The Effect of Sunlight and Fluorescent Tube Light on Inks and Papers

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Following a case involving claimed sunlight effects on paper and ink, and a document examination conclusion suggesting chemical erasure, paper, and ink from various sources were subjected over various periods of time to radiation from sunlight through a window and to radiation from a room fluorescent tube light. All of the papers tested showed a darkening, and most showed a reduction of UV stimulated blue luminescence (fluorescence) and blue light stimulated red luminescence following exposure to sunlight. All of the inks showed changes in apparent optical absorption of light following exposure to sunlight, with some showing dramatic changes of colour, infrared absorption, and luminescence properties. None of the papers or inks tested showed any detectable change upon exposure to the fluorescent tube light. Document examiners should be aware of environmental effects such as sunlight causing changes in the optical properties of paper and inks which potentially might be misinterpreted as a difference in type of paper or ink, or wrongly ascribed to the effects of chemical erasure.

The inspiration for this research came from a case worked by Forensic Document Services. One party alleged that apparent differences in some inks seen on a questioned document, and the accompanying darkened areas of paper visible under ultraviolet (UV) illumination, were caused by the effects of partial sunlight exposure over an extended period of time. Another party was relying on evidence that these effects were caused by chemical interference with the paper and inks. A preliminary study indicated that sunlight could affect the UV response of paper, as well as cause the obvious visual "yellowing" that usually occurs following exposure of paper to sunlight over a period of time. Thus, a more detailed study was commenced.

Methods and Materials

Paper

Various sheets of paper were chosen at random either directly from the ream or from a pad. The papers selected were as follows.

1. 60gsm Typewriting paper.
2. Lined pad paper.
3. Canon brand photocopier paper.
4. Champion brand photocopier paper.
5. Reflex brand photocopier paper.
6. Renew brand recycled photocopier paper.
7. Victory brand photocopier paper.
8. Xerox brand photocopier paper.

Four of the pieces of paper from each paper type were ruled horizontally every 2 cm and placed inside individual manila folders which were labelled with the paper type and a number one to four. Initially, 2 cm of each piece of paper contained in the folders labelled one and two were exposed to ambient sunlight for two weeks. Apart from an occasional spell of cloudy weather, this resulted in exposure to morning sunlight filtered through window glass for an average of four to five hours per day. Thereafter, every two weeks, an additional two centimetre length of these pieces of paper was exposed. The duration of the last period of exposure was one week. A similar set of exposure times using fluorescent tube light (Crompton 36W white), for 24 hours a day at a distance of 1.3 m, were conducted on the pages contained in each of the folders labelled three and four.

As controls, one piece of each of these paper types was placed inside a folder that was exposed to sunlight, a folder that was exposed to fluorescent light, and a folder inside a drawer. These control pieces of paper were not directly exposed to light.

Inks

Two spiral lines of each of the following pens were drawn on three pieces of white photocopier paper and three pieces of lined pad paper. These pieces of paper were then placed inside individual manila folders which were labelled with the paper type and a number one to three. The same procedure as above was observed, with 2 cm of ink line exposed every two weeks to both sunlight (those folders num-

bered one) and fluorescent tube light (those folders numbered two). The last period of exposure was for one week only.

The pens used were as follows.

Black Ink Pens:

1. Faber Fