JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, May 2010, Vol. 55, No. 3
doi: 10.1111/j.1556-4029.2010.01346.x
Available online at: interscience.wiley.com

TECHNICAL NOTE

CRIMINALISTICS; QUESTIONED DOCUMENTS

Andrew Parkinson,[1] *B.Sc.; Michael Colella,*[1] *M.Sc; and Tegan Evans,*[1] *B.Sc.*

The Development and Evaluation of Radiological Decontamination Procedures for Documents, Document Inks, and Latent Fingermarks on Porous Surfaces*†

ABSTRACT: Criminal acts such as an attack utilizing a radiological dispersal device (RDD or dirty bomb), the manufacture of such a device, or the illicit trafficking of radioactive materials would warrant a criminal investigation. This could involve the collection, transportation, and analysis of radiologically contaminated trace evidence. But are law enforcement agencies and forensic scientists capable of dealing with this? This research investigates the decontamination efficacy of two decontamination techniques (chemical and physical) designed for the removal of radiological material from documents of forensic importance. The impact that these procedures have on the development of latent fingermarks and the forensic analysis of the inks on these documents is also studied. It was found that slight changes in the color and chemical composition of a variety of document inks and a destruction of fingermark ridges occurred after chemical decontamination. Physical decontamination had no impact on these parameters.

KEYWORDS: forensic science, radiological forensics, radiological decontamination, counter terrorism, document inks, latent fingermarks, document examination

The continual illicit trafficking of radiological and nuclear materials has prompted an increase in awareness of crimes involving these materials. Within the period of January 1993 to December 2008, there have been 1562 confirmed incidents of nuclear materials trafficking reported to the International Atomic Energy Agency (IAEA) (1). This alarming statistic indicates that there is a potential for criminals to use radiological materials for malevolent purposes. The possibility of criminal acts such as an attack utilizing a radiological dispersal device (RDD), the manufacture of such a device, or illicit trafficking of radioactive materials would warrant a criminal investigation. This could involve the collection, transportation, and analysis of radiologically contaminated trace evidence. But are law enforcement agencies and forensic scientists capable of dealing with this?

Traditional forensic laboratories may not be able to receive and analyze radiologically contaminated evidence, because they do not have the appropriate instruments and equipment to contain the radioactive contamination and perform the forensic procedures safely. On the other hand, nuclear facilities are able to handle radiological materials, although often they do not have the forensic instrumentation or the expertise to do the appropriate analysis. A solution to this problem would be to have a forensic facility in a nuclear complex. However, with many countries not having these facilities, procedures need to be in place, so that the radiological contamination can be removed from the evidence or lowered to safe levels prior to it entering a forensic laboratory.

Previous studies (2,3) have developed decontamination procedures for forensic evidence contaminated with chemical and biological materials; however, no research and development has been undertaken for radiological contamination. While numerous radiological decontamination products and technologies are available on the market, they are usually tested and used during the decommissioning and decontamination of hard, nonfragile surfaces in nuclear facilities. These procedures may not be suitable for forensic evidence because of the fact that it is found in trace amounts and is fragile in nature. Any procedure that destroys or alters the evidence in any way will have a dramatic impact on the forensic investigation.

Document analysis, as part of a forensic investigation, determines the integrity of written communications and records. It involves the analysis of documents recovered as evidence using a variety of scientific processes and methods. Document analysis may be used to establish the legitimacy of a document (forgery, alterations, additions, or deletions); identify or eliminate persons as the source of handwriting; or identify or eliminate the source of writing or other impressions and marks (4). To do this, the examiner usually analyzes a number of components within the document. These can include writing and printing inks (5–7), paper varieties (8), and latent fingermarks (9,10).

The removal of radiological material from document evidence is problematic. The fact that the documents are generally fragile and can contain inks and latent fingermarks dictates the methods used. Therefore, a low impact technique is recommended, so that these attributes can be preserved. In this study, a chemical

---

[1] Australian Nuclear Science & Technology Organisation, PMB 1, Menai, NSW, Australia 2234.

*Presented at the 2008 International Association of Forensic Sciences Meeting, July 21–25, 2008, in New Orleans, LA.

†Supported by the Australian Government Department of Prime Minister and Cabinet, Australian Nuclear Science & Technology Organisation, and the Australian Federal Police (Contract: NSST 06-032).

Received 9 Sept. 2008; and in revised form 16 Feb. 2009; accepted 4 April 2009.

decontamination technique and a physical decontamination technique were developed to lower radiological contamination from document evidence. A number of forensic techniques were utilized to analyze the document ink and latent fingermark components before and after decontamination to determine whether they were impacted by the decontamination procedure.

Materials and Methods

Contamination of the Documents

Three radioactive isotopes were chosen to represent the range of commercially available isotopes. Because of the limited availability of certain radioisotopes, suitable surrogates with similar physical and chemical properties were used. These isotopes and their surrogates are outlined in Table 1.

Under controlled conditions, the documents were contaminated under the following procedure:

- Background radiation readings (in triplicate) were taken using a Ludlum™ 3030 Alpha-Beta sample counter (Ludlum Measurements, Inc., Sweetwater, TX) at a 2-min counting time.
- Using an air displacement pipette (Finnepipette™, Thermo Fisher Scientific, Waltham, MA), 0.5 mL of the radioactive solution was dispensed onto the document.
- The documents were left overnight to dry (*c.* 18 h).
- A contamination reading was recorded using the Ludlum™ 3030 Alpha-Beta sample counter (2-min counting time).

