J Forensic Sci, May 2003, Vol. 48, No. 3
Paper ID JFS2002421_483
Available online at: www.astm.org

Myriam Azoury,[1] M.Sc.; Rachel Gabbay,[2] M.Sc.; Drorit Cohen,[1] B.A.; and Joseph Almog,[3] Ph.D.

ESDA Processing and Latent Fingerprint Development: The Humidity Effect

ABSTRACT: The influence of humidification in the ESDA process on subsequent development of fingerprints on paper items was studied. It was found that, while the DFO process is nearly insensitive to previous humidification, fingerprint development with ninhydrin or with indanedione can be significantly affected by previous humidification of the paper.

KEYWORDS: forensic science, latent fingerprints, ESDA, humidity, ninhydrin, DFO, 1,2-indanedione, paper, questioned documents

Paper evidence is commonly encountered in cases of forgery, fraud, extortion, and kidnapping, as well as in association with terrorist activity. These paper items often undergo two consecutive examinations in forensic laboratories: ESDA (Electrostatic Detection Apparatus, Foster & Freeman, UK (1,2) for the detection of indented impressions and a subsequent search for latent fingerprints by optical, physical, and chemical techniques. Previous studies have stated that the ESDA process should be performed before chemical fingerprint development (3), and this is generally the sequence found in most forensic laboratories.

For indented writing recovery, the paper evidence is often exposed to high humidity prior to ESDA processing (4–8). The effect of humidity conditioning prior to ninhydrin treatment was previously investigated by Moore (3), who recommended refraining from keeping paper exhibits in the ESDA humidifier for extended periods of time.

The present study was designed to evaluate the effect of humidity conditioning for various exposure periods on the quality of fingerprints developed with three chemical reagents: DFO, ninhydrin, and indanedione (the latter in two formulations). Paper exhibits of two types with "controlled" fingerprints were left for different periods of time in the ESDA humidifier, processed by ESDA, and finally treated with the above-mentioned fingerprint reagents.

Methodology

Exhibits

Two types of paper were used in this study: A4/80 g white printer paper (Paper 1, Kym Lux, Finland) and white writing paper with a blue grid of the kind often found in student notebooks (Paper 2). Sequential natural fingerprints ranging from strong to weak ("depletion" prints) from ten "good" and "average" donors were deposited on paper samples. Each set of depleted prints was obtained by successive impressions of the same finger. A total of 160 sets of eight or nine depleted fingerprints were prepared on each type of paper by repeating the print deposition process. Each set of depleted prints was then cut in two vertically so that one half of each print would be on each side of the cut.

Within one to eight days after the fingerprints had been deposited, the right side of each set of depleted fingerprints underwent the ESDA process. The left side of each set of depleted prints became the "control" side and was processed only for fingerprints.

Humidity and ESDA Processing

Forty sets of each type of paper (right half only) were left in the ESDA humidifier for periods of 2, 4, 15, and 60 min. While the manufacturers' instructions state that the humidifier "maintains an atmosphere of approximately 100% RH," (9), measurements with a hygrometer showed that under normal ESDA conditions a relative humidity of 80 to 95% is achieved. The variation is apparently due to the influx of ambient air when the humidifier is opened to wipe condensation from the lid and insert the document.

Studies on the optimization of the ESDA technique have used a special chamber (4,5) or room (7,8) to allow the paper to equilibrate in a temperature and humidity-controlled environment prior to ESDA processing and even during processing (7,8). For the purposes of the present study, we chose to use the humidifier supplied by the manufacturer of the ESDA and hope to study the effectiveness of such environmental controls on fingerprint processing in another ongoing project.

After the appropriate length of time in the humidifier, the samples were immediately processed by ESDA according to the manufacturers' instructions (9). The ESDA results were not recorded in this study.

Fingerprint Treatment

Following the ESDA process, the paper samples were left at ambient environment for a period of 2 to 3 h. Both halves of each set of depleted prints were then processed together for latent fingerprints. As shown in Table 1, for each type of paper and length of

[1] Latent Fingerprint Laboratory, Division of Identification and Forensic Science (DIFS), Israel Police, National H.Q., Jerusalem, Israel.
[2] Questioned Documents Laboratory, Division of Identification and Forensic Science (DIFS), Israel Police, National H.Q., Jerusalem, Israel.
[3] Casali Institute of Applied Chemistry, The Hebrew University of Jerusalem, Israel.
Received 7 Dec. 2002; accepted 6 Jan. 2003; published 1 April 2003.

