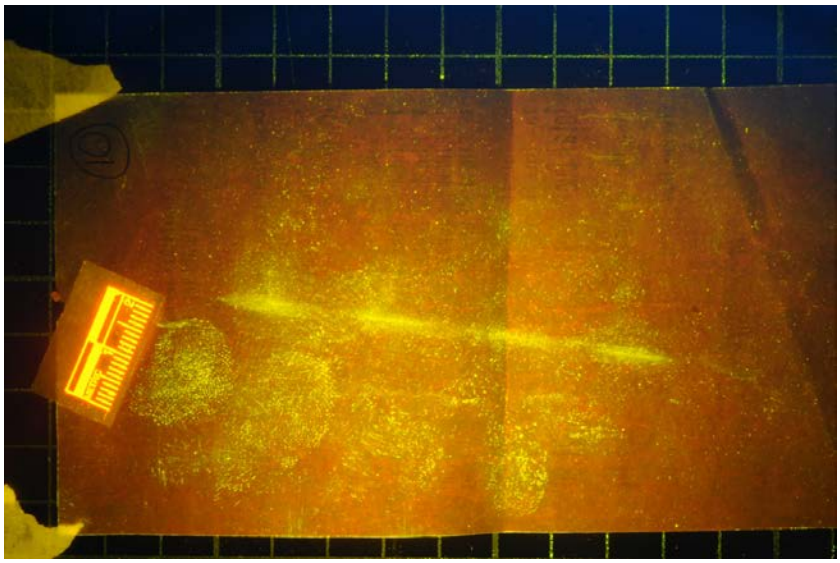

Figure 15: Latent print development that occurred after 1,2-indanedione/ zinc chloride processing on the non-thermal side of a real receipt

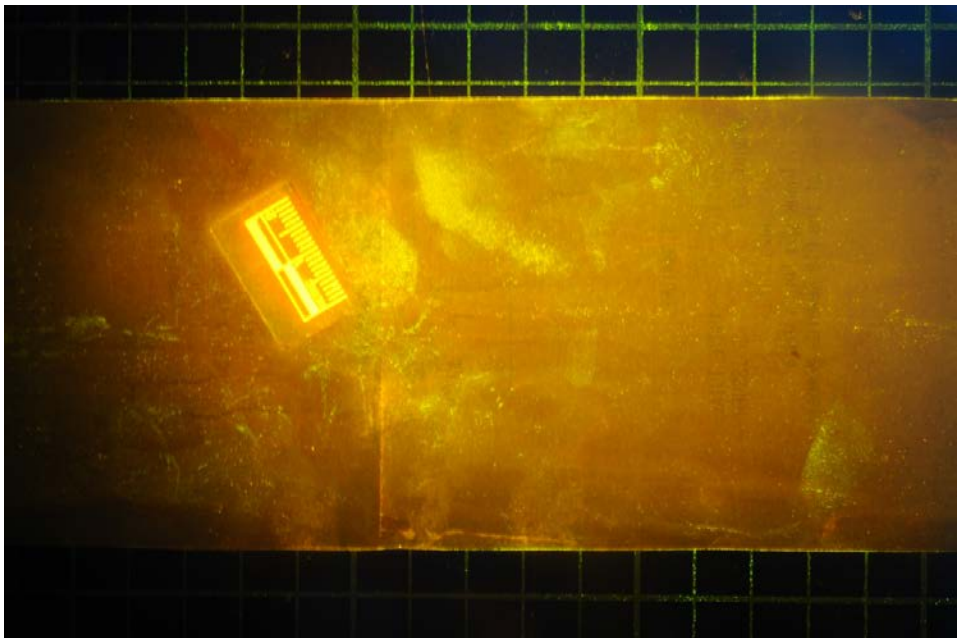

Figure 16: Latent print development that occurred after PDMAC® paper processing on the non-thermal side of a real receipt

Phase 3-Comparison Study

Materials and Methods

The purpose of this study was to compare the quality of fingerprint development between 1,2-indanedione/ zinc chloride, PDMAC® paper, and ThermaNin®. For each comparison pair (1,2-indanedione/ zinc chloride vs. PDMAC®, 1,2-indanedione/ zinc chloride vs. ThermaNin®, and PDMAC® vs. ThermaNin®), 10 separate fingerprints were deposited on clean thermal paper. 5 fingerprints were deposited on thermal side samples while the other 5 prints were deposited on non-thermal side samples. Fingerprints were allowed to sit for 24 hours. After 24 hours, each fingerprint was cut approximately in half. Each fingerprint half was then processed using one of the two methods of its assigned comparison pair. Whole fingerprints were then put back together and visualized. Each half was ranked on a quality scale: A score of “0” was given if no development could be

seen, a score of “1” was given if development was faded or partial, a score of “2” was given if development was of good quality, and a score of “3” was given if development was of great quality. Representative photographs were taken of each comparison.

