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Evaluation of Iodine-Benzoflavone and Ruthenium Tetroxide Spray Reagents for the Detection of Latent Fingermarks at the Crime Scene

ABSTRACT: The performance of two spray reagents, iodine-benzoflavone and ruthenium tetroxide (RTX), was evaluated and compared with the conventional technique currently used at the crime scene, that is, powdering. Neither the spray techniques nor powdering were shown to be suitable for all surfaces and ages of marks tested. On some surfaces such as glass and treated wood, powdering was still the superior technique, whereas the spray techniques produced better development on wallpaper, vinyl, and brick. Sequencing work showed that RTX was incompatible with powdering and cyanoacrylate (with a rhodamine 6G stain). Iodine-benzoflavone can be used successfully either before or after powdering in a sequence; however, it was incompatible with cyanoacrylate. Two non-CFC formulations of iodine-benzoflavone using HFC4310mee and HFE7100 solvents were tested and shown not to be as effective as the original Arklone (CFC-113) formulation; however, the HFC4310mee solvent is recommended as the most suitable replacement solvent. Due to the expense of the commercial RTX spray, attempts at formulating a more cost-effective version were also carried out. A formulation was developed that gave comparable development to the commercial version but at a much cheaper cost, and with a shelf life of up to two months. Recommendations are presented for which techniques are suitable for different surfaces and ages of marks. Powdering was shown to be the best technique on all ages of marks tested on treated wood, glass, and also on marks aged three days and older on paint. Iodine-benzoflavone was the best technique on wallpaper, vinyl, brick, and raw wood. RTX was the best detection technique for fresh marks and marks aged up to one day on wallpaper and paint.

KEYWORDS: forensic science, crime scene, fingermarks, fingermark detection, fingermark sprays, powdering, non-CFC formulations, Arklone substitutes

Fingerprints are considered to be one of the most important and frequent forms of evidence used for identification purposes, and can assist a criminal investigation in a number of ways. Most fingerprints left at a crime scene are latent prints (more accurately defined as "marks"). Hence methods that will make these marks visible are required. There has been much research into developing new and improved laboratory techniques to develop better-quality latent marks; however, little benefit has flowed on to crime scene applications. The main technique used at the crime scene is powdering, and even with more serious crime it is rare that more sophisticated techniques are employed. Therefore, the aim of this study was to evaluate the use of two spray reagents, iodine-benzoflavone and ruthenium tetroxide (RTX), and compare the efficiency of these with the conventional powdering technique currently used at the crime scene.

Powdering is the most commonly used technique for smooth, nonporous surfaces, and works by the powder particles mechanically adhering to the moisture and oily components of the mark deposit (1). There are both advantages and disadvantages with the use of the powdering technique. Advantages include it being a simple inexpensive technique, requiring little experience to use; it yields instantaneous results that can be "lifted"; and it does not require the use of sophisticated equipment. Disadvantages include the risk of mark obliteration caused by contact between the brush and the fragile fingermark ridges, and, because powdering is rather insensitive aged marks (marks that have dried out and lost their "stickiness") are difficult to develop (2). Studies into the causes of obliteration of latent marks found ridge smearing or brushing to be a major cause (3). A 2001 review estimated that around 10% of latent marks at the crime scene are rendered difficult to identify when developed using powder (2).

The application of ruthenium tetroxide as a latent mark fuming technique has been known since 1920 (4). Numerous different methods of application have been described, including fuming as a dipping solution (5–7). The spray application of RTX was proposed to overcome previous difficulties with conventional methods using RTX, which had rendered the technique impractical and thus limited its widespread use to develop latent fingermarks (7).

The spray application of RTX, proposed in 1998 for use "on the spot" at the crime scene, involves dissolving ruthenium tetroxide in a saturated halogenide (7). The RTX spray method can be applied on many surface types, including porous, nonporous, and difficult surfaces such as thermal sensitive paper, cloth, leather, vinyl, wood and even human skin. Dark brown to black marks are obtained which are stable over time.

The development of latent fingermarks using a solution of iodine and a benzoflavone fixing agent took place first in 1983 (8); the technique was modified in 1987 to a two-solution method to overcome the problem of weighing out iodine crystals at the crime scene (9). It was found that best results were obtained with fresher marks (generally less than a week old), as older marks were less efficiently developed. The technique develops dark blue marks, and is said to work on both porous and nonporous

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surfaces, including emulsion- and gloss-painted walls, and wallpaper.

A current major problem with the use of iodine-benzoflavone spray is that the preferred carrier solvent, Arklone, has now been banned as it contributes to the destruction of the ozone layer. There has been much research carried out over the past ten years for a suitable solvent to replace Arklone in ninhydrin and DFO formulations (10–13). Two solvents that have been mentioned in the literature (11–13) as suitable replacements are HFC4310mee (1,1,1,2,3,4,4,5,5,5-decafluoropentane) and HFE7100 (1-methoxynonafluorobutane). Both are currently used as replacements for Arklone in the ninhydrin formulation by different police forces. To date, there has been no suitable alternative carrier solvent proposed for the iodine-benzoflavone formulation, so the use of CFC replacement solvents was investigated in this project. (Some police services use cyclohexane or methyl cyclohexane as a replacement for Arklone in the iodine-benzoflavone formulation. These solvents are highly flammable and their use in a spray reagent at a crime scene is particularly hazardous and should be avoided where possible.)

Materials and Methods

General Approach

Two non-CFC carrier solvents, HFE7100 and HFC4310mee, were tested as possible replacement carrier solvents for Arklone in the iodine-benzoflavone formulation on a variety of surfaces with both fresh and aged marks. Towards the end of the study, the possibility of using a blended solvent, methanol in HFC4310mee, was investigated to see if this improved the results.