TABLE 1—*Layout of the experiments including ESDA humidifier time storage, and fingerprint treatment applied to each type of paper.*

No. Sets of Depleted Prints	Storage Time in ESDA Humidifier Prior to ESDA Process	Fingerprint Treatment	
		Reagent	No. Sets Treated
40	2 min	Ninhydrin	10
		a. DFO / b. ninhydrin	10
		Indanedione (I)	10
		Indanedione (II)	10
40	4 min	Ninhydrin	10
		a. DFO / b. ninhydrin	10
		Indanedione (I)	10
		Indanedione (II)	10
40	15 min	Ninhydrin	10
		a. DFO / b. ninhydrin	10
		Indanedione (I)	10
		Indanedione (II)	10
40	60 min	Ninhydrin	10
		a. DFO / b. ninhydrin	10
		Indanedione (I)	10
		Indanedione (II)	10

time in the ESDA humidifier, ten sets of depleted prints were treated by dipping in one of the following reagent solutions:

DFO—0.025% solution in CFC113 also containing methanol and acetic acid. For processing, the articles were placed in a dry oven at 100°C for 30 min (10).

Ninhydrin—0.5% solution in HFE7100 also containing acetic acid and ethyl acetate. For processing, the articles were placed in the dark at ambient temperature for 2 to 8 days (10).

1,2-indanedione (formulation I, DIFS)—0.2% indanedione in HFE7100 also containing ethyl acetate. The treated articles were placed in a humidity chamber at 100°C and 55% RH for 20 min (11).

1,2-indanedione (formulation II, PSDB)—0.025% indanedione in HFE7100 also containing ethyl acetate and acetic acid. For processing, the articles were placed in a dry oven at 100°C for 10 min (12).

DFO-ninhydrin sequence—One week after DFO processing, all DFO-treated exhibits (both halves) were further treated with ninhydrin.

The layout of the experiment is presented in Table 1.

Fingerprint Evaluation

The matching half-prints of each set were then mounted side-by-side on a white paper and evaluated by a senior latent fingerprint examiner. The purple-colored fingerprints developed with ninhydrin were observed under room light. The luminescent prints developed with DFO and indanedione were illuminated with a Polilight L-500 (Rofin, Australia) at 505 nm (DFO) or 505/530/555 nm (indanedione) and viewed through a 549-nm cut-off filter (DFO and indanedione) and a 590-nm cut-off filter (indanedione).

The matching half-prints were evaluated and divided into two groups: (1) those prints with no discernible difference between the left and right sides and (2) prints with evident differences between the two halves. The latter group was further divided into two subgroups: (a) ESDA side lower quality, and (b) ESDA side higher quality. The prints of lower quality (Subgroup a) were classified again in relation to their control: (I) no difference in ridge detail, but overall print contrast decline and (II) degradation in ridge detail to such an extent that their identifiability was affected.

Results

The experimental results are shown in Tables 2 and 3 and Figs. 1 and 2. Tables 2 and 3 show the number and the quality of the fingerprints developed on each type of paper at each stage of the study. Figures 1 and 2 plot the percentage of deteriorated and enhanced fingerprints, respectively, as a function of the humidification time for each reagent and paper type. In general, the results of this study show that humidity conditioning can enhance (short exposure) or degrade (long exposure) the developed fingerprints, depending on the reagent used, the type of paper, and the conditioning time.

DFO

As seen in Table 2 and Fig. 1, humidification periods of up to 60 min are tolerable and do not affect the quality of the developed prints on both types of paper. No difference could be observed between both halves of the DFO-treated prints on 1:1 sized prints (Fig. 3*a*). Close examination of several enlarged photographs revealed only an occasional slight decline in fluorescence intensity (Fig. 3*b*). Diffusion along the ridges was not observed in DFO-developed prints, even after 60-min humidification. However, humidification for 3 h in the ESDA humidifier brought about a total deterioration (Type II) of all the latent prints on both types of paper when treated with DFO.