Phase 3 Comparison Study Results

Table 12: A summary of the scores received for fingerprints in the 1,2-indanedione/zinc chloride and PDMAC® comparison group

Print (Thermal)	1,2-indanedione/ Zinc Chloride Score	PDMAC® Score	Print (Non-thermal)	1,2-indanedione/ Zinc Chloride Score	PDMAC® Score
1	1	1	1	2	2
2	1	1	2	3	3
3	1	2	3	3	2
4	2	3	4	3	2
5	2	3	5	3	2

Table 13: A summary of the scores received for fingerprints in the 1,2-indanedione/zinc chloride and ThermaNin® comparison group

Print (Thermal)	1,2-indanedione/ Zinc Chloride Score	ThermaNin® Score	Print (Non-thermal)	1,2-indanedione/ Zinc Chloride Score	ThermaNin® Score
1	1	1	1	2	2
2	1	1	2	2	2
3	1	1	3	2	2
4	1	1	4	3	2
5	1	1	5	2	2

Table 14: A summary of the scores received for fingerprints in the PDMAC® and ThermaNin® comparison group

Print (Thermal)	PDMAC® Score	ThermaNin® Score	Print (Non-thermal)	PDMAC® Score	ThermaNin® Score
1	1	1	1	2	2
2	1	1	2	2	2
3	1	1	3	3	2
4	1	1	4	2	3
5	1	2	5	3	3

Phase 3 Comparison Study Evaluation

The results tended to vary depending on the specific fingerprint. For example, Table 12 showed that the 5 thermal side fingerprints developed in the 1,2-indanedione/ zinc chloride and PDMAC® paper group ranged from a score of 1 to 3. Additionally, in 3 out of 5 fingerprints, PDMAC® paper received a higher rating than 1,2-indanedione/ zinc chloride. As shown in Figure 17, the half processed with PDMAC® paper had brighter fluorescence and the ridges were clearer. However, the results for non-thermal side prints did not follow this trend. 1,2-indanedione/ zinc chloride scored higher than PDMAC® for 3 out of 5 prints. The fluorescence of 1,2-indanedione/zinc chloride was brighter than that of PDMAC® paper. This suggested that PDMAC® paper worked better for thermal side prints, while 1,2-indanedione/ zinc chloride worked better for non-thermal side prints.