Development, Optimization, and Validation of the Decontamination Procedures

A chemical decontamination technique and a physical decontamination technique were chosen as the methods of choice as they are both very cheap, easy to perform, and have the potential to provide good decontamination values. The physical decontamination method involved simply scraping the surface of the document with a straight edge (e.g., scalpel or knife) followed by the use of a pencil eraser to remove any excess contamination.

The chemical technique involved the sonication (Unisonics™—Ultrasonic cleaner, Unisonics Australia Pty Ltd, Brookvale, Australia) of the document evidence in a solution of DEZ-1 decontamination agent (Raddez Chimmed™; Russia). This product is a complexing agent, consisting of a powdered mixture of surface-active substances and chelating agents. As documents usually contain printing and writing inks, two solvent systems were utilized to ensure the inks were not destroyed. These were deionized water (Modulab IIW, Continental Water Systems, San Antonio, TX) and cyclohexane (Lab Scan Analytical Sciences, POCH S.A., Gliwice, Poland).

A variety of experiments were completed to optimize the chemical technique's ability to remove Cs-137 from copy paper (Mondi™ Triolex recycled business paper) and to minimize sample damage. These included experiments involving changes in decontamination solution concentrations (0%, 5%, 10%, and 25%) and changes in sonication times (0, 5, 10, 15, 20, 25, and 30 min).

Scanning electron microscopy (SEM) was used to confirm the decontamination efficacy measurements obtained using the alpha–beta counter. To do this, the paper samples were placed in a 5% solution of stable cesium nitrate (Fluka® Chemicals, Milwaukee, WI), to simulate Cs-137 contamination, and decontaminated with the optimized chemical procedure. Backscatter electron imaging on the SEM was used to determine whether the cesium had been removed from the paper and also to determine whether there was any damage to the paper's structure. Pre- and postdecontaminated documents were mounted onto graphite stubs and then analyzed on a JEOL JSM-6400 SEM using an attached Noran Instruments Voyager Series IV X-ray microanalysis system. The SEM was operated at an accelerating voltage of 15 kV.

Once the chemical technique was optimized, it was compared with the physical technique via the decontamination of a variety of radioisotopes (Cesium 137, Strontium 85, and Yellowcake [U_3O_8]).

The Decontamination Procedure and the Evidential Forensic Interpretation

The validated chemical and physical procedures were evaluated to determine whether they had any effect on the forensic procedure and interpretation. The impact that these procedures had on fingermark development and the analysis of documents inks was investigated.

Latent Fingermark Development—Because of the fragile nature of latent fingermarks, it is unlikely that they would survive the decontamination procedures. Therefore, four common fingermark reagents (ninhydrin, diazafluoren-9-one [DFO], zinc indanedione, and physical developer) were used to develop latent fingermarks prior to and after the decontamination procedures. The developed marks were analyzed before and after decontamination to determine whether their ridge detail remained intact.

All the reagents and techniques used to visualize latent fingermarks are standard methodologies endorsed by the Forensic & Technical Services Laboratory of the Australian Federal Police (AFP). Specific details about the reagent formulations can be obtained from the AFP handbook (11). The enhanced marks were

TABLE 1—*Properties of the radioisotopes used to contaminate the documents.*

Radioisotope of Concern	Surrogate Used in Experimentation	Surrogate's Properties
Cesium-137	Cesium-137 in 0.5 M HCl + 0.5 M HNO_3 solution Supplier: Idaho Isotope International, Idaho Falls, ID	Half-life = 30.1 years Radiation type = γ, β radiation Form = $CsNO_3$ in 500 mL water Specific activity ~ 250 cps/mL
Americium-241	Uranium-238 (Yellowcake/U_3O_8) suspended in water Supplier: ANSTO, Lucas Heights, Australia	Half-life = 4468 million years; Radiation type = γ, α radiation; Form = U_3O_8 in 500 mL water Specific activity ~ 220 cps/mL
Strontium-90	Strontium-85 in 0.5 M HCl + 0.5 M HNO_3 solution Supplier: Perkin Elmer Life Sciences, Waltham, MA	Half-life = 64.8 days; Radiation type = β radiation; Form = $SrNO_3$ in 500 mL water Specific activity ~ 180 cps/mL

recorded using a Nikon© D70 digital SLR in conjunction with Tamron© SP AF Di 90 mm macro lens. General details of the processes used to enhance and image the fingermarks are as follows.

Diazafluoren-9-one (DFO) Reagent—Latent marks on the paper substrate were processed by submersing them in a 50-mL bath of diazafluoren-9-one (Lightning Powder Company®, Jacksonville, FL) reagent for 30 sec. The substrates were removed and allowed to air-dry for 15 min and finally placed on a press (Singer™ Elna Magic Steam Press, La Vergne, TN) at a preset temperature of 165°C. Fingermarks were visualized in luminescent mode using a Polilight® (Rofin, Melbourne, Australia) set to the specific wavelength of 530 nm and imaged using a red 590-nm barrier filter.