A commercial version of RTX spray was purchased for evaluation and, due to the expense of the product, attempts at formulating a more cost-effective version were also carried out. This involved chemically generating ruthenium tetroxide fumes and dissolving the fumes in a suitable solvent. The solvents tested were HFE7100 and HFC4310mee.

Both the RTX and iodine-benzoflavone sprays were compared with conventional powdering to evaluate their ability to effectively detect and develop latent marks at the crime scene. Comparison of the techniques was carried out on a range of surfaces that were selected as being representative of those typically encountered. A direct side-by-side comparison was performed between each of the techniques on latent marks aged up to two months. The performance of the techniques on more "difficult" surfaces, including brick and raw wood, was evaluated later in the project.

A preliminary evaluation was undertaken to ascertain whether or not the sprays would fit into a sequence of reagents for use at the crime scene. This involved determining whether the sprays had an effect on subsequent powdering or cyanoacrylate fuming/fluorescent staining. Also, as both sprays may pose an occupational health and safety hazard at the crime scene, a health and safety evaluation of the sprays was carried out. Consideration was given as to what safety procedures would need to be enforced for the safe use of such reagents at the crime scene.

Preparation and Application of the Solutions

Three different carrier solvents were tested in the iodine-benzoflavone formulation; these included Arklone (CFC-113) and two possible replacement solvents, HFE7100 and HFC4310mee. The formulations were prepared as described in Ref 14 for the "spray application" of iodine-benzoflavone:

- Stock solution A: 12% w/vol 7,8-benzoflavone in dichloromethane.
- Stock solution B: 0.1% w/vol iodine in carrier solvent.
- Working solution: Solution A (2 mL) is mixed with solution B (100 mL) and the combined reagent allowed to stand for 5 min then filtered before use.

Commercial RTX spray was purchased from Kenzoh Mashiko, and attempts at formulating a cheaper alternative were carried out based on information published in cited references (5,7,15). This was achieved by mixing 25 mL of a 1% aqueous ruthenium chloride solution and 25 mL of a 5% aqueous ceric ammonium nitrate solution with 125 mL of the carrier solvent in a separating funnel for 10 min. Two carrier solvents were tested—HFE7100 and HFC4310mee. Two layers were obtained—a black upper layer (aqueous) and yellow bottom layer (organic). The yellow layer was collected and dried over anhydrous sodium sulphate for 24 h. Due to stability problems (see Results section), ceric ammonium nitrate was added to the solution at a 0.5–5% w/vol ratio in an attempt to improve the shelf life of the reagent.

All spray reagents were stored in the dark at room temperature. Surfaces were treated with each reagent by lightly applying the solution using a hand-pumped garden spray gun at a distance of about 10 cm.

Visualization and Recording of Developed Marks

A VSC2000/HR Video Spectral Comparator (Foster & Freeman, U.K.) was used for the recording of developed marks on each substrate. Developed marks were recorded under white light illumination unless otherwise specified.

Comparison of Latent Mark Development

The fingermark development tests involved the direct comparison between the different fingermark reagents. A "good" fingermark donor placed three sets of marks on each surface. The first set was deposited after rubbing the fingers across oily parts of the face, and then two successive sets deposited without recharging the fingers. This allowed strong, medium, and weak latent marks to be obtained. The marks were then cut down the middle and each half tested with a different reagent to allow a direct comparison between the reagents. The comparisons were based on the quality of ridge development, development intensity/contrast, extent of ridge diffusion, and the extent of any background staining.

Optimization of Spray Reagents

Both spray reagents were optimized by comparing the different respective formulations against each other.

For iodine-benzoflavone, the testing was carried out on five surfaces—wallpaper, vinyl, glass, paint, and treated wood—with marks of the following ages: fresh, one day, three days, and one week. The comparisons were conducted between: (*a*) Arklone and HFC4310mee; (*b*) Arklone and HFE7100; and (*c*) HFC4310mee and HFE7100 formulations. Towards the end of the project, a blended solvent formulation using 10% methanol vol/vol in HFC4310mee was also tested.

The performance of the commercially available RTX spray and the cheaper alternatives formulated using HFE7100 and HFC4310mee were compared on seven surfaces—wallpaper, vinyl,

TABLE 1—*Comparisons between spray reagents and conventional fingermark powder.*

Technique	Compared With
Iodine-benzoflavone	commercial RTX HFE-based RTX powder
Commercial RTX	iodine-benzoflavone HFE-based RTX powder
HFE-based RTX	commercial RTX iodine-benzoflavone powder

glass, paint, treated wood, raw wood and brick—with marks aged up to two months.

Comparison of Spray Techniques with Conventional Techniques

A direct comparison was carried out between the spray reagents iodine-benzoflavone and RTX and traditional fingermark powdering (Table 1). The testing was carried out on wallpaper, vinyl, glass, paint, and treated wood, with marks aged up to two months (Table 2). Towards the end of the project, the techniques were compared on more "difficult" surfaces—brick and raw wood—with marks aged up to one week.

Black or white fingermark powder (whichever gave the best results) used in the comparison testing was applied by a continental squirrel-hair brush (Lightning Powder Co., U.S.).

