A Comparison of field and laboratory conditions on the longevity of submerged latent fingerprints

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A Comparison on the Longevity of Submerged Marks in Field and Laboratory Conditions

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Abstract: This study compares (1) the rate of degradation of submerged fingermarks (latent fingerprints) in field and laboratory conditions and (2) several development methods. Sebaceous-rich and eccrine-rich marks were deposited on metal, plastic, and glass surfaces before being submerged in both laboratory and field conditions of sea, river, and lake water environments. Samples were removed at various time intervals of up to 14 weeks and were developed using one of three reagents: Oil Red O (solvent red 27), Sudan black (solvent black 3), and gentian violet (basic violet 3). The quality of the marks was assessed using a minutia counting method. Results showed that eccrine-rich marks did not survive even for short times whereas sebaceous-rich marks had extended survival. Marks that were submerged in field conditions survived longer than those that were submerged in laboratory conditions. The three visualization methods showed that gentian violet and Sudan black performed equally well in developing sebaceous secretions and were superior to Oil Red O at submersion intervals of longer than 10 days. Of the substrates that were tested, glass produced superior results, but all surfaces yielded high-quality marks during the times used in this investigation. It is recommended that future work use field conditions to examine longevity of submerged marks and that fingermark visualization should be attempted for submerged items even if they are recovered after some months of being underwater.

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Introduction

There have been several investigations into the recovery of fingermarks (latent fingerprints) from objects that have been submerged in water [1–12]. These publications show that, in principle, it is possible to recover marks from surfaces after they have been submerged in water for extended periods of time. The visualization of latent marks has been carried out using a variety of chemical and physical development techniques including dye staining or powder dusting [1, 2, 6, 11, 12], Sudan black B [2], small particle reagent [3, 5, 11, 12], physical developer [7], Oil Red O (ORO) [3, 7, 8, 10], and cyanoacrylate fuming [6, 9, 11–13]. The use of laboratory environments to simulate field conditions has been attempted [1–8, 10], whereas others have preferred to age their submerged marks in field conditions [9, 11, 12]. A variety of water types have also been investigated [6, 9, 11, 12], with common types being rain, sea, and fresh water, both in laboratory and field environments. Finally, the length of time that marks have been submerged has been variable, with time periods ranging from a few minutes [1–5, 12] to a day 2, 7, 9, 10–12], a week [3, 7, 9, 10–12], a month [3, 7, 10–12], or a quarter year [7]. The methods used to evaluate fingermark retention have ranged from simple photographs or numbers of marks, showing that fingermarks could be developed by way of proof of principle [1–5], to some form of scoring system to evaluate the effectiveness of techniques for comparison purposes [6–12].

At the time of writing, there are no published studies on:

- the use of Gentian violet for developing submerged marks
- comparisons of whether laboratory conditions for aging submerged marks are comparable to field conditions
- the time of submersion beyond 42 days

In this paper, gentian violet was compared to two other lipophilic dyes (ORO and Sudan black B) for effectiveness in developing fingermarks from submerged items. Although normally used for porous surfaces, ORO has been used for nonporous surfaces with some success [7]. These three reagents were chosen for ease of use in field situations by nonexpert practitioners. The study was extended to cover a 12-week period, and a comparison was made of field-located items in sea, river, and lake environments with laboratory items stored in water recovered from these sites. The developed latents were evaluated using a minutia count approach.

Materials and Methods

Materials

Three smooth, nonporous materials [glass, metal, and unplasticized polyvinyl chloride (uPVC)] representing a range of items that may be recovered from water were used. The glass that was used was 75 mm x 25 mm x 1.2 mm clear glass microscope slides (Fisher Scientific, Loughborough, U.K.). Brushed stainless steel was bought as 1 m x 1 m x 1 mm sheets (ASC Metals Group, Northampton, U.K.) and was cut into 75 mm x 25 mm pieces. The uPVC was purchased (Wickes DIY, Wolverhampton, U.K.) as 2.5 m x 50 mm x 1 mm sheets and was cut to 75 mm x 25 mm size. Sample marks were deposited on slide-sized materials and stored in plastic slide cases (100 slides per case) that had been modified by having an approximately 10 cm radius round hole cut into both the lid and base to allow water to freely access the samples. Laboratory submersion experiments were carried out in water-filled plastic boxes (70 cm x 40 cm x 25 cm, filled with 50 dm^3 water). Gentian violet, Sudan black, and ORO solutions were prepared as described by Mankevich [14].