Ninhydrin Reagent—In a similar method to DFO, latent marks on paper were processed by submersing them in a 50-mL bath of ninhydrin reagent for 20–30 sec. The substrates were removed and allowed to air-dry for 2 h. Fingermarks were imaged using a Polilight® set to white light band.

Zinc Indanedione—Latent marks on paper were processed by submersing them in a 50-mL bath of zinc indanedione reagent for 30 sec. The substrates were removed and allowed to air-dry for 15 min and finally placed on a press (Singer™ Elna Magic Steam Press) at a preset temperature of 165°C. Fingermarks were visualized in luminescent mode using a Polilight® set to the specific wavelength of 505 nm and imaged using an orange 550-nm barrier filter.

Physical Developer—The deposited fingermarks were developed using a multi-step process. Preliminary steps required the marks to be soaked in distilled water for *c.* 10 min followed by a bath containing maleic acid (Chem-Supply©, Port Adelaide, Australia) for 5 min, then placed into a second bath of distilled water for *c.* 10 min. The prepared marks were then placed into a working solution of physical developer for 10–15 min (or until there was sufficient ridge detail and contrast with the substrate), removed, and rinsed in distilled water for *c.* 15 min. The air-dried fingermarks were imaged using a Polilight® set to white light band.

Document Ink Analysis—A range of commonly found document inks on printer paper were put through the validated decontamination procedures and analyzed using a variety of forensic techniques to determine whether the procedures had an adverse impact on the document inks. This included red, blue, and black ballpoint pen inks (BIC® medium [Clichy, France]), felt tip marker inks (Artline® 700), and gel pen inks (Uniball© micro [Mitsubishi Pencil Co. Ltd., Tokyo, Japan]); and cyan, magenta, yellow, and black inkjet printer inks (HP™ Vivera Photosmart 4280 [Hewlett-Packard Company, Palo Alto, CA]), and laser printer inks (Xerox™ laser [Xerox Corporation, Norwalk, CT]) analyzed using the techniques outlined below.

Microspectrophotometry (MSP)—The SEE 2100 microspectrophotometer (CRAIC Technologies™, San Dimas, CA) integrated with proprietary spectral software was used to gain objective color information on the various ink samples. MSP measurements were in reflectance mode (15× objective magnification). The intensity (in % reflectance) versus wavelength (in nm) was measured between 380 and 880 nm, at 50 scans per measurement, using a 75 W Xenon lamp.

A reference scan of the background (print media paper) was taken before collecting five sample scans at different positions along the length of the sample, to account for inherent variations (e.g., nonhomogeneous uptake of ink, surface anomalies, thickness, and the presence of contaminants). Further treatment of the data with spectral software allowed the results to be presented in the form of average spectra.

Video Spectral Comparator (VSC)—The Video Spectral Comparator 2000 High Resolution (Foster and Freeman™ VSC 2000HR) was used to examine the luminescent properties of the control and the decontaminated ink and paper samples in the visible and ultraviolet (UV) regions of the spectrum. The digital images were exported to a commercially available image manipulation software package (Adobe™ Photoshop® 5.0) for offline processing.

Thin Layer Chromatography (TLC)—TLC was performed using Merck™ TLC Silica gel 60 F_{254} plates. The extraction and development methodology was adapted from the ASTM Standard Guide for Test Methods for Forensic Writing Ink Comparison (12). All ink samples were removed from the paper substrate by cutting *c.* 1 cm of the ink line from the document, followed by extraction with the appropriate solvents in micro vials (Agilent Technologies©, Santa Clara, CA).

All ballpoint and laser printer inks were extracted from the paper substrate using 20 μL of pyridine (AJAX© Chemicals, Sydney, Australia), and all felt tip, gel, and inkjet inks were extracted with a 20-μL mixture of absolute ethanol (Chem-Supply©) and distilled water (50:50 v/v). All the extracted solutions were spotted onto the activated plate (activated by heating the TLC plate to 100°C for 10 min) using glass capillary tubes and allowed to air-dry to remove any residual extraction solvent. A paper blank was spotted onto each plate as internal reference standards.

All plates were developed using a mobile phase solvent system consisting of ethyl acetate, absolute ethanol, and distilled water (70:35:30 v/v, respectively). The solvent front was allowed to elute a distance of ~5 cm from the origin of the ink spots. The developed plates were imaged and digitally recorded under white light and long wavelength UV light (350–650 nm). The TLC plate images were enhanced (i.e., brightness, color, and contrast) using Adobe™ Photoshop image processing software to allow for more accurate measurements of the retention factor (R_f) values of the samples.

Results and Discussion

Development, Optimization, and Validation of the Decontamination Procedures

The addition of the DEZ-1 concentrate to water and cyclohexane increased the solutions' decontamination efficacy dramatically. When no decontamination agent was used, values of 88% in water and 0.2% in cyclohexane were achieved. With the addition of DEZ-1 into the solutions, the decontamination efficacy was increased to 97% for both solvent systems. Even with these high decontamination values, the documents were unable to be decontaminated to background radiation levels and were often seen at 10× the background level. Figure 1 shows that no improvements in decontamination efficacy occur when the concentration of DEZ-1 was increased systematically from 2% to 25% in both the solvents. In fact at the higher concentrations of DEZ-1, there was an increase in destruction of the paper sample. Therefore, the optimized concentration of the tested DEZ-1 solutions is 2% in water and cyclohexane.

By increasing the time the documents spent in the ultrasonic bath, the decontamination efficacy remained relatively constant. It can be seen in Fig. 2 that some slight increases in the % decontamination could be seen at the longer sonication times (15–30 min); however, this would be attributed to the destruction of the

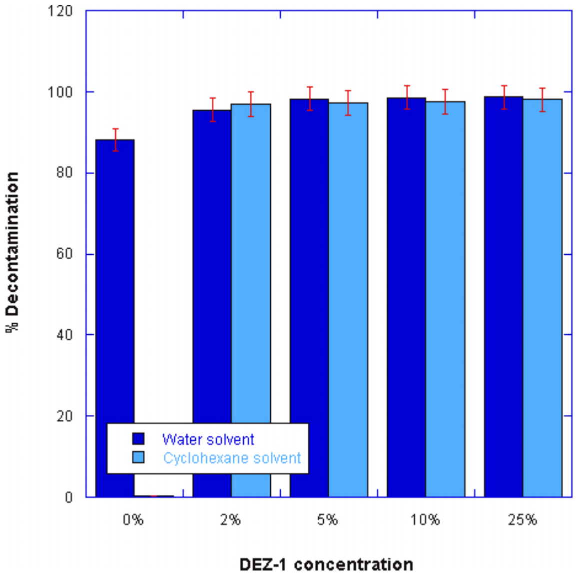

FIG. 1—*Decontamination efficacy with varying DEZ-1 concentrations.*

documents instead of an improvement in decontamination efficacy. It was also seen that sonication provides a significant improvement in decontamination when compared to the simple soaking/washing (0 min) of the documents. From these results, sonication times over 5 min are not recommended as this increases the risk of document destruction without any significant increase in decontamination efficacy.

To enhance the decontamination efficacy measurements obtained using the alpha–beta counter, SEM was used to image the decontamination process. The backscatter images (Fig. 3) indicate that the contaminated paper has three constituents. Further analysis using energy dispersive X-ray (EDX) spectroscopy indicates that these constituents are the carbon-based paper (dark areas), calcium carbonate and calcium alumino silicates (gray area), and the contaminating cesium nitrate (bright spots). The majority of the cesium nitrate is removed after decontamination; however, it can be seen in the postdecontamination EDX spectra of the calcium alumino silicates (Fig. 4) that it still contains cesium. This would be attributed to the cesium's strong affinity to the alumino silicates.

Both the results of the alpha–beta counter and the SEM analysis suggest that the total removal of radioactive contamination from the porous paper is very difficult because of the radioactive ions' affinity to the alumino silicates in the paper. Therefore, these decontamination procedures should be considered primarily as a method to reduce the level of radiation from a contaminated document (i.e., increase safe handling), not a method for the complete removal of radioactive species. It is also important to consider the radiological clearance standards of the appropriate authorities to

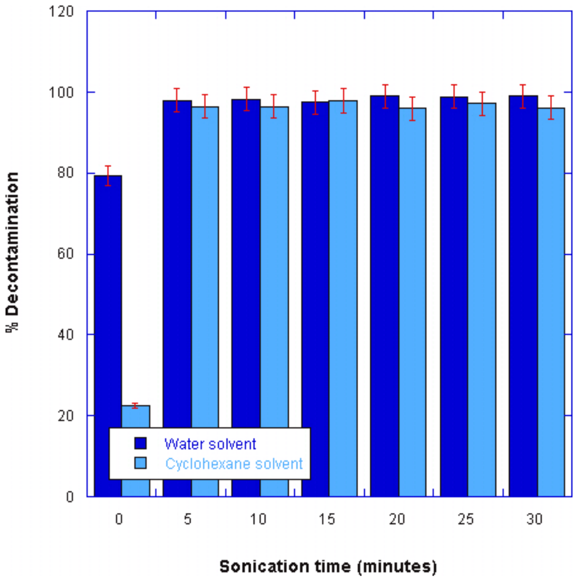

FIG. 2—*Decontamination efficacy with variations in ultrasonic cleaning time.*

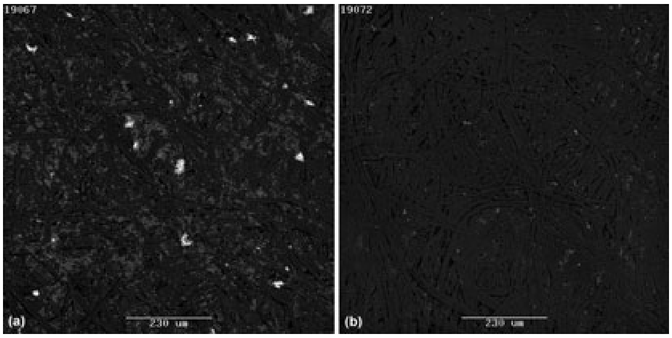

FIG. 3—*SEM backscatter imaging of Cs contaminated printer paper (a) predecontamination and (b) postdecontamination.*