Ninhydrin

As previously reported (3), in this experiment it was found that extended exposure to high humidity significantly degraded latent fingerprints for the ninhydrin process. This happened on both types of paper. Humidification periods of up to 4 min caused quality decline in about 23% of the fingerprints on Paper 2, while no difference was observed on Paper 1. About 70% of the fingerprints were affected after 15 min, and total deterioration occurred after 60 min on both types of paper. As seen in Table 2, the humidification effect is detected at first by a decrease in print contrast (print Type I). Longer exposures cause degradation to ridge detail (print Type II, Fig. 4). On the other hand, humidification for *very short* periods (up to 2 min) had a favorable effect on the print quality: about 5% of the ninhydrin-treated prints on Paper 1 and 21% on Paper 2 exhibited clearer marks. Close examination of a ninhydrin-treated print, which had been stored in the humidifier for 15 min (Fig. 5), reveals a clear difference between both halves. Sharp limits between the purple-colored ridges and the white background are noticed on the left half print, in contrast to diffused limits on the ESDA-treated print. While the pore details are very sharp on the left half, they can hardly be noticed on the right half.

TABLE 2—*The effect of humidity conditioning at different exposure times on developed fingerprints.*

Fingerprint Treatment	Storage Time in ESDA Humidifier	Number of Prints: Total No. of Prints Developed	No Difference	ESDA Side Lower Quality: Total	ESDA Side Lower Quality: I	ESDA Side Lower Quality: II	ESDA Side Higher Quality
A4 White Printer Paper (Paper 1)							
DFO	2 min	68	68	0	0	0	0
	4 min	63	63	0	0	0	0
	15 min	80	80	0	0	0	0
	60 min	60	60	0	0	0	0
Ninhydrin	2 min	25	24	0	0	0	1
	4 min	20	20	0	0	0	0
	15 min	32	10	22	15	7	0
	60 min	25	0	25	0	25	0
Indanedione (I)	2 min	50	50	0	0	0	0
	4 min	53	53	0	0	0	0
	15 min	50	27	20	20	0	3
	60 min	48	15	33	5	28	0
Indanedione (II)	2 min	42	15	2	2	0	25
	4 min	42	17	0	0	0	25
	15 min	37	36	0	0	0	1
	60 min	32	25	7	0	7	0
White Writing Paper with Blue Grid (Paper 2)							
DFO	2 min	31	31	0	0	0	0
	4 min	31	31	0	0	0	0
	15 min	40	40	0	0	0	0
	60 min	35	35	0	0	0	0
Ninhydrin	2 min	23	18	0	0	0	5
	4 min	21	18	5	5	0	0
	15 min	25	8	17	0	17	0
	60 min	18	0	18	0	18	0
Indanedione (I)	2 min	58	48	4	4	0	6
	4 min	54	54	0	0	0	0
	15 min	46	43	3	0	3	0
	60 min	51	45	6	3	3	0
Indanedione (II)	2 min	58	58	0	0	0	0
	4 min	54	48	6	6	0	0
	15 min	47	30	15	6	9	2
	60 min	32	13	19	14	5	0

TABLE 3—*The effect of humidity conditioning at different exposure times on DFO-ninhydrin-treated fingerprints.*

Paper Type	Storage Time in ESDA Humidifier	Number of Prints: No. of Prints Revealed with Ninhydrin	No Difference	ESDA Side Lower Quality: Total	ESDA Side Lower Quality: I	ESDA Side Lower Quality: II	ESDA Side Higher Quality
No. 1	2 min	19	19	0	0	0	0
	4 min	18	18	0	0	0	0
	15 min	17	0	17	0	17	0
	60 min	12	0	12	0	12	0
No. 2	2 min	16	11	0	0	0	5
	4 min	10	6	4	4	0	0
	15 min	17	0	17	0	17	0
	60 min	17	0	17	0	17	0

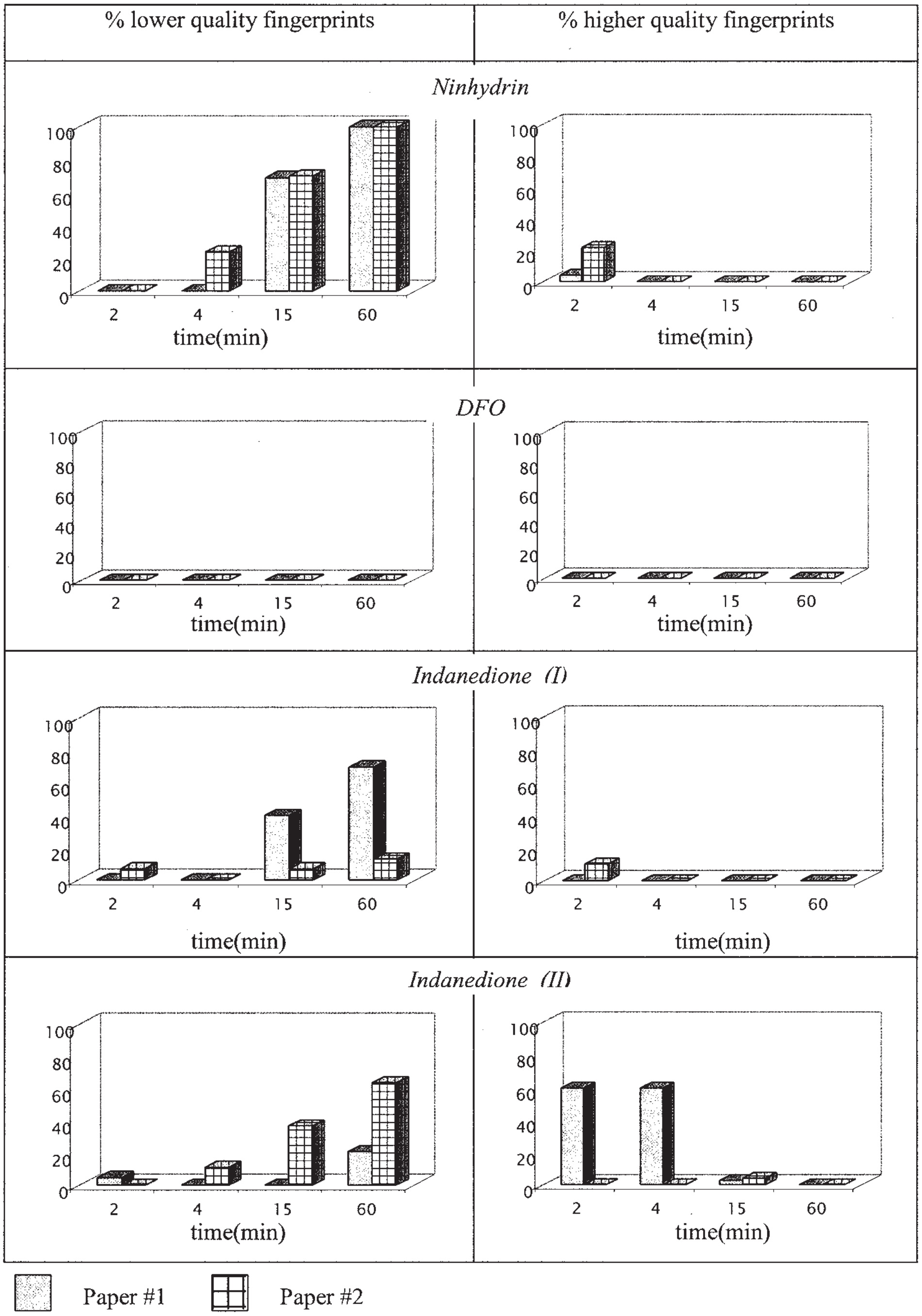

FIG. 1—*Lower- and higher-quality prints versus humidification period for each type of paper and fingerprint reagent.*

Indanedione

As can be seen (Table 2 and Fig. 1), exposure of 15 min and above to high humidity had a remarkably adverse effect on indanedione development. Shorter exposures, however, not exceeding 4 min, had a favorable effect on the print quality (Fig. 6). For both indanedione formulations, it was noticed that not only *pre-exposure* to high humidity, but also atmospheric humidity at the time of development caused considerable fluctuations to the fingerprint quality.

DFO Followed by Ninhydrin

In many fingerprint laboratories, ninhydrin is applied after the completion of DFO processing, and new fingerprints are occasionally revealed. When this sequence was applied in our experiment (one week after ESDA conditioning and DFO development), results were similar to those obtained by ninhydrin itself. As shown in Table 3 and Fig. 2, very short exposures (2 min) in the ESDA humidifier enhanced about 30% of the DFO-ninhydrin-treated fingerprints on Paper 2. Even just slightly longer exposures (4 min) had

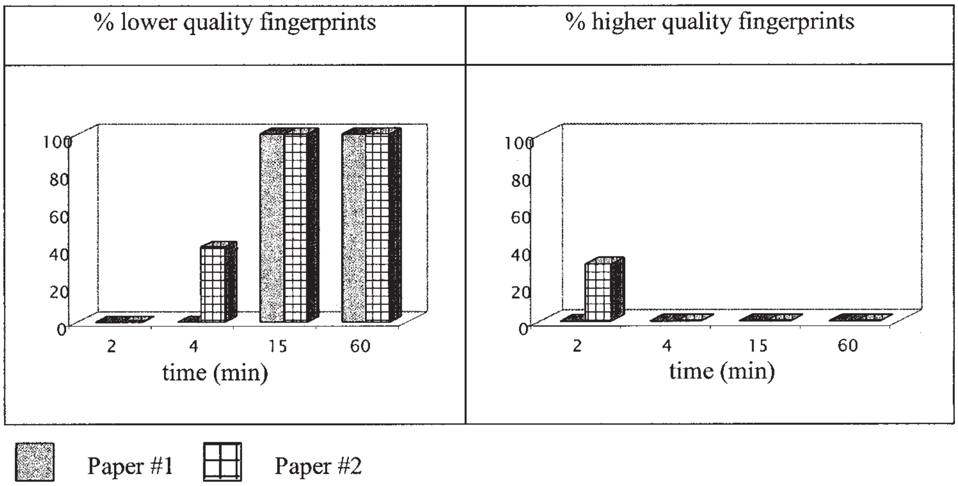

FIG. 2—*Lower- and higher-quality prints versus humidification period after DFO-ninhydrin sequence for both types of paper.*

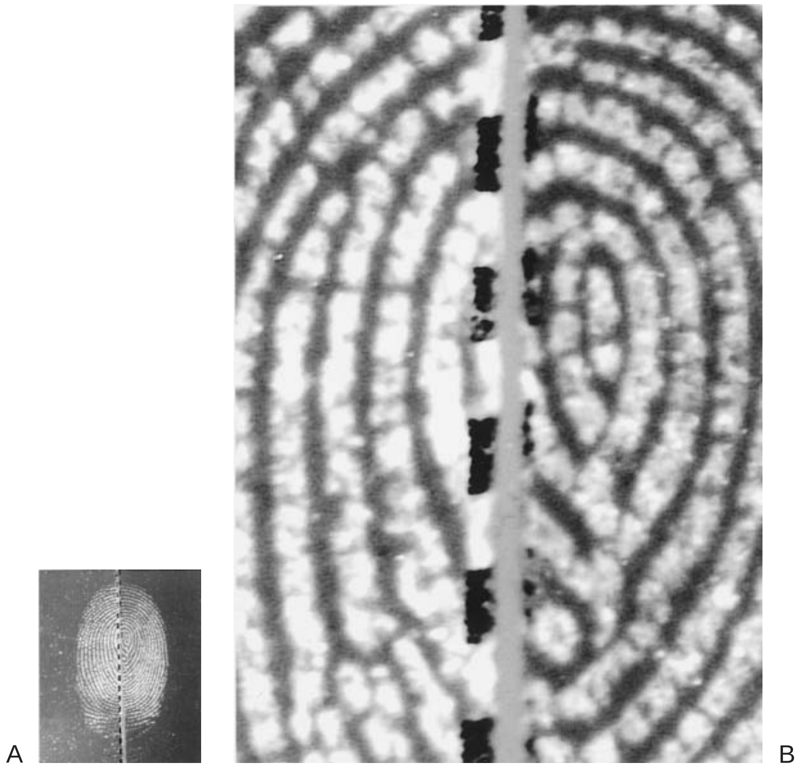

FIG. 3—*DFO-treated print: right half of the print was kept in ESDA humidifier for 60 min prior to fingerprint process*: (a) *1:1 sized print*; (b) *enlarged print.*

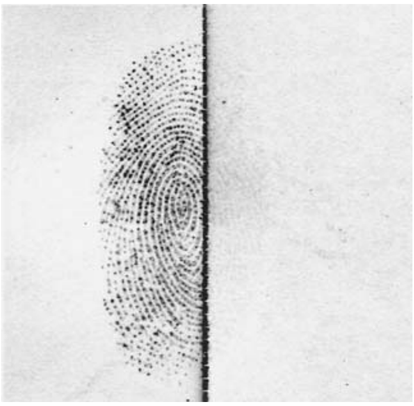

FIG. 4—*Ninhydrin-treated print: right half of the print was kept in ESDA humidifier for 60 min prior to fingerprint process.*