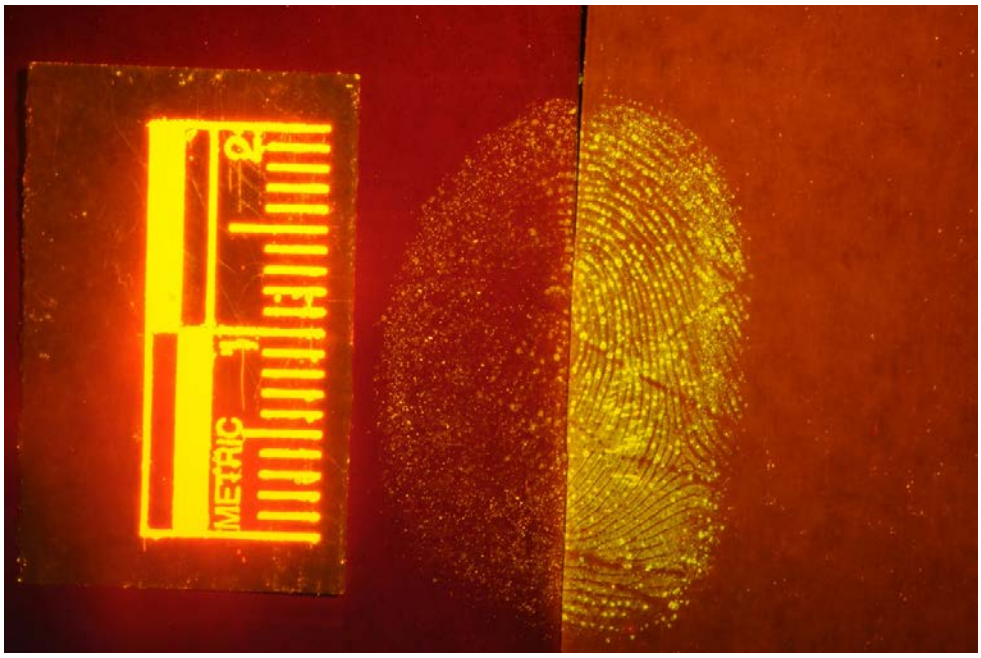

Figure 17: A thermal side latent fingerprint where the left half was processed with 1,2-indanedione/ zinc chloride and the right half was processed with PDMAC® paper

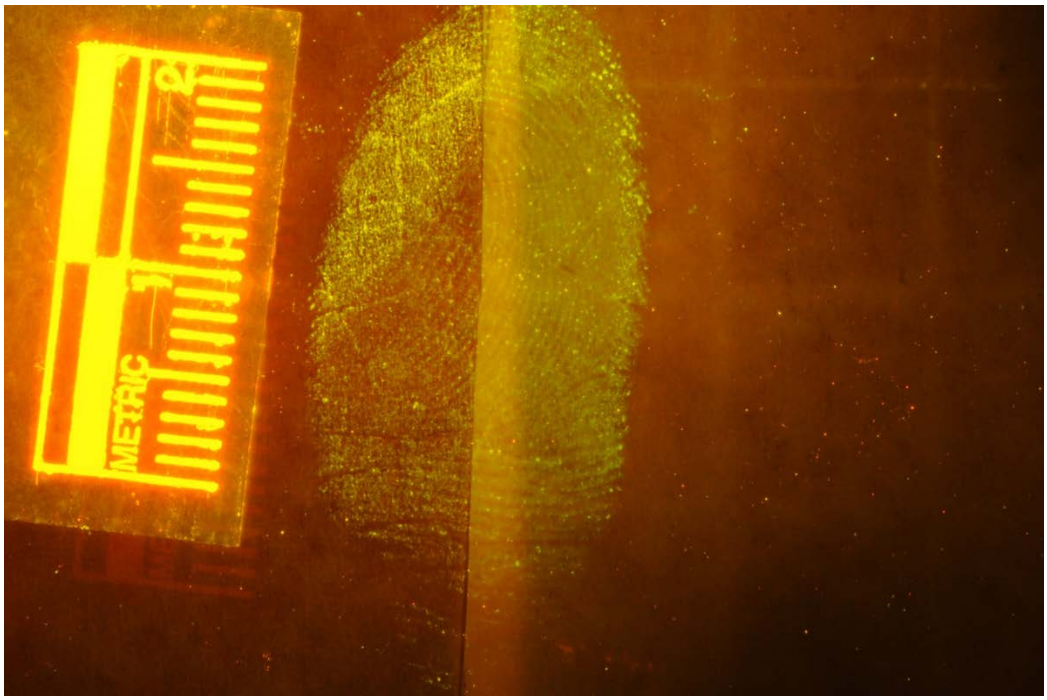

Figure 18: A non-thermal side latent fingerprint where the left half was processed with 1,2-indanedione/ zinc chloride and the right half was processed with PDMAC® paper

Comparing 1,2-indanedione/ zinc chloride and ThermaNin®, results were poor across the board for thermal side samples, as every print half received a score of 1. Development failed to occur for these prints, as evident in Figure 19. The edge of the 1,2-indanedione/ zinc chloride half was fluorescent, but no ridges were visible within the print except for a few small sections. The ThermaNin® half seemed to just be a solid pink marking instead of having ridges. This could have been due to a deposition issue. The quality of print for non-thermal side samples improved, with scores of 2 or 3 for each print half. ThermaNin® development for this set of prints were a bit fainter, as shown in Figure 20. The ridges were slightly difficult to make out on the 1,2-indanedione/ zinc chloride half due to buildup, but the fluorescence overall made the print easier to visualize.