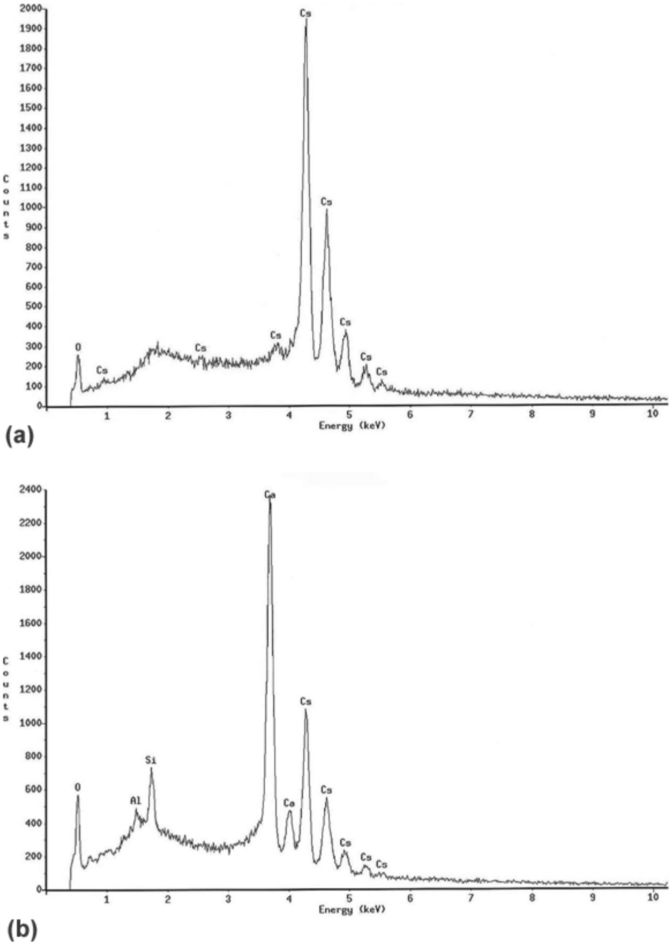

FIG. 4—*Energy dispersive X-ray spectra (a) cesium nitrate particulates (bright spots), (b) contaminated calcium alumino silicate (gray area).*

determine whether the evidence can be classified as "safe." Using the Australian Nuclear Science and Technology Organisation's (ANSTO) radiological clearance standards, all the decontaminated samples were classified to have safe levels of radiation.

The comparison of the optimized chemical method with the physical decontamination method provided some interesting results. The chemical decontamination procedure was the most successful method for the removal of the liquid cesium-137 and strontium-85 isotopes from the paper samples, giving decontamination values of 97% in water and 92% in cyclohexane. The physical method was unsuccessful at decontaminating both of these isotopes, with decontamination values of 1.2 and 0.2%, respectively. However, the physical method was much more successful at removing the yellowcake particulates from the documents. In this scenario, decontamination values of 99% were achieved using the physical method, while values of 85–89% (water) and 45–60% (cyclohexane) were achieved using the chemical methods.

From these results, it is recommended that if decontamination is required and the contaminating radioisotope is in the liquid form (e.g., cesium and strontium), then a chemical method using 2% DEZ-1 solution in water or cyclohexane may be used. When the contaminating radioisotope is in a solid form (i.e., yellowcake), then a physical method (e.g., eraser) can be used to remove the contaminant.

The Decontamination Procedure and the Evidential Forensic Interpretation

Latent Fingermark Development—As expected, none of the techniques was able to develop fingermark ridges after the chemical or physical decontamination procedure had occurred. From this result, it would suggest that all of the amino acid, protein, and sebaceous oil components are being totally removed from the paper by the ultra sonic cleaning process and physical scraping process.

However, when the chemical decontamination procedure followed the fingermark development, in some instances, all of the ridge details were maintained. This was dependent on the development technique, with some techniques being more susceptible to the decontamination procedure. Figure 5 shows that the ninhydrin and zinc indanedione developed marks were destroyed by the chemical decontamination procedure, while the diazafluoren-9-one and physical developer enhanced marks maintain their quality and ridge detail. This observation implies that the reaction products of these reagents with the amino acids in the fingermarks are more robust than that obtained when ninhydrin or zinc-indanedione is reacted. Physical decontamination had no impact on any of the developed marks (results not shown).

From these results, it is suggested chemical decontamination has to follow fingermark development using either diazafluoren-9-one or physical developer. If other developmental techniques are needed, then the developed fingermark should be photographed and recorded before it is chemically decontaminated as it will be destroyed after this procedure.

Document Ink Analysis—From the validation experiments, it was observed that the different ink types behaved differently to the different solvents. As a result, the methods listed in Table 2 are the recommended methods for the removal of solid and liquid radiological materials from documents containing the inks that were tested. However, because only one manufacturer for each ink sample was studied, these results would vary in real life because of the large variety of manufacturers found on the market. A more extensive study, involving a variety of manufacturers, would be needed to further validate these methods for a variety of ink types.