Sequencing Tests

The possibility of using more than one technique in a sequence to detect latent marks is important because a sequence of techniques may allow more marks to be detected and may also improve the overall quality obtained in treated marks. Therefore, the effect of iodine-benzoflavone and RTX spray, when used before or after powdering, was tested. The testing was carried out on paint and glass with marks aged one day and one week. To determine if the sprays have any effect on subsequent powdering, a direct comparison was made on each surface between powdering only and powdering after the application of the spray reagents. Tests were also carried out to see if powdering first had any detrimental effect on the results obtained from spray development. This was carried out by spraying one half of the fingermark deposit and comparing the results with the other half which was developed using powder initially followed by spraying. Thus the comparisons undertaken were as follows: (*a*) powdering/spray versus powdering only and (*b*) spray/powdering versus spray only.

A limited amount of work was also carried out to determine what effect the sprays would have on the results obtained from subsequent cyanoacrylate fuming. The testing was carried out using fresh marks on plastic where one half was first sprayed with the iodine-benzoflavone or RTX sprays and then fumed with cyanoacrylate, and the other side treated by cyanoacrylate fuming only. A rhodamine 6G stain was applied as described in Ref 14, and the results recorded under white light and also in the luminescence mode (505 nm excitation, 565 nm observation or 530 nm excitation, 590 nm observation).

Results and Discussion

Non-CFC Formulation of Iodine-Benzoflavone

The results indicated that the different carrier solvent formulations clearly play a role in the effectiveness of each technique to develop latent fingermarks. The non-CFC iodine-benzoflavone formulations were generally shown to be less effective than the original Arklone (CFC-113) formulation. Occasionally, on fresher or heavily charged marks, the HFC4310mee formulation produced equivalent or slightly better results in comparison with the Arklone formulation (Fig. 1), but was shown to be less effective on older marks. The fingermark development achieved with the HFE7100 formulation was consistently of lower quality in comparison with results achieved with the Arklone formulation.

The direct comparison between the HFC4310mee and HFE7100 formulations indicated that the HFC4310mee formulation consistently gave better-quality fingermark development on all surfaces

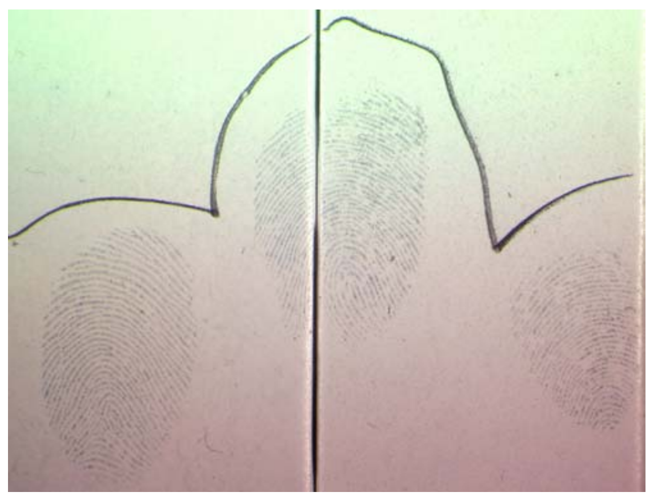

FIG. 1—*Comparison of HFC4310mee* (left) *and Arklone* (right) *iodine-benzoflavone formulations for fresh marks on paint.*

TABLE 2—*Recommended techniques for each surface and latent mark age.*

	Surface Type						
Age	Treated Wood	Glass	Wallpaper	Vinyl	Paint	Brick	Raw Wood
Fresh	powder	powder	RTX	IB	IB and RTX	(5 h) IB	n/t
1 day	powder	powder	IB	IB	RTX	n/t	IB
3 days	powder	powder	IB	IB	powder	(5 days) IB	n/t
1 week	powder	powder	IB	IB	powder	n/t	n/a
2 weeks	powder	powder	n/a	IB	powder	n/t	n/t
1 month	powder	powder	n/a	IB	powder	n/t	n/t
2 months	powder	powder	n/a	IB	powder	n/t	n/t

NOTE: n/a indicates that no technique developed any latent mark detail; n/t indicates that no technique was tested at this age.

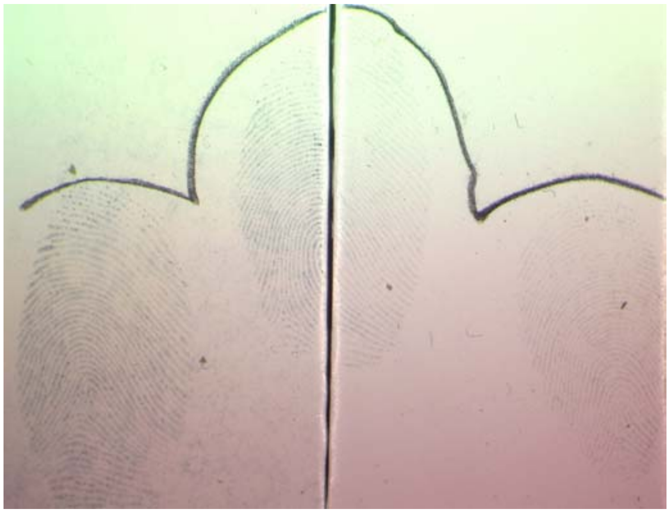

FIG. 2—*Comparison of HFC4310mee* (left) *and HFE7100* (right) *iodine-benzoflavone formulations for fresh marks on paint.*