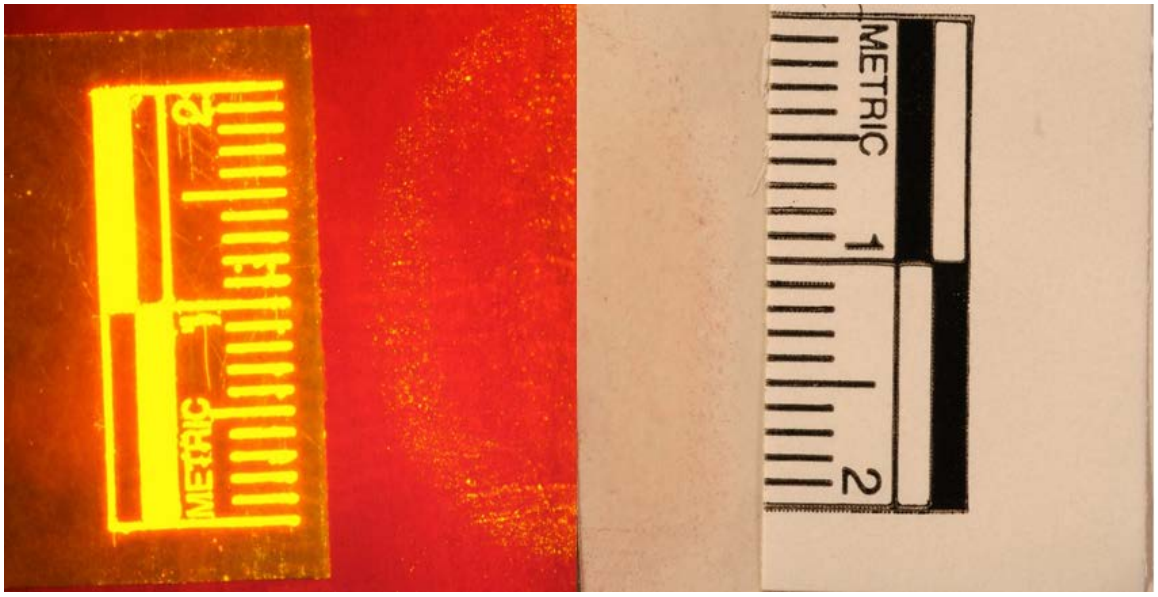

Figure 19: A thermal side latent fingerprint where the left side was processed with 1,2-indanedione/ zinc chloride and the right side was processed with ThermaNin®

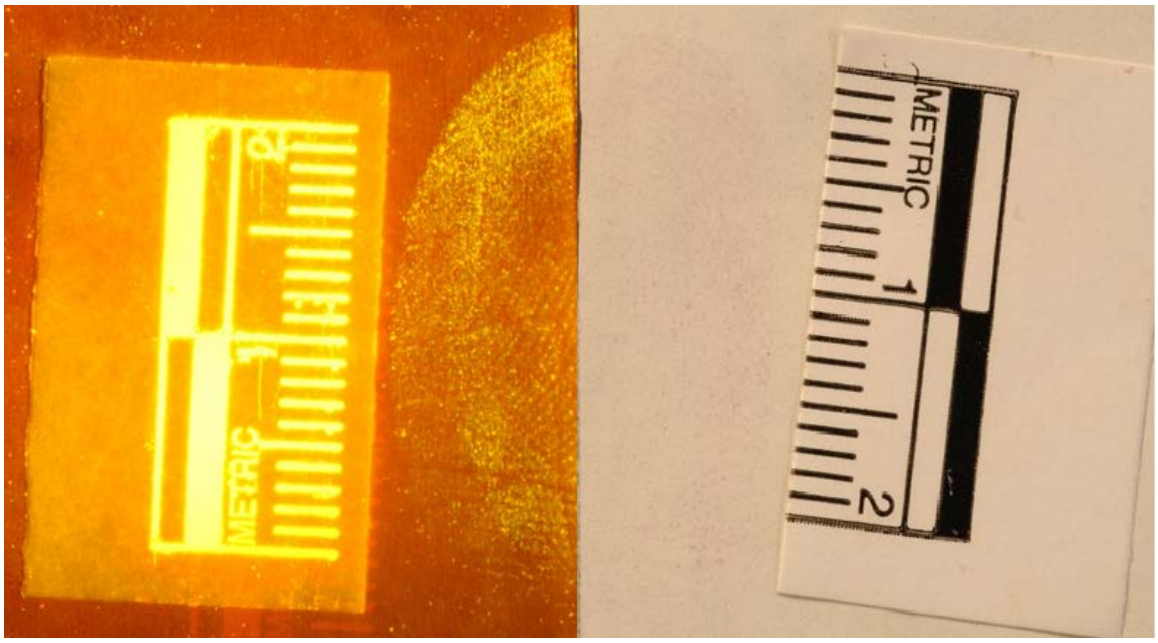

Figure 20: A non-thermal side latent fingerprint where the left side was processed with 1,2-indanedione/ zinc chloride and the right side was processed with ThermaNin®