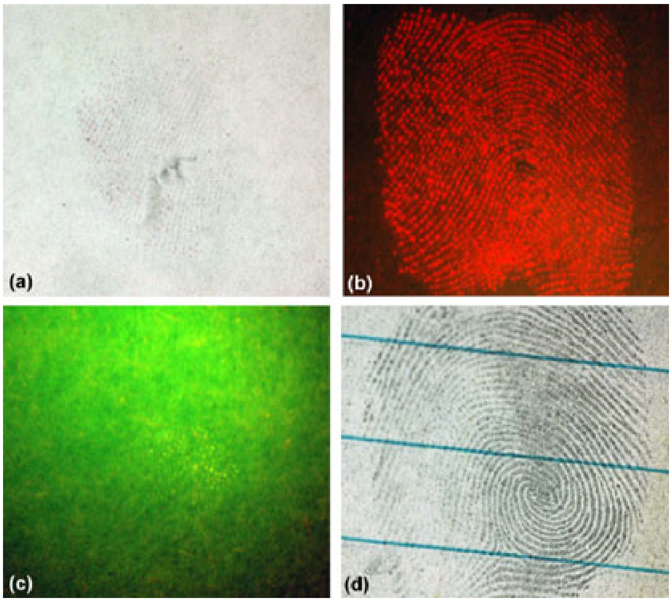

FIG. 5—*Developed fingermark with (a) ninhydrin (b) diazafluoren-9-one, (c) zinc indanedione and (d) physical developer after chemical decontamination.*

When these decontamination methods were used and the document inks were analyzed postdecontamination using MSP, VSC, and TLC, it was found that the physical decontamination technique had no effect on the forensic interpretation of the document ink evidence. However, the chemical decontamination procedure did impact the quality of the inks.

It can be seen in the proceeding sections that the chemical method slightly alters the color and photoluminescent properties of some of the document inks and therefore could result in a misinterpretation of the data during the forensic examination. Each of the instrumental techniques are described later and compare samples that have not been decontaminated to samples that have been treated with the physical and chemical decontamination procedures. Because of the large amount of data, only the results of the most dramatic changes are reported.

Microspectrophotometry (MSP)—The MSP data indicate that the chemical decontamination procedure generates some slight color changes in a variety of colors of a variety of ink samples, while the physical decontamination technique has no impact. It is these color changes that could result in a misinterpretation of the MSP results during a forensic comparison process.

The destruction of the spectral properties seems to be random, not limited to type or color of ink, and is very hard to predict. Peak shouldering, peak broadening, and wavelength shifts were seen to occur in the red ballpoint pen, red felt tip pen, blue gel pen, and magenta inkjet printer inks, while the other inks maintained their spectral properties (results not shown). This data can be seen in Fig. 6.

TABLE 2—*Validated decontamination methods for radiological material on documents.*

Ink Type	Liquid Contaminants	Solid Contaminants
Ballpoint inks	2% DEZ-1 in water	Physical method
Felt tip inks	2% DEZ-1 in water	Physical method
Gel pen inks	2% DEZ-1 in cyclohexane	Physical method
Inkjet printer inks	2% DEZ-1 in cyclohexane	Physical method
Laser printer inks	2% DEZ-1 in water	Physical method

The cause of the changes in the inks' spectral properties would be attributed to a variety of interactions between the inks and the decontamination agent. DEZ-1 contains a mixture of chelating agents and surface-active substances (detergents). The chelating agents are designed to react with ions, and the detergent then removes the newly formed complex from the substrate. It is these chelating agents that could be removing ions from the molecules in the inks and thus changing its spectral properties. This type of interaction could be the cause of the observed alteration in wavelengths (e.g., peak shouldering and peak broadening).

Video Spectral Comparator (VSC)—The filtered light examinations using the VSC showed some interesting changes after the chemical decontamination technique was applied. These changes complemented the changes seen in the MSP spectra described in the previous section. Like the other results, the physical decontamination had no impact on the interpretation of the VSC results.

The major change that occurred in the inks, after chemical decontamination, was the dispersion of the ink into the surrounding paper and an increase in the inks' luminescence under filtered color and UV light. The increase in luminescent properties of ink samples could result in an incorrect comparison between a sample that has been chemically decontaminated and one which has not. This poses a problem during the forensic interpretation of the document evidence containing these inks.

These changes were not specific for each type of ink and therefore could not be predicted. In general, the writing inks (ballpoint, felt tip, and gel) were more susceptible to this change than the printer inks (inkjet and laser). The results for the red ballpoint pen, red felt tip pen, blue gel pen, and magenta inkjet printer inks are shown in Fig. 7.

Thin Layer Chromatography (TLC)—TLC was used to analyze the dye components of each of the document inks and to determine whether their properties were altered by the decontamination techniques. If the mobility of any of the components changed after decontamination, this would indicate that the chemical composition of that dye had been altered.