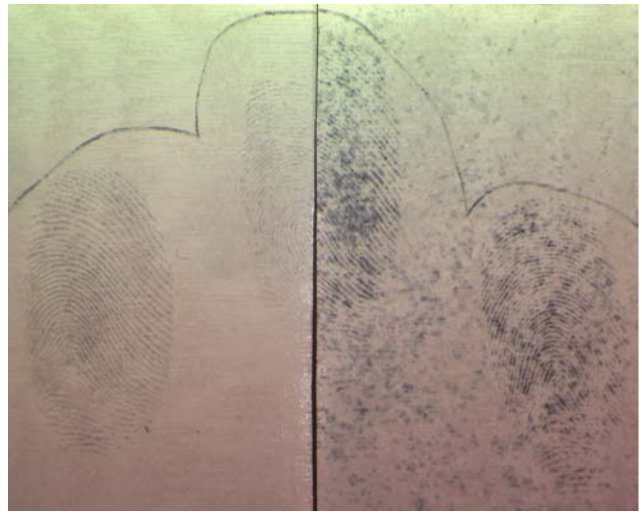

FIG. 3—*Comparison between Arklone* (left) *and 10% methanol in HFC4310mee* (right) *iodine-benzoflavone formulations for one-day-old marks on wallpaper.*

and for all ages of marks tested (Fig. 2). The main difference observed was with respect to the intensity and contrast of development, and not due to differences in background staining or ridge diffusion. The results clearly indicated that, based on quality of fingermark development, the HFC4310mee formulation performed better than the HFE7100 formulation, and therefore would be the recommended choice as the replacement carrier solvent for Arklone.

Other factors considered in this study included the stability of both the stock and working solutions and the ease of preparation. There was no difference noted in the stability of the respective iodine stock solutions (solution “B”), with all solutions still being stable after 14 weeks. There was, however, a difference noted in the stability of the respective working solutions, with the Arklone formulation being the least stable and the HFC4310mee formulation the most stable. When the stock solutions are mixed, a black precipitate forms. The HFC4310mee solution did form a black precipitate, although a smaller amount formed than for the Arklone and HFE7100 formulations, and there also appeared to be a slower rate of formation. The solutions were tested on fresh marks on paint four hours after the working solutions were prepared, and the HFC4310mee formulation was the only one capable of developing a usable fingermark image (pale blue). The Arklone formulation gave significant yellow background staining, and the HFE7100 formulation developed a pale yellow image of the mark.

There was some difficulty in preparing the stock iodine solutions. The iodine was easiest to dissolve in the Arklone formulation and hardest to dissolve in the HFC4310mee formulation. It was found that initial grinding of the iodine crystals using a mortar and pestle facilitated the dissolution process, and therefore this step is strongly recommended when attempting to prepare the HFC4310mee formulation. The solutions need to be mixed with stirring for a significant time for complete dissolution of the iodine, and occasionally the application of a limited amount of heat (needs to be minimal due to the low boiling points of the solvents) was shown to help the process.

Towards the end of the study, the possibility of using a blended carrier solvent made up of 10% methanol in HFC4310mee was investigated. The results showed that, on all surfaces and for all ages of latent marks, the blended solvent gave stronger development in terms of intensity of mark development. However, the advantage gained with darker development was outweighed by the high background staining that occurred, which affected the contrast observed in developed marks (Fig. 3). Despite spraying from the farthest distance possible and as lightly as possible, the background staining was observed to occur at the same rate as ridge development. The blended solvent also caused some ridge diffusion in developed marks. This can be explained by the high polarity of methanol, which is more likely to cause ridge diffusion than the relatively non-polar HFC4310mee solvent. The performance of the blended solvent on vinyl was quite impressive (Fig. 4). Some ridge diffusion and background staining still occurred; however, the advantage of the darker mark development on vinyl outweighed the background staining disadvantage. The preliminary results indicate that the blended solvent approach is promising but requires further optimization. Future work should incorporate the testing of lower concentrations of methanol (such as 5% or 2.5% vol/vol) in the HFC4310mee carrier solvent. A reduced concentration of methanol may still increase the strength of development without causing significant ridge diffusion or background staining. It is also recommended that studies be undertaken to look at blended carrier solvents based on HFE7100.

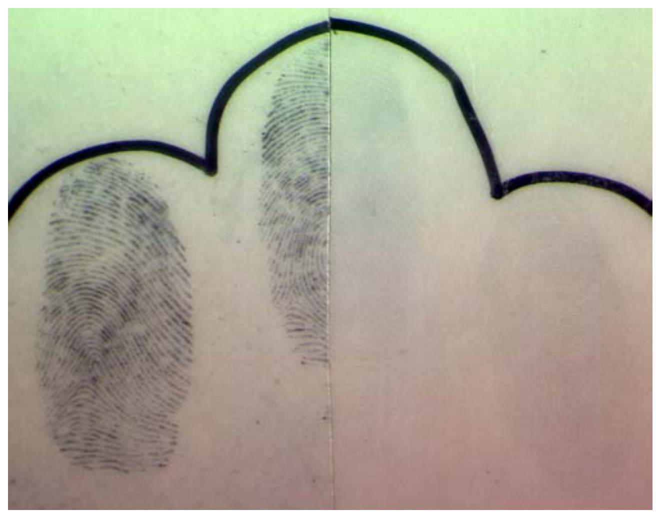

FIG. 4—*Comparison between 10% methanol in HFC* (left) *and HFC* (right) *iodine-benzoflavone formulations for one-day-old “depleted” marks on vinyl.*

HFE7100 currently sells for approximately AUS$70/kg (supplier: Solvents Australia), whereas HFC4310mee is more expensive