Similar to the results discussed above, the prints in the PDMAC® paper and ThermaNin® comparison group received a majority of poor scores for thermal side samples. Again, the non-thermal side prints yielded better results, with each print half receiving a score of at least 2. In one case, the PDMAC® half was scored higher than the ThermaNin® half, and in another case the opposite occurred. For the 3 remaining prints, the scores were equal. As shown in Figure 21, the half processed with PDMAC® paper had nice fluorescence, but some of the ridges did not fully develop. The ThermaNin® half had a dark pink development which gave nice contrast against the white background.

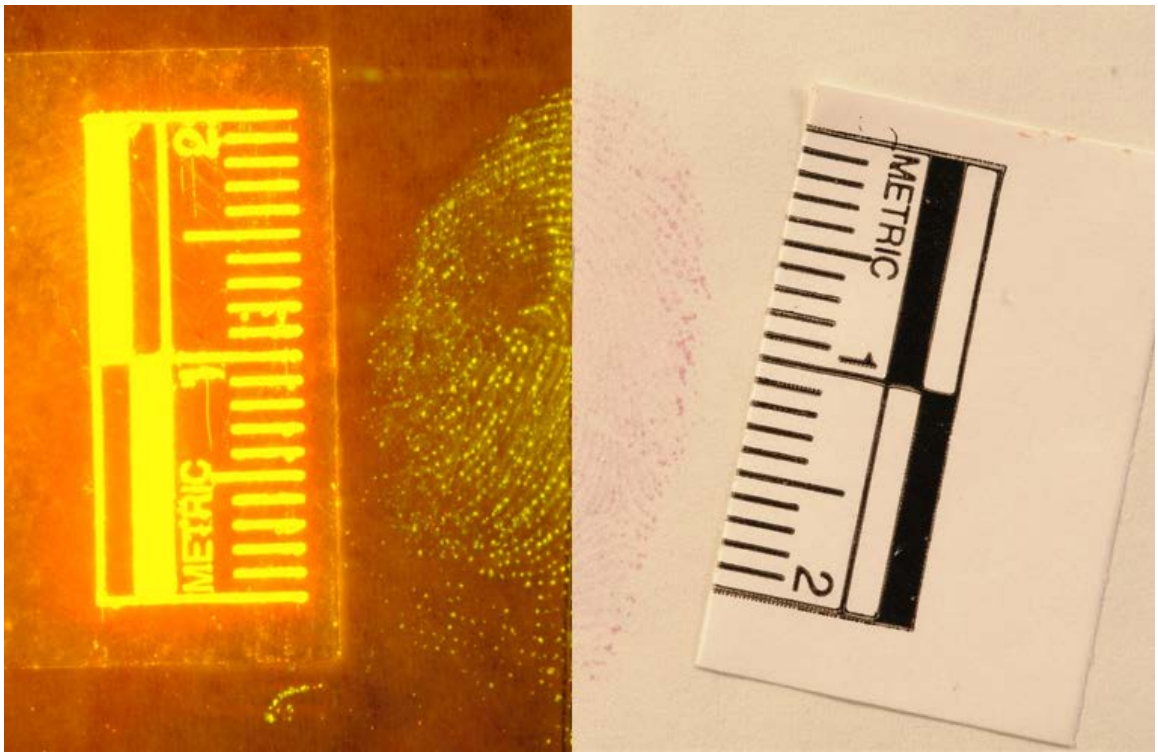

Figure 21: A non-thermal side latent fingerprint where the left side was processed with PDMAC® paper and the right side was processed with ThermaNin®

As can be seen, the results from the comparison study were a bit inconsistent, with processes producing sufficient results for some fingerprints and not others. A possible explanation for this could be poor deposition in some of the fingerprints, leading to poor ridge development. The one major conclusion that could be drawn from this phase was that these three processes gave better results on the non-thermal side across the board.