Methods

Sample mark depositions were of two types: eccrine-rich and sebum-rich. Eccrine-rich marks were created by thoroughly washing and rinsing the hands with detergent and water to remove extraneous secretions and contaminants. The hands were inserted into talc-free laboratory latex gloves for a period of 60 minutes and were kept warm to encourage perspiration. Sebum-rich marks were created by thoroughly washing and rinsing the face two hours prior to the experiment. Right before depositing the marks, the hands were rubbed over the surface of the forehead and side of nose. Loaded fingers were then carefully deposited onto the substrate, with optimum deposition pressure, determined by experiment to be 8 to 10 kPa for the male and female donor used in this study. Deposited marks were left for at least four hours to dry before submersion. In all, 1435 marks were deposited, of which 900 were used for laboratory and 570 for field investigations. A set of five fingermarks were deposited consecutively before the finger was reloaded with either sebum or perspiration. This involved repeating both the washing and incubation steps.

Submersion and Staining

Laboratory Trial

The sample materials with deposited marks were loaded into the prepared slide cases, which were then placed in water-filled boxes that were covered and placed outside. The water that was used for the laboratory trial was recovered from the field location and was changed weekly with freshly obtained water. Temperature and acidity were measured regularly using a thermocouple and field pH meter. The laboratory trial temperature dropped during the course of the trial from just above 11 °C at the start to between 7 and 8 °C by the end. The pH of the sea water varied: sea water [obtained near Prestatyn, North Wales (ordnance survey grid reference SJ 04894 83216)] varied between 7.78 and 7.88; river water varied between 7.8 and 8.0; lake water varied between 7.7 and 8.0.

Field Trial

The sample materials with deposited marks were loaded into the prepared slide cases, which were then placed into the water at two locations: a lake-based location at Ashley quarry/lake near Stoke-on-Trent (ordnance survey grid reference SJ 75267 35689) and the River Severn at Ironbridge (ordnance survey grid reference SJ 68267 03173). The field trial temperature dropped during the course of the trial from just above 5 °C at the start to 3.5 °C by the end for the lake; the river temperature remained constant at about 5 °C. The pH varied with river water between 7.8 and 8.0 and for lake water between 7.7 and 8.0. (A third location in the sea was deemed unfeasible because of recovery problems during a pilot study–a slide case could not be recovered.)

For both field and laboratory trials, between 24 and 30 samples were removed at regular intervals and the slide cases were re-submerged. Samples were removed on the following days: 15, 30, 45, 80, and 100 for field trials and on days 6, 9, 11, 14, 17, 20, 30, 45, 60, and 90 for laboratory trials. Fingermark visualization was accomplished by immersing slides in the gentian violet or Sudan black staining solution for 2 minutes, or the ORO for 5 to 60 minutes, depending on efficacy of development, followed by rinsing with distilled water, and drying.

Photography and Analysis

Developed marks were photographed using a Canon 550D SLR digital camera with the camera attached to a copy stand, fitted with three extension rings coupled to an 18 mm to 55 mm lens to give a macro effect. Lighting was provided by oblique illumination at an angle of 55 degrees or a Meike Led Macro Ring Flash FC100 at the end of the lens.

The analyses of the fingermarks used a minutia count method to assess mark quality. Three reference donor fingerprints were captured using a Crossmatch ID1000 Livescan. Fifteen minutiae from 21 minutiae that were identified within a rectangle placed around the core of the fingerprint (Figure 1a) were selected on the basis of clarity and reproducibility in the three reference prints. The boundary of the rectangle was set by using the same two minutiae to provide the top left and bottom right vertices. Adobe Photoshop CS6 was used to view unaltered images and to examine the fingerprints for the presence of the minutiae (Figure 1b). A reproducible system for establishing the presence of a minutia within a developed fingermark was used to minimize analyst bias. The number of minutiae that were present was used as a measure of mark quality.

(a) *(b)*

Figure 1

Livescan of exemplar print showing: (a) area bounded in red from which to choose minutiae; (b) area marked up with 21 minutiae.

Results

Assessment of Mark Development

The quality of the recovered mark was assessed by counting the number of minutiae from within an area around the fingerprint core that was bounded by a rectangle (Figure 1), which was then compared with the same minutiae identified on a scanned marked-up print. There is a danger in using this method, because when the print pattern is known, the evaluator may attribute minutiae to a location when the evidence for their existence is questionable. The authors have adopted a procedure that applies objective measures to the minutia evaluation process. Thus, a minutia was counted only if it was unambiguously identified in recovered marks as being the same as the Livescan exemplar.

Comparison of Recovery of Sebum- and Eccrine-Rich Marks

The pilot project investigated the recovery of both eccrine- and sebum-rich marks. In this experiment, there was little or no visualization of the eccrine marks after submersion. Thus, the results presented below are entirely for sebum-rich marks. The pilot project also tested a range of methods, suitable for use in the field, that included a variety of commonly used powders and physical developer as well as the three methods reported in this research. Methods that are primarily used in laboratory conditions, such as cyanoacrylate fuming, were not considered in this trial. The initial survey (a single day of submersion with limited number of marks) showed that, although all methods were capable of developing marks, the three methods chosen for further investigation developed higher quality marks from submerged sebum-rich latent marks. A selection of developed marks for these three methods is shown in Figure 2.

Comparison of Development Methods

Three development methods were compared for their effectiveness at revealing submerged prints in both laboratory (Figure 3) and field (Figure 4) environments. Each data point in the figures is the mean of between 8 and 12 replicates (laboratory) and 15 replicates (field). Figure 3 shows that both Sudan black and gentian violet were equally effective at recovering prints over time. ORO was as effective at revealing latent marks during the first 10 days of the trial (the first two data points) but became inferior in showing prints after that time. The results from the field trial shown in Figure 4 are much more variable, as

(a) *(b)* *(c)*

Figure 2

Marks developed after submersion in a variety of conditions: (a) 7 days on steel in lake water (laboratory) developed with ORO; (b) 84 days in river water on steel developed with gentian violet; (c) 42 days in sea water on glass developed with Sudan black.

is expected from the lack of control of experimental conditions. The data generally changes little over time with the exception of the 45-day submersion samples. The 45-day samples may have been exposed to slightly different local conditions that caused this particular set to degrade more quickly than samples that had been submerged for longer periods. In this experiment, the recovered print quality did not degrade for any of the three reagents that were tested in field trials at anything like the same rate as our laboratory trial, the reasons for which will be discussed later.

Retention of Marks on Substrates

Figure 5 shows how different substrates retained latent marks over the time of submersion in laboratory conditions (mean of 10 replicates for each data point). It can be seen that no particular surface gave superior retention; all surfaces showed loss of detail with time. Results for the field trial, shown in Figure 6 (mean of 15 replicates for each data point), are more variable. The same issues with the 45-day recovered marks that were discussed earlier are also present here. For the surfaces that were tested, it is clear that glass retained better ridge detail, but all surfaces that were tested showed the ability to retain latent marks over extended time periods.

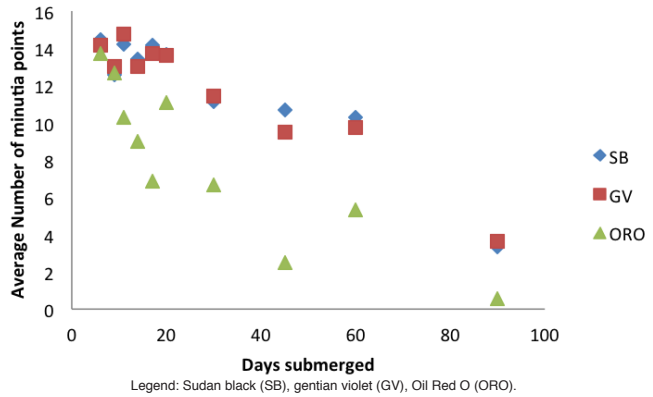

Figure 3

Chart illustrating the effect of development method on the number of minutiae developed. A summary for all water types and substrates under laboratory conditions.

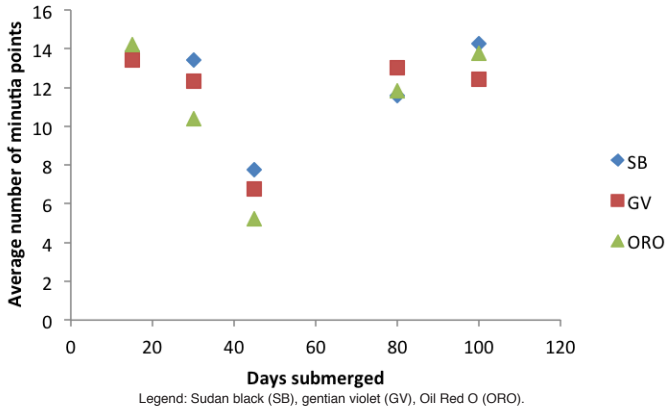

Figure 4

Chart illustrating the effect of development method on the number of minutiae developed. A summary for all water types and substrates for field conditions.

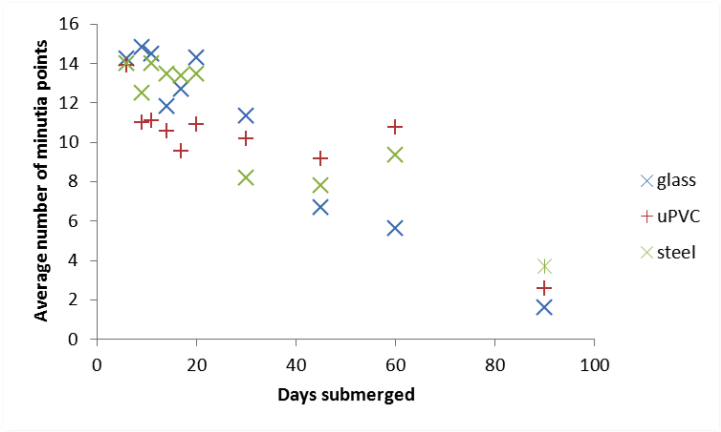

Figure 5

Chart illustrating the recovery results for various substrates. A summary for all water types and development reagents for laboratory conditions.

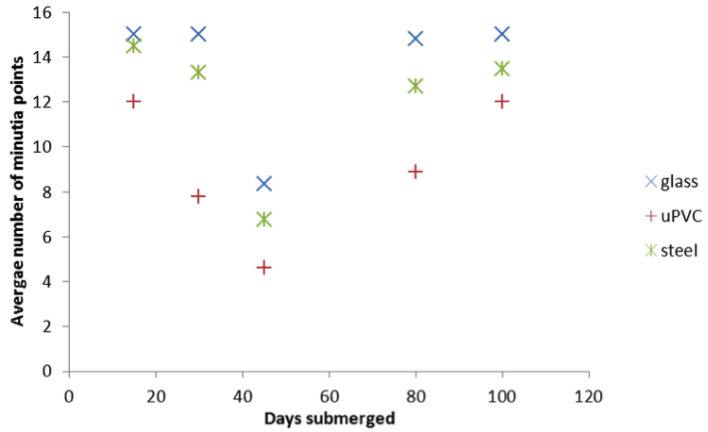

Figure 6

Chart illustrating the recovery results for various substrates. A summary for all water types and development reagents for field conditions.

Discussion

The lack of recovery of eccrine-rich prints after submersion was expected. As reviewed by Yamashita and French [15] and Girod et al. [16], the composition of eccrine-rich material (sweat) is mainly water, with the vast majority of the remaining components being water-soluble amino acids and salts. Submersion in water is likely to allow the diffusion away from the surface of these materials. One caveat to this observation is that most of the trials here were performed with only two donors, one male and one female, and it is known that eccrine secretions vary between individuals [16, 17]. The lack of development of eccrine-rich marks contrasts with sebum-rich marks, where effective development results because there is a much higher proportion of lipids. These are generally water-insoluble materials that do not so easily diffuse or dissolve upon submersion. The results show excellent recovery of sebum-rich prints from all surfaces tested.

The method of assessing development by counting minutiae is worthy of further consideration. This method was chosen because it is most representative of the features used by latent print examiners when conducting AFIS searches because most AFIS algorithms are minutiae based. A second reason for using a minutia counting method is that the score generated is a real number. Thus, a score of 10 (10 minutiae found) is twice the number of a score of 5. The consequence of using a number-based evaluation method means that statistical manipulations of discrete data, such as mean, are valid for this type of data. Many other assessment methods use relative grading systems to assess quality [7, 18, 19]. Most authors are aware that the "numbers" that are obtained by grading mark development should not be treated as though the number is a true integer, but care needs to be taken when statistically evaluating non-numeric data sets. The use of such methods has been questioned because of the lack of expertise by evaluators [19], but the minutia-counting method has been applied by undergraduate students with success, suggesting that identification of minutiae by nonexperts can be carried out with some objectivity. This is possible because there are exemplar prints stored in a livescan system with which to compare developed latent marks, and the developed latents are laid down in controlled conditions where distortion factors are limited. The issue with this method is one of analysis time. One advantage of this method that may counteract the time taken for individual print analysis is that once a "score" has been found for depletion sets on a particular surface, other depletion sets can be scored similarly, and the results can be directly compared without the need to split prints. Split prints do eliminate any variability in composition, which may arise even between fingers on the same hand. In building comparison matrices, this may result in a considerable saving of time. Finally, a larger range of numbers is more discriminating and this may be important in differentiating the performance characteristics of a range of similarly effective development methods. It is the authors' intention to publish a fuller version of this method that takes into consideration some of the other variables that are mentioned elsewhere. (See Sears et al. [19] for a discussion of methodologies).

This paper demonstrates that in field conditions, marks were retained on smooth, nonporous surfaces for as long as the trial proceeded (95 days). As far as the authors are aware, this is the longest field trial of submerged marks to date [1–5, 7, 9–12] and should encourage practitioners to attempt finger mark recovery on a range of suitable surfaces after submersion for even extended periods of time. Some care needs to be made in over-interpreting these results, however. The samples were placed onto microscope slide-sized surfaces and placed into microscope slide cases with holes cut to allow water to enter. Although water freely permeated, there will have been much protection of the samples from the environmental challenges (e.g., currents, silts) that could have eroded unprotected marks.

The field conditions contrasted markedly with the laboratory conditions. In the laboratory conditions, the marks degraded much more quickly. Although submersion tanks were left outside during the trial and water was exchanged weekly, there are differences between the laboratory and field conditions that may account for the degradation differences. Temperatures in the field conditions were lower than in the laboratory trials and this may have slowed degradation processes. However, steeping materials in "still" water in tanks allows microflora to establish themselves and these may have degraded the sebum-containing materials during the course of the trial. Both of these aspects may be worthy of further exploration in future work. The results that are presented here may also support the excellent development of marks seen in short timescale experiments that utilize ORO [7], because over a limited time of submersion, ORO is an effective development reagent.