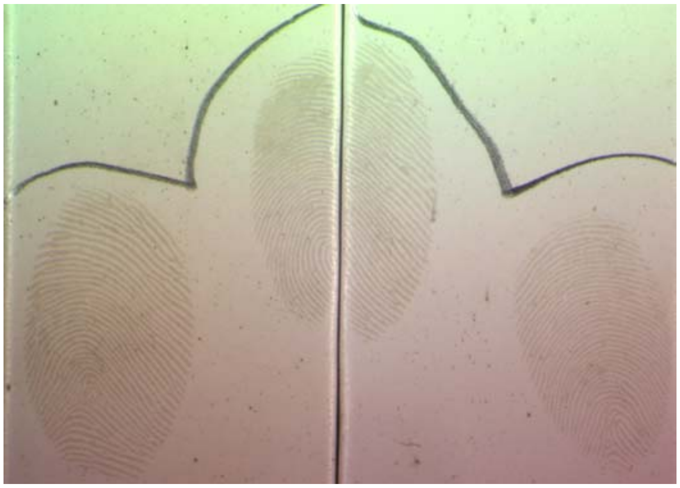

FIG. 5—*Comparison between commercial RTX* (right) *and HFE-based RTX* (left) *for fresh marks on paint.*

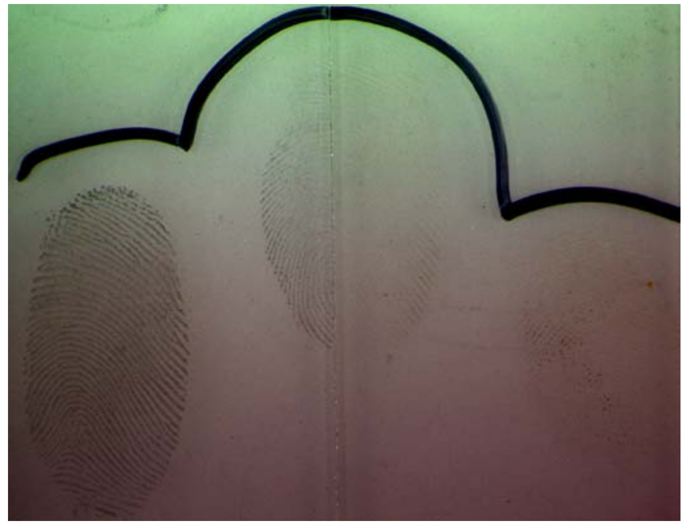

FIG. 6—*Comparison between powder* (left) *and commercial RTX* (right) *for one-day-old marks on glass.*

at around AUS$100/kg (supplier: Novaline). However, the increased cost for HFC4310mee is outweighed by the superior fingermark development that can be achieved using this carrier solvent in comparison with HFE7100.

Spray Application of RTX

HFC4310mee was found to be unsuitable as a carrier solvent for this reagent as little or no ruthenium tetroxide could be dissolved in the solvent, with only a clear solution being obtained that failed to develop any latent marks. However, ruthenium tetroxide did dissolve in HFE7100 at a suitable concentration, producing a pale yellow solution that was capable of developing fingermark images.

The results of the comparison between the commercial reagent and the HFE-based RTX spray indicated that performance was comparable on all surfaces and for all ages of marks tested (Fig. 5). There was a slight difference in the intensity of development, with the commercial version occasionally developing slightly darker brown marks; however, the difference was minimal. The commercial version also produced a higher degree of background staining and, on weaker marks where the advantage of a slightly stronger developer would be beneficial, the background staining negated any possible advantage.

The commercial RTX reagent is said to be stable for over three years as long as the solution is not mixed with water or organic substances. However, problems were encountered with the stability of the HFE-based RTX spray. After 24 h, the yellow solution turned green with fine black particles forming, and eventually the solution turned completely black. Several variations for the preparation of the HFE-based RTX spray were evaluated to determine the best conditions for obtaining a more stable product.

Ceric ammonium nitrate was reported to act as a stabilizer in the RTX solution, preventing the reduction of ruthenium tetroxide to black ruthenium dioxide (15). This was clearly demonstrated in this study as the addition of ceric ammonium nitrate at 0.5% and 1.0% w/vol to the HFE-based RTX solution increased the shelf life of the reagent to one month. At a 2.5% w/vol concentration the solution was stable for six weeks, and at a 5.0% w/vol concentration the solution was stable for two months. Therefore, an increased shelf life can be obtained by increasing the concentration of ceric ammonium nitrate in the HFE-based RTX solution. Drying the spray reagent thoroughly during synthesis and maintaining the solution in an anhydrous state were found important with respect to the stability of the product.

A comparison between the price of making the HFE-based RTX solution and buying the spray commercially was carried out. In Australia, 150 mL of the commercial RTX spray costs approximately AUS$150, whereas the same volume of HFE-based RTX formulated spray costs approximately AU$30 (with ceric ammonium nitrate at 5.0% w/vol). Overall, the findings of this project indicate that the HFE-based RTX spray formulation, stabilized with ceric ammonium nitrate, can develop latent marks as effectively as the commercial version, is more cost-effective, and has a shelf life of two months.

Comparison of Spray Techniques with Conventional Techniques

The comparison between spray techniques and conventional techniques showed that there is no one universal technique that is best for all surface types and for all ages of marks. The better technique varied from surface to surface, and also with different aged marks on the same surface. On some of the surfaces examined, conventional fingermark powder performed better than the spray techniques, and on others the replacement of powdering with the spray techniques would be recommended. Table 2 lists the recommended technique for each surface and for all ages of mark tested.

Powdering was shown to be the best technique for all ages of marks tested on treated wood, glass, and also on marks aged three days and older on paint (Fig. 6). The spray techniques did not develop marks on treated wood at any age, and powdering still developed mark detail after two months of aging (Fig. 7).