Phase 4- Magnetic Powder Study

Materials and Methods

The purpose of this study was to determine whether the use of magnetic powder on thermal paper samples inhibited the abilities of 1,2-indanedione/ zinc chloride, PDMAC® and ThermaNin® to develop the latent fingerprints. In this experiment, regular black magnetic powder and fluorescent magnetic powder (Sirchie®) were used. For each type of magnetic powder, 6 sets of 5 fingerprints were deposited (half were deposited on the thermal side and half were deposited on the non-thermal side). The deposited fingerprints were left undisturbed for 1 week. Following 1 week, each sample was processed with either black or fluorescent magnetic powder, and then either ThermaNin®,1,2-indanedione/ zinc chloride, or PDMAC® paper. The number of fingerprints seen were recorded after each step, and were counted even if poor quality.

Phase 4 Magnetic Powder Results

Table 15: A summary of the amount of latent fingerprints that were developed after using black magnetic powder, 1,2-indanedione/ zinc chloride, PDMAC® paper and ThermaNin®

Group 1 (T)	Black Powder	5 (Markings)	1,2-indanedione/ zinc chloride	0	PDMAC®	2 (Ridge Detail)
Group 2 (T)	Black Powder	5 (Markings)	PDMAC®	0		
Group 3 (T)	Black Powder	5 (Markings)	ThermaNin®	0		
Group 1 (NT)	Black Powder	4 (Markings)	1,2-indanedione/ zinc chloride	2 (Markings)	PDMAC®	2 (Markings)
Group 2 (NT)	Black Powder	4 (Markings)	PDMAC®	0		
Group 3 (NT)	Black Powder	4 (Markings)	ThermaNin®	0		

Table 16: A summary of the amount of latent fingerprints that were developed after using fluorescent magnetic powder, 1,2-indanedione/ zinc chloride, PDMAC® paper and ThermaNin®

Group 1 (T)	Fluorescent Powder	5 (Markings)	1,2-indanedione/ zinc chloride	0	PDMAC®	0
Group 2 (T)	Fluorescent Powder	5 (Markings)	PDMAC®	0		
Group 3 (T)	Fluorescent Powder	5 (Markings)	ThermaNin®	0		
Group 1 (NT)	Fluorescent Powder	5 (Markings)	1,2-Indanedione / zinc chloride	0	PDMAC®	0
Group 2 (NT)	Fluorescent Powder	4 (Markings)	PDMAC®	0		
Group 3 (NT)	Fluorescent Powder	5 (Markings)	ThermaNin®	0		

Phase 4 Magnetic Powder Evaluation

Due to the age of the fingerprints, only dark markings, or smudges, developed with the black magnetic powder (Figure 22).

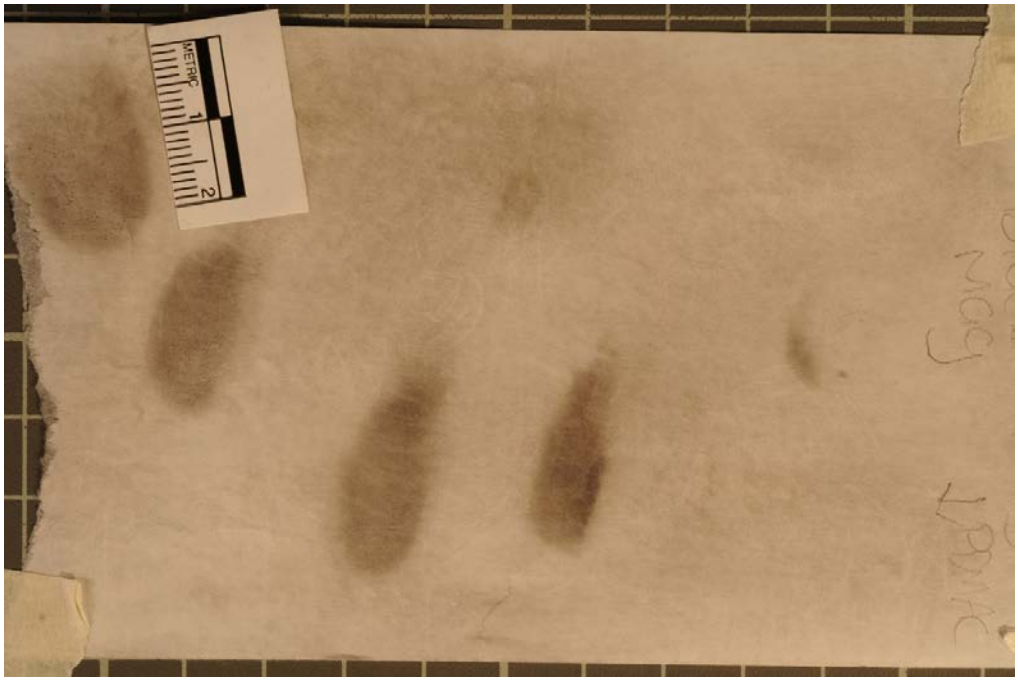

Figure 22: An example of the fingerprint smudges that occurred after processing thermal side prints with black magnetic powder