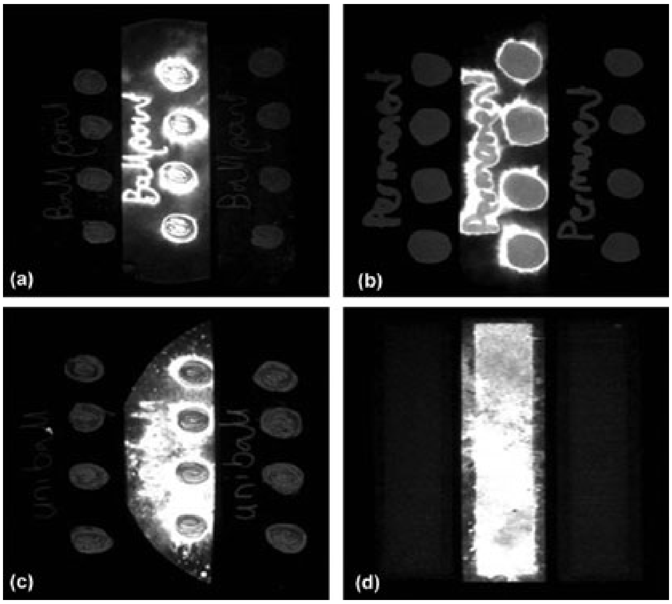

FIG. 7—*Video Spectral Comparator of (a) red ballpoint, (b) red felt tip, (c) blue gel and (d) magenta inkjet inks under 480–620 nm filtered light (no decon [left], chemical decon [middle], physical decon [right]).*

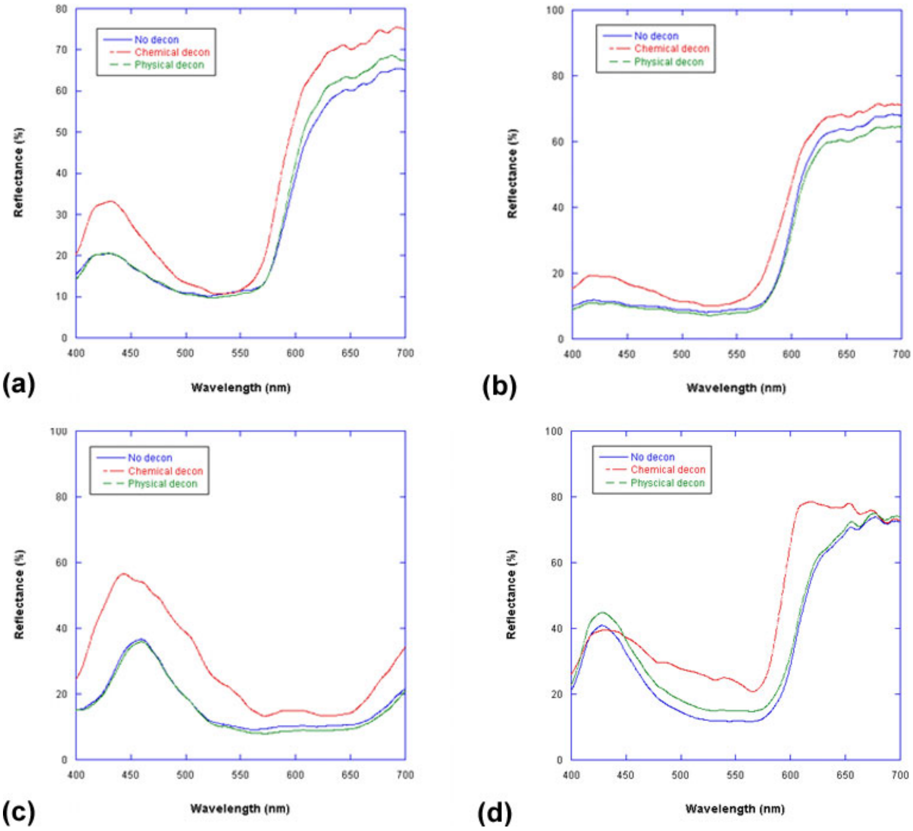

FIG. 6—*Microspectrophotometry of (a) red ballpoint, (b) red felt tip, (c) blue gel, and (d) magenta inkjet inks after physical and chemical decontamination.*

On each of the chromatograms (Fig. 8), the reference ink sample (1) was spotted next to ink samples that had undergone chemical (3) and physical (5) decontamination. Paper blanks (2, 4, and 6) were also spotted next to each of the ink samples to ascertain whether the impact was just on the ink or on the paper as well.

It can be seen in Fig. 8 that the chemical decontamination technique has impacted on the mobility of some of the ink bands in a number of the writing ink samples (ballpoint, gel, and felt tip), while the physical procedure has no effect. This would suggest that the chemical composition of these inks has slightly changed during the chemical decontamination process. The likely cause of these changes would be the interaction of the chelating agents in the decontamination solution with the components in the dyes (as described previously). These chemical alterations would also account for the color and luminescent changes seen in the MSP and VSC data.

Interestingly, there were no changes in the printer ink chromatograms. The mobility of each of the ink bands remains relatively consistent after chemical and physical decontaminations. As changes in the MSP and VSC data were seen with these samples, it would suggest that these inks do not undergo chemical change but instead are more likely diluted into the solution.

Conclusion

The illicit possession, trafficking, and use of radiological materials would warrant a criminal investigation with the forensic exploitation of physical evidence playing a pivotal role. With no validated decontamination procedures in place to remove or lower harmful radiological contamination from the evidence, the forensic analysis and potential convictions could be compromised.

This study has developed two decontamination techniques (physical and chemical) that can be utilized to lower radiological material from a variety of contaminated document evidence. Total decontamination of the documents was not achieved; however, the procedures were able to lower the amount of contamination to safe levels (under ANSTO guidelines).