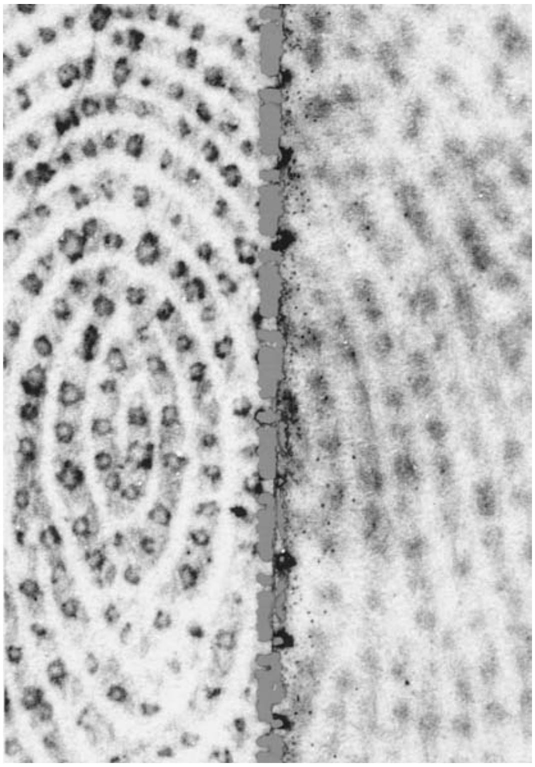

FIG. 5—*Ninhydrin-treated print (enlarged): right half of the print was kept in ESDA humidifier for 15 min prior to fingerprint process.*

FIG. 6—*Indanedione (II)-treated print: right half of the print was kept in ESDA humidifier for 4 min prior to fingerprint process.*

a detrimental effect on the quality: about 40% of the prints were inferior to those obtained without previous humidification (Type I). On Paper 1, no difference was noticed after either 2 or 4-min humidification. Extended humidification (15 and 60 min) caused total deterioration to all ninhydrin-developed fingerprints (Type II), on both types of paper.

Discussion

Before analyzing the results, it must be emphasized that this study had several limitations:

1. The ESDA process was always done just once, by the same technician, using the same protocol. The cumulative effect of multiple ESDA processes was not investigated.
2. The time elapsed between the ESDA process and the fingerprint development was kept unchanged and was structured to conform the actual procedure for accelerated casework.
3. The influence of the time elapsed between the fingerprint deposit and the ESDA treatment was not examined. This interval was always between one and eight days.
4. The ambient conditions were not controlled. The experiments were carried out at 20 to 23°C and 27 to 75% RH as recorded in the laboratory.

The following phenomena have been identified throughout this study:

1. Pre-exposure to high humidity has a significant effect on fingerprint development by ninhydrin and indanedione. Short exposures enhance the print contrast, whereas long exposures bring about a considerable deterioration, which is expressed by loss of the sharp boundaries between the ridges and the furrows.
2. DFO development is much less susceptible to prior humidification.
3. Long exposure to high humidity also affects the DFO process.
4. Different papers are affected at different rates.

Two phenomena in particular require explanation: (a) the different effect of short and long exposures, (b) the striking difference between DFO and the other two reagents. Concerning the first observation, we assume that short humidification provides just the right amount of polar environment for fast and complete reaction between perspiration amino acids and the fingerprint reagent. Longer exposures to high humidity cause lateral migration of the amino acids in the paper, in a chromatographic-like manner, which blurs the boundaries of the developed prints. The difference between DFO, on one hand, and ninhydrin and indanedione, on the other hand, is harder to explain. The following possibilities have been considered:

1. As in regular paper chromatography, various amino acids migrate at different speed. Some migrate faster than others. If DFO reacts with the "faster" amino acids at a lower rate than it reacts with the slower ones, the sharpness of the ridges could be retained. After long exposure, however, the "slower" amino acids migrate too and, hence, even DFO prints will have a diffused appearance. Indeed, kinetic studies have shown that DFO reacts with the amino acid histidine much more slowly than it does with the other amino acids (results to be reported in a forthcoming paper). So, if histidine migrates more quickly than the rest, DFO may not "feel" its migration. This possibility is currently under investigation.