In 2 out of 30 cases (7%), PDMAC® paper and 1,2-indanedione/ zinc chloride processing showed fluorescent development over the black magnetic powder development (Figure 23).

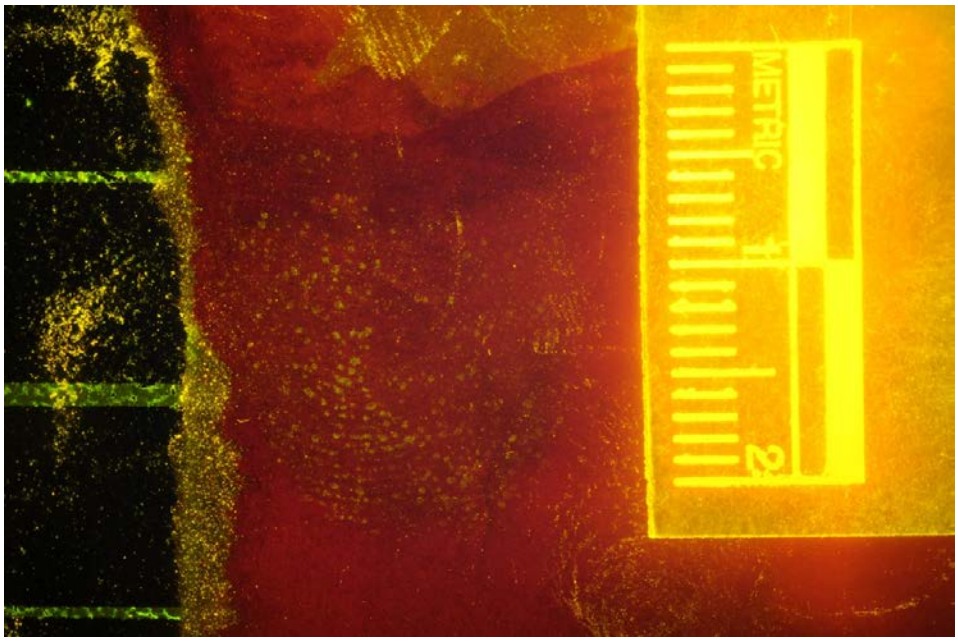

Figure 23: Partial ridge detail of a thermal side print that developed after processing with 1,2-indanedione/ zinc chloride followed by PDMAC® paper. The sample was previously processed with black magnetic powder.

Additionally, one sample showed purple coloration from ThermaNin® processing, but it occurred on only a portion of two markings (Figure 24).