Iodine-benzoflavone was the best technique on wallpaper, vinyl, brick, and raw wood. The results on brick were very impressive, and marks aged five days were still developed with some clear ridge detail visible (Fig. 8). As would be expected, powdering failed to develop any significant ridge detail on brick, but the spray techniques developed good clear ridge detail. The effectiveness of iodine-benzoflavone to develop latent marks was clearly shown to decrease with the increasing aging of the marks, and it was also shown to be less sensitive for weaker fingermark deposits. These results are in agreement with previous testing involving the Arklone formulation (9,17).

RTX developed fresh marks with very good contrast and clear ridge detail, especially on wallpaper, paint, and brick. However, the

FIG. 7—*Mark treated with white powder on treated wood aged one month (both sides).*

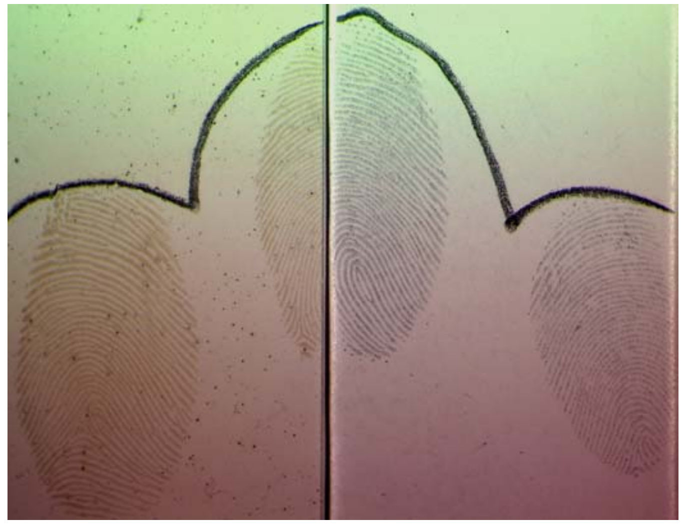

FIG. 9—*Comparison between commercial RTX* (left) *and iodine-benzoflavone* (right) *for fresh marks on paint.*

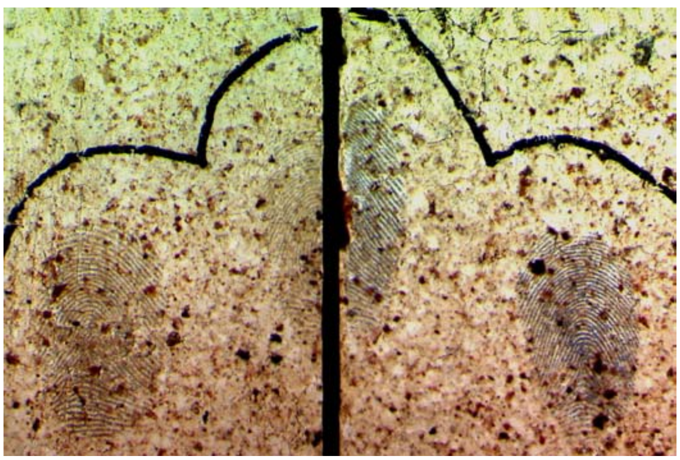

FIG. 8—*Comparison of commercial RTX* (left) *and iodine-benzoflavone* (right) *for marks aged 5 h on brick.*

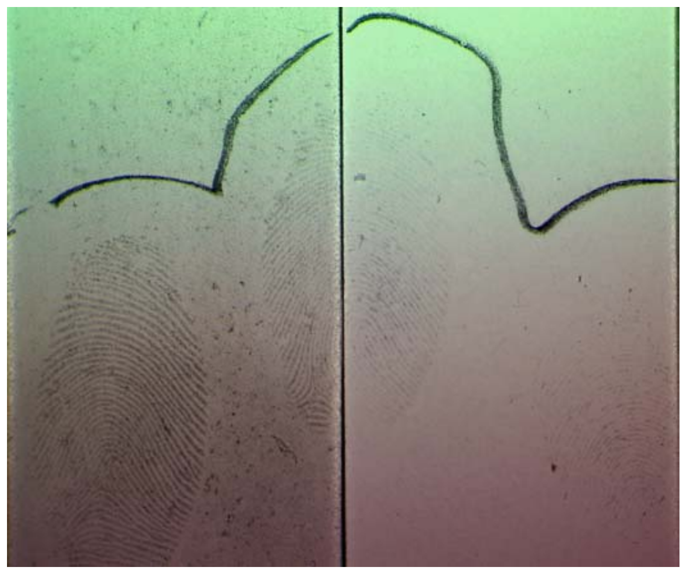

FIG. 10—*Comparison between powdering* (left) *and iodine-benzoflavone* (right) *for one-week-old marks on paint.*

spray was relatively insensitive for the detection of aged marks, and gave only faint development once marks were older than three days. It was the best detection technique for fresh marks and marks aged up to one day on wallpaper and paint.

The best technique occasionally varied with different aged marks on the same surface. For example, on paint the spray reagents both developed very clear ridge detail on the fresher marks (Fig. 9) but, after aging the latent marks for three days, powdering produced better overall results (Fig. 10). Therefore, the likely age of the latent marks of interest must be considered before deciding whether powdering or a spray technique should be employed.

Even though iodine-benzoflavone and RTX spray produced better results than powdering on some surfaces, the use of these reagents will increase costs and also result in occupational health and safety issues for the user. Cleanup costs must also be taken into consideration. The increased performance of the spray reagents over powdering for developing latent marks on surfaces such as wallpaper, vinyl, and brick justifies their use in certain circumstances (e.g., for more “serious” cases).