As documents often contain a number of other types of evidence, including inks and latent fingermarks, their forensic analysis is very complex. The analysis of these components with a variety of forensic techniques indicated that the chemical decontamination procedure had an impact on the forensic interpretation of the results, while the physical decontamination had no impact on these parameters. Slight changes in the color and chemical composition of a variety of document inks and the destruction of fingermark ridges could pose a problem during the forensic exploitation of the evidence after chemical decontamination.

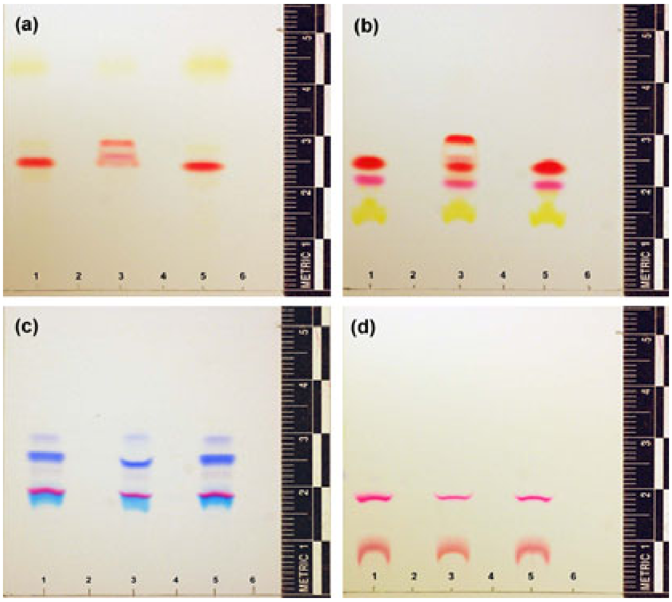

FIG. 8—*TLC chromatograms of (a) red ballpoint, (b) red felt tip, (c) blue gel and (d) magenta inkjet inks (no decon [1], chemical decon [3], and physical decon [5]).*

No decontamination and analysis of the documents in a certified environment would be the best option; however, this may not be always possible (lack of instrumentation and expertise). Therefore, the challenges mentioned have to be carefully considered before these procedures are utilized by the forensic scientist.

Acknowledgments

The authors acknowledge Mr. David Hill and Mr. Joel Davis, Australian Nuclear Science & Technology Organisation and Prof. Claude Roux and the staff from the Centre for Forensic Science, University of Technology, Sydney for their unwavering scientific and technical assistance throughout this study.

References

1. International Atomic Energy Agency illicit trafficking database fact sheet. Vienna, Austria: International Atomic Energy Agency, http://www-ns.iaea.org/downloads/security/itdb-fact-sheet-2009.pdf
2. Hoile R, Walsh SJ, Roux C. Bioterrorism: processing contaminated evidence, the effects of formaldehyde gas on the recovery of latent fingermarks. J Forensic Sci 2007;52(5):1097–102.
3. Wilkinson DA, Hulst AG, Reuver LP, Krimpen SH, Baar BM. The fate of the chemical warfare agent during DNA extraction. J Forensic Sci 2007;52(6):1272–83.
4. American Society for Testing Materials (ASTM) Designated E444-07. Standard guide for scope of work of forensic document examiners. West Conshohocken, PA: American Society for Testing Materials, 2007.
5. Adam CD, Sherratt SL, Zholobenko VL. Classification and individualisation of black ballpoint pen inks using principal component analysis of UV-vis absorption spectra. Forensic Sci Int 2008;174(1):16–25.
6. Laporte GM, Arredondo MD, Mcconnell TS, Stephens JC, Cantu AA, Shaffer DK. An evaluation of matching unknown writing inks with the United States International Ink Library. J Forensic Sci 2006;51(3):689–92.
7. Saferstein R. Criminalistics: an introduction to forensic science, 8th edn. New Jersey: Pearson Prentice Hall, 2004.
8. Giles A. The forensic examination of documents. In: White P, editor. Crime scene to court: the essentials of forensic science. Cambridge: The Royal Society of Chemistry, 1998.
9. Olsen RD, Lee HC. Identification of latent marks. In: Lee HC, Gaensslen RE, editors. Advances in fingerprint technology. 2nd edn. Boca Raton, FL: CRC Press LLC, 2001;41–61.
10. Lee HC, Gaensslen RE. Methods of latent fingermark development. In: Lee HC, Gaensslen RE, editors. Advances in fingerprint technology. 2nd edn. Boca Raton, FL: CRC Press LLC, 2001;105–75.
11. Stoilovic M, Lennard C. Workshop manual—fingerprint detection and enhancement, incorporating the application of optical enhancement techniques in forensic science, 3rd edn. Canberra: Australian Federal Police, 2006.
12. American Society for Testing Materials (ASTM) Designated E1422-01. Standard guide for test methods for forensic writing ink comparison. West Conshohocken, PA: American Society for Testing Materials, 2007.

Additional information and reprint requests:
Andrew Parkinson, B.Sc.
Australian Nuclear Science & Technology Organisation
Private Mail Bag 1
Menai, NSW
Australia, 2234
E-mail: andrew.parkinson@live.com.au