Development reagents were chosen because they had at times been applied to submerged or wetted materials in previous studies [2, 4, 7, 8]. The results clearly show that both gentian violet and Sudan black are superior reagents for recovering

marks from submerged prints when compared to ORO. These results are a little surprising, because all these reagents are thought to be lipophilic dyes that penetrate lipid-rich areas with latent marks. The fact that both Sudan black and gentian violet behave very similarly and ORO behaves differently suggests that the former two are possibly targeting different parts of the sebum emulsion than the latter. The relative binding of lipophilic dyes to fingerprint components has been investigated by Garrett and Bleay [20] and Cadd et al. [21] who showed that Sudan black and basic violet 2 and 3 bind differently to the components that are found in sebaceous secretions. This study suggests that ORO binds differently from either of those reagents. In addition, the use of gentian violet as a field reagent may be questionable because of concerns about carcinogenicity [22]. However, other workers in this area have explored a greater range of mark development reagents and this study would need to be extended before valid conclusions could be drawn.

The substrates chosen all showed the ability to retain latent marks for the time of submersion. However, superior marks were recovered from glass than from the other two surfaces.

Conclusion

Eccrine-rich latent marks were not likely to be recovered after submersion in water for any length of time. Sebum-rich marks, however, were retained for at least the length of this trial. A minutiae-based assessment system to assess fingerprint development efficiency is possible. Caution should be exercised when carrying out short timescale trials because some reagents are effective only over short times. Submersion in the "field" produced significantly different results from "laboratory" conditions. If possible, it is recommended that further investigation be concentrated mainly on field conditions. Practitioners should use Sudan black as the reagent of choice, because of its effectiveness and safety on most smooth, nonporous surfaces.

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References

1. Hanggi, G. A.; Alfutis, H. M. Improved Technique in the Development of Latent Fingerprints. *Ident. News* **1969**, *19*, (6), 5–11.
2. Stone R. S.; Metzger, R. A. Comparison of Development Techniques Sudan Black B Solution/Black Magna Powder for Water-Soaked Porous Items. *Ident. News* **1981**, *31* (1), 13–14.
3. Onstwedder, J.; Gamboe, T. E. Small Particle Reagent: Developing Latent Prints on Water-soaked Firearms and Effect on Firearms Analysis. *J. For. Sci*. **1989**, *34* (2), 321–327.
4. Beaudoin, A. New Technique for Revealing Latent Fingerprints on Wet, Porous Surfaces: Oil Red O. *J. For. Ident*. **2004**, *54* (4), 413–421.
5. Cucè, P.; Polimeni, G.; Lazzaro, A. P.; De Fulvio, G. Small Particle Reagents Technique Can Help to Point Out Wet Latent Fingerprints. *For. Sci. Inter.* **2004**, *146*, (Supplement), S7–S8.
6. Soltyszewski, I.; Moszczynski, J.; Pepinski, W.; Jastrzebowska, S.; Makulec, W.; Zbiec, R.; Janica, J. Fingerprint Detection and DNA Typing on Objects Recovered from Water. *J. For. Ident*. **2007**, *57* (5), 681–687.
7. Wood, M. A.; James, T. ORO. The Physical Developer Replacement? *Sci. & Just*. **2009**, *49* (4), 272–276.
8. Beaudoin, A. Does Water Really Ruin All Possibilities of Developing Latent Fingerprints on Paper? *Actual. Chim*. **2010**, *342–343*, 59–61.
9. Devlin, B. E. Recovery of Latent Fingerprints after Immersion in Various Aquatic Conditions. M.Sc. thesis, George Mason University, 2011.
10. Beaudoin, A. Fingerprint Staining Technique on Dark and Wetted Porous Surfaces: Oil Red O and Rhodamine 6G. *J. For. Ident*. **2012**, *62* (4), 315–329.