Sequencing

RTX spray should not be applied in a sequence either before or after powdering. When applied before powdering, the results indicated that, although the powder generally adhered to the fingermark ridges, it also adhered to other parts on the surface, rendering the ridge detail unclear. When the RTX spray was applied following powdering, it did not develop any significant brown colouration in the ridge detail. The reason for this is probably due to a physical effect in that the powder coating on the ridges does not allow either development to be seen, or development to occur at all (as the spray does not effectively penetrate the powder coating).

The effect of the RTX sprays on later cyanoacrylate fuming was tested. When the marks that had been fumed with cyanoacrylate and stained were viewed under white light, there appeared to be no difference between the side that had previously been treated with RTX and the untreated side (Fig. 11). However, when viewed in the luminescence mode, the side that had been treated with RTX did

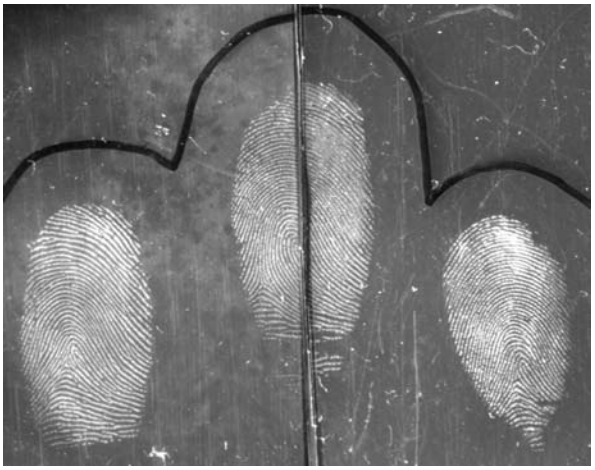

FIG. 11—*Left side of plastic sprayed with commercial RTX, then cyanoacrylate/stain; right side just cyanoacrylate/stain (viewed under white light).*

FIG. 12—*Same as Fig. 11, but viewed in the luminescence mode under 505 nm excitation with observation at 565 nm. Integration time: one second.*

not luminesce (Fig. 12), and only when the integration time was increased was any mark detail visible (Fig. 13).

The results indicate that the RTX spray has a quenching effect on the luminescence of cyanoacrylate-fumed fingermarks stained with rhodamine 6G. Hence, the application of RTX spray would not be recommended in a sequence before cyanoacrylate fuming. Future work could investigate whether the same phenomenon occurs on other types of surfaces apart from plastic, and also with other fluorescent stains.

Iodine-benzoflavone, unlike RTX, can be applied either before or after powdering. The results indicate that it is not necessary to wait until the blue mark development has faded before powdering. Tests were carried out both when the blue mark development was still visible and also when it had faded, and both showed that there was no effect on subsequent fingermark powdering. The results of this testing are in agreement with those previously reported by Pounds and Allman (16).

Iodine-benzoflavone also develops blue mark detail when applied after powdering, and hence could be used in a sequence of reagents either before or after the application of fingermark powder. It would appear more logical to use iodine-benzoflavone before powdering in a reagent sequence. However, if in certain cases the scene had already been powdered, then the iodine-benzoflavone reagent could

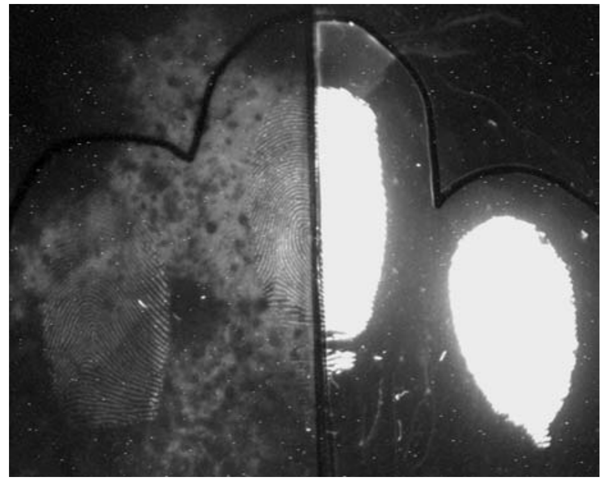

FIG. 13—*Same as Fig. 12, but with a longer integration time (11.5 s).*

FIG. 14—*Left side cyanoacrylate/stain only; right side sprayed with iodine-benzoflavone, then cyanoacrylate/stain (viewed under white light).*

still be applied to possibly develop more latent marks, or to improve the quality of those marks already developed.

The effect of iodine-benzoflavone treatment on subsequent cyanoacrylate fuming was also tested. When iodine-benzoflavone was sprayed onto the plastic surface, it developed blue marks and left a white residue over the surface (Fig. 14). This white residue, possibly unreacted benzoflavone, was unaffected by fuming with cyanoacrylate; however, it was washed off the surface when the rhodamine 6G stain was applied. The presence of the white contaminant on the surface made it difficult to assess the level of cyanoacrylate development before staining. Iodine-benzoflavone treatment did not appear to affect the degree of luminescence after cyanoacrylate fuming and rhodamine 6G staining. However, ridge detail was found to be more diffuse and unclear in parts (Fig. 15). A possible explanation for this is that the white reside from the iodine-benzoflavone treatment interferes with the ability of the cyanoacrylate to polymerize uniformly along the fingermark ridges. It is therefore not recommended that iodine-benzoflavone be applied to a surface if subsequent cyanoacrylate fuming is envisaged.