2. Another option is that water itself may have a detrimental effect on the reaction between ninhydrin and indanedione with amino acids. This possibility was ruled out by a test tube experiment, in which both reagents were reacted with alanine in an aqueous solution. The reactions occurred faster and the luminescence (indanedione) was stronger than in other solutions (e.g., alcohol). Attempts to "rejuvenate" latent prints after long exposure to high humidity by drying in a desiccator were unsuccessful. The developed prints had the same diffused appearance as without drying. This result also rules out the possibility that it is the migration of the reaction product that is responsible for the loss of sharpness rather than the substrate. If the paper is dried prior to the development, then the product should not migrate.

At this stage we assume that the full explanation for the significant difference from exposure to humidity on the three reagents lies in a more complex phenomenon involving all four components: paper, sweat, reagent, and water. This hypothesis could also explain why different papers are affected at a different rate.

While this study was undertaken in the context of humidity conditioning for ESDA examinations prior to processing for fingerprints, the findings about the humidity effect's apparent benefits on subsequent development of fingerprints seem to coincide quite well with preliminary observations from a completely separate project. Comparisons of the daily recorded RH in the fingerprint laboratory and the number of useable prints developed over an 18-month period seem to indicate that the humidity effect can make a significant difference in operational results. Ongoing studies are investigating how to optimize environmental factors to specific reagents and also how to optimize specific reagents to the working environment.

Conclusions

The optimal conditions for ESDA detection of indented writing on documents can affect subsequent fingerprint development. Two of the three amino acid reagents, ninhydrin and indanedione, are particularly sensitive to pre-exposure to high humidity: while very short exposure can improve the results, longer exposures—more than a few minutes—significantly reduce the quality of the developed prints. DFO, on the other hand, is much less susceptible to previous humidification: even 1-h exposure to high humidity does not affect print quality. Hence, DFO is the recommended technique for fingerprint development on paper items that have been exposed to high humidity.

Paper items that have been exposed to high humidity for a long period cannot be "cured" for fingerprint development by reconditioning at low humidity.

Acknowledgments

The authors are indebt to Moran Mehadri and Sigal Siton for their technical assistance and to Dr. Arie Zeichner and Mr. Peter Tytell for useful and constructive comments in the preparation of this paper.

References

1. Foster DJ, Morantz DJ. An electrostatic imaging technique for the detection of indented impressions in documents. Forensic Sci Int 1979;13:51–4.
2. Ellen DM, Foster DJ, Morantz DJ. The use of electrostatic imaging in the detection of indebted impressions. Forensic Sci Int 1980;15:53–60.
3. Moore DS. The electrostatic detection apparatus (ESDA) and its effects on latent prints on paper. J Forensic Sci 1988;33(2):357–77.
4. Noblett MG, James EL. Optimum conditions for examinations of documents using an electrostatic detection apparatus (ESDA) device to visualize indented writings. J Forensic Sci 1983;28(3):697–712.
5. Baier PE. Application of experimental variables to the use of the electrostatic detection apparatus. J Forensic Sci 1983;289(4):901–10.
6. Riebeling IJ, Kobus HJ. Some parameters affecting the quality of ESDA results. J Forensic Sci 1993;39(1):15–20.
7. Pearse ML, Brennan JS. Importance of absolute humidity in the operation of the electrostatic detection apparatus. Forensic Sci Int 1996;83:121–31.
8. D'Andrea F, Mazzella WD, Khanmy A, Margot P. The effects of the relative humidity and temperature on the efficiency of the ESDA process. International Journal of Forensic Document Examiners 1996;2(3):209–13.
9. ESDA Operating Instructions, Foster and Freeman Ltd., 25 Swan Lane, Evesham, Worchestershire WR11 4PE, UK.
10. Kent T, editor. Manual of fingerprint development techniques. 2nd ed. Sandridge: Home Office, 1998.
11. Wiesner S, Springer E, Sasson Y, Almog J. Chemical development of latent fingerprints: 1,2-Indanedione has come of age. J Forensic Sci 2001;46(5):1082–4.
12. Merrick S, Gardner SJ, Vaughn GS, Hewlett DF. An operational trial of ozone-friendly DFO and 1,2-indanedione formulations for latent fingerprint detection, J Forensic Identification 2002;52(5):595–605.

Additional information and reprint requests:
Myriam Azoury
Head, Latent Fingerprint Laboratory
Division of Identification and Forensic Science (DIFS)
Israel Police, National H.Q.
Jerusalem 91906
Israel