11. Trapecar, M. Finger Marks on Glass and Metal Surfaces Recovered from Stagnant Water. *Egyptian J. For. Sci*. **2012**, *2* (2), 48–53.
12. Trapecar, M. Fingerprint Recovery from Wet Transparent Foil. *Egyptian J. For. Sci*. **2012**, *2* (4), 126–130.
13. Nic Daeid, N.; Carter, S.; Laing, K. Comparison of Vacuum Metal Deposition and Powder Suspension for Recovery of Fingerprints on Wetted Nonporous Surfaces. *J. For. Ident*. **2008**, *58* (5), 600–614.
14. Mankevich, A. Latent Fingerprint Processing Techniques–Selection & Sequencing Guide. 2013. http://www.cbdiai.org/Reagents/main.html (Accessed July 11, 2013).
15. Yamashita, B.; French, M. Latent Print Development. In *The Fingerprint Sourcebook*; McRoberts, A., McRoberts, D., Eds.; National Institute of Justice: Washington, D.C., 2011; Chapter 7, pp 7–8.
16. Girod, A.; Ramotowski, R.; Weyermann, C. A Composition of Fingermark Residue: A Qualitative and Quantitative Review. *For. Sci. Inter*. **2012**, *223* (1), 10–24.
17. Bailey, M. J.; Bright, N. J.; Croxton, R. S.; Francese, S.; Ferguson, L. S.; Hinder, S. J.; Jickells, S.; Jones, B. J.; Jones, B. N.; Kazarian, S. G.; Ojeda, J. J.; Webb, R. P.; Wolstenholme, R.; Bleay, S. Chemical Characterisation of Latent Fingerprints by MALDI, ToF-SIMS, MeV-SIMS, GC-MS, XPS and ATR-FTIR Spectroscopic Imaging–An Intercomparison. *Anal. Chem*. **2012**, *84* (20), 8514–8523.
18. Jasuja, O. P.; Toofany, M. A.; Singh, G.; Sodhi, G. S. Dynamics of Latent Fingerprints: The Effect of Physical Factors on Quality of Ninhydrin Developed Prints–A Preliminary Study. *Sci. & Just*. **2009**, *49* (1), 8–11.
19. Sears, V. G.; Bleay, S. M.; Bandey, H. L.; Bowman, V. J. A Methodology for Finger Mark Research. *Sci. & Just*. **2012**, *52* (3), 145–160.
20. Garrett, H. J.; Bleay, S. M. Evaluation of the Solvent Black 3 Fingermark Enhancement Reagent: Part 1–Investigation of Fundamental Interactions and Comparisons with Other Lipid-Specific Reagents. *Sci. & Just*. **2013**, *53* (2), 121–130.
21. Cadd, S. J; Bleay, S. M; Sears, V. G. Evaluation of the Solvent Black 3 Fingermark Enhancement Reagent: Part 2–Investigation of the Optimum Formulation and Application Parameters. *Sci. & Just*. **2013**, *53* (2), 131–143.
22. Littlefield, N. A.; Blackwell, B. N.; Hewitt, C. C.; Gaylor, D. W. Chronic Toxicity and Carcinogenicity Studies of Gentian Violet in Mice. *Fund. Appl. Toxicol*. **1985**, *5* (5), 902–912.

Article

Water-Soaked Porous Evidence: A Comparison of Processing Methods

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Abstract: This study compared the U.K. Home Office formulation for physical developer (PD) against Oil Red O (ORO) and a modified formulation of physical developer (MPD) that uses Tween 20 instead of Synperonic-N for enhancing fingermarks. Three different donors deposited fingermarks on porous surfaces (white paper, leaflets, and cardboard), with aging periods varying from 7 to 28 days. None of the techniques that were tested provided enhancement of latent fingermarks on leaflets, whereas poor-quality enhancement was observed on cardboard. In contrast, all techniques were more successful on white paper surfaces. The results obtained on white paper suggested that PD and MPD performed similarly, with PD detecting 82.3% of the deposited fingermarks and MPD detecting 86.5% of the deposited fingermarks. PD yielded a higher percentage (38.5%) of fingermarks with fine ridge detail (i.e., those with grade 2 or above) than MPD (35.4%). ORO, however, yielded poor results, enhancing only 4.5% of latent fingermarks, but showed no ridge detail in any of the enhancements (i.e., only showed grade 1 enhancements.)

Introduction

Approximately 99% of a latent fingermark is water [1]. This is rapidly lost through evaporation, meaning that over time, methods that rely on water being present lose their effectiveness. These methods also lose their effectiveness if the item has been exposed to water or high humidity. On aged latent finger-

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