Occupational Health & Safety (OH&S) Evaluation

Iodine-benzoflavone—The use of iodine-benzoflavone at the crime scene will increase the health and safety risk to persons applying the technique. Consideration of appropriate OH&S precautions is mandatory prior to using the spray at the crime scene. A

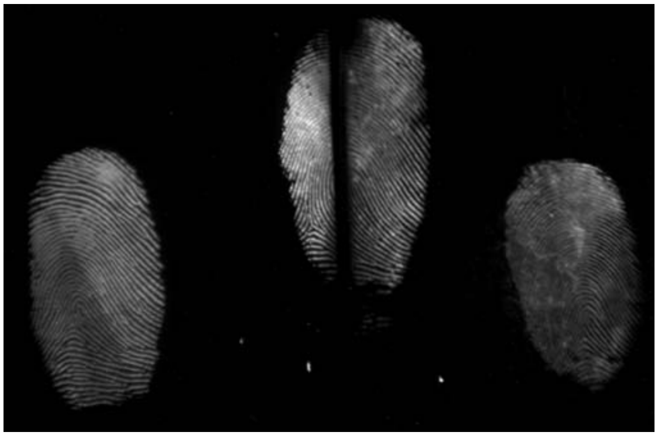

FIG. 15—*Same as Fig. 14, but viewed in the luminescence mode under 505 nm excitation with observation at 565 nm. Integration time: 1.4 s.*

preliminary assessment of the OH&S risk encountered when spraying 100 mL of iodine-benzoflavone (Arklone formulation) was carried out in 1992, and this showed that, based on a ten-minute exposure time, it is unlikely that exposure of individuals is significant and respiratory protective equipment is not expected to be needed, even if the process was carried out three to four times a day. If spraying larger amounts, however, or if the worker is to be exposed for a longer period, then respiratory protective equipment should be worn (17).

The replacement solvent recommended in this study, HFC4310mee, is similar to Arklone in that it is nonflammable and has a low toxicity. Like Arklone, HFC4310mee is highly volatile and may quickly form a concentrated atmosphere in a confined or unventilated area, and may act as an asphyxiant (18). For this reason, work must be carried out in a well-ventilated area.

OH&S precautions should include: opening all windows and doors to allow for the maximum possible ventilation of vapors, and wearing appropriate personal protective equipment, including gloves, coveralls, and a filtered breathing apparatus. The work should not be carried out in an enclosed space such as a basement. In these circumstances, application using a brush or paint roller should be considered as an alternative. Once the scene has been processed (all evidence recorded), it must be decontaminated and, if necessary, redecorated. This would involve cleaning all treated surfaces with a bleach-based solution.

RTX—Ruthenium tetroxide is classified as hazardous according to Worksafe Australia criteria (19). It is an oxidizing agent and is classified as corrosive. The substance is considered extremely toxic by all exposure routes, and may be fatal from a single acute exposure.

Exposure standard information is not available for ruthenium tetroxide; however, the toxic properties are assumed to be similar to those of osmium tetroxide and therefore it is considered highly toxic. Safety precautions given by Mashiko include that RTX processing should be carried out either in a fume hood or an adequately ventilated area; and safety goggles, chemical-resistant plastic or rubber gloves, and coveralls should be worn (20).

The previous recommendations given for the use of iodine-benzoflavone would also apply for using RTX; however, as RTX is considered more toxic than iodine-benzoflavone, respiratory equipment is recommended for its safe use at a crime scene. Further research is required to investigate the amount of airborne ruthenium tetroxide generated when spraying the commercial and HFE-based RTX reagents.

Given the toxic nature of ruthenium tetroxide, the use of iodine-benzoflavone should be considered as a safer alternative. RTX is recommended only for relatively fresh marks on wallpaper and paint, and the difference in strength of development between iodine-benzoflavone and RTX is minimal on these surfaces. The increased safety risk and the increased cost of the reagent suggest that use of the RTX spray as a crime scene technique may not be justified.

Conclusions

The purpose of this study was to evaluate iodine-benzoflavone and RTX spray reagents for the detection of latent fingermarks at the crime scene. The results indicate that there is no one universal technique that can be used on all surfaces. On some surfaces, conventional fingermark powders produced better overall results than the spray techniques; on other surfaces, the use of the spray techniques would be recommended. The most significant advantage spray techniques have over powdering would be their use on more difficult surfaces such as brick, wallpaper, and raw wood.

Comparative testing indicated that the HFC4310mee iodine-benzoflavone formulation consistently gave stronger fingermark development than the HFE7100 formulation, and hence it is recommended that HFC4310mee be the solvent used to replace Arklone. Initial testing showed that a blended solvent of 10% methanol in HFC4310mee provided darker mark development; however, it also produced background staining and some ridge diffusion. Further research is required to evaluate other formulations containing a lower concentration of methanol.

A more cost-effective RTX formulation was developed that uses HFE7100 as a carrier solvent. This formulation, stabilized with ceric ammonium nitrate, was shown to give comparable development to that obtained with the commercial reagent, at a much cheaper cost and with a shelf life of two months.

Sequencing tests indicated that iodine-benzoflavone can be used before or after powdering; however, the reagent is incompatible with cyanoacrylate fuming. RTX spray cannot be used in a sequence with powdering or cyanoacrylate (with rhodamine 6G staining).

The use of the spray reagents poses a higher health and safety risk at the crime scene than conventional powders. This leads to increased costs in terms of personal protective equipment and scene cleanup. However, the increase in performance on some surfaces such as wallpaper, vinyl, and especially brick, justifies the extra cost and effort.

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