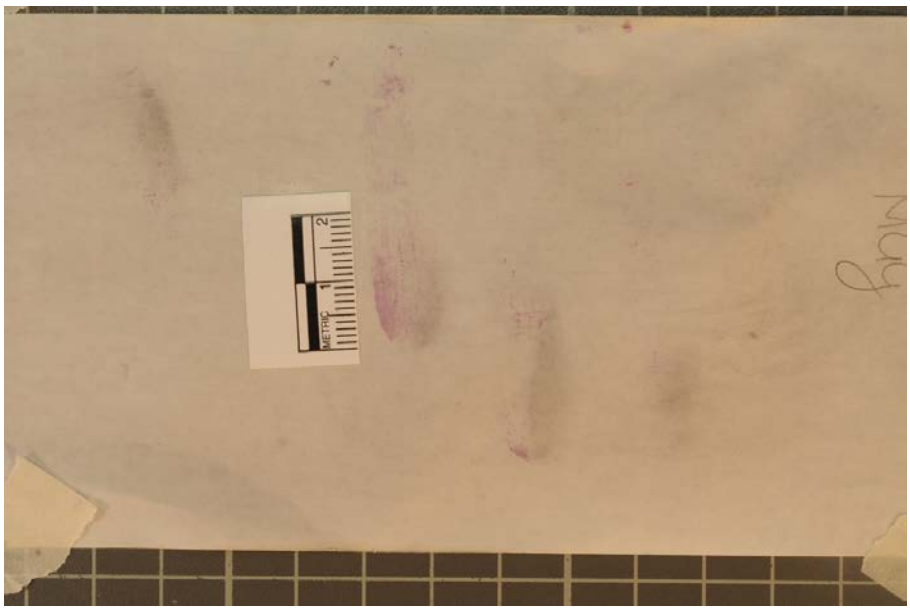

Figure 24: The results of non-thermal side latent prints that were processed by black magnetic powder followed by ThermaNin®

The fluorescent magnetic powder fluoresced at a different wavelength than 1,2-indanedione/ zinc chloride and PDMAC paper®, as can be seen in Figures 25 and 26. As shown in Figures 26, little contrast between the background and print smudges occurred after visualizing the sample under 1,2-indanedione/ zinc chloride's specific wavelength.

Figure 25: Thermal side sample after processing with fluorescent magnetic powder

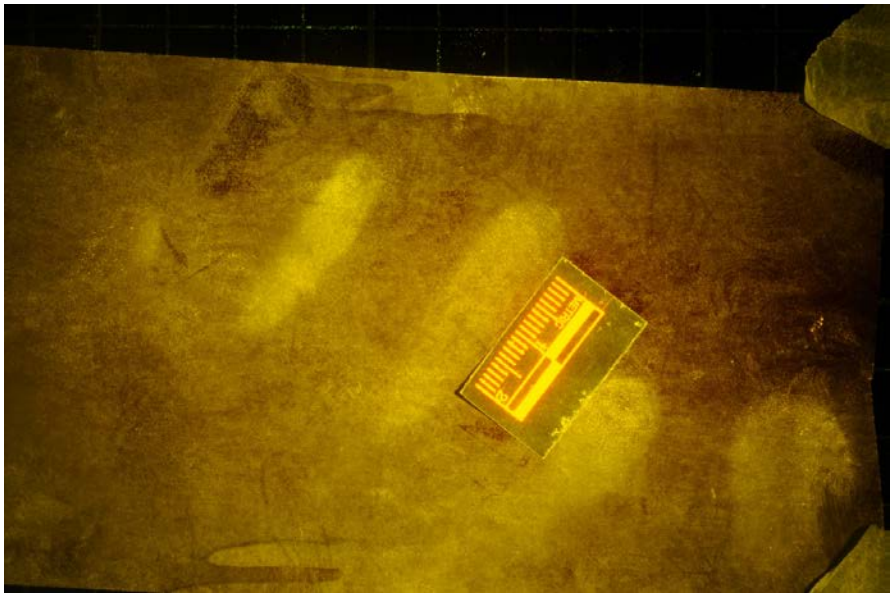

Figure 26: Thermal side sample after processing with fluorescent magnetic powder followed by 1,2-indanedione/ zinc chloride

From the results of this phase, it is not advised to apply magnetic powder on thermal paper evidence prior to ThermaNin®, 1,2-indanedione/ zinc chloride, or PDMAC® paper. Magnetic powder greatly hindered the development abilities of these techniques.

Conclusions

From the results of this study, 1,2-indanedione/ zinc chloride and PDMAC® paper were the top methods to process latent fingerprints on thermal paper. Other methods from the literature were able to develop fingerprints on their own; however, none worked well in combination with each other.

1,2-indanedione/zinc chloride and PDMAC® paper were able to consistently develop prints on both sides of thermal paper with sufficient quantity and quality. Additionally, these processes were simple to use; samples could be left to develop while performing other tasks. These two processes usually produced the same results. However,

in some cases, using them sequentially allowed additional latent prints to develop or enhance fluorescence. Therefore, it is suggested that a sequence of these two methods would allow a latent print examiner to have more confidence in the results obtained from thermal paper evidence. Additional studies into this modified sequence should be performed in order to further validate its use. Since the deposition of prints from Phase 1 was at times poor, it should be repeated to gain a more accurate depiction of how the age of a fingerprint affects the development abilities of the modified sequence. Additionally, a consistency study should be performed for this sequence in order to determine how often it is able to develop all existing fingerprints; Then a likelihood ratio can be obtained to statistically substantiate the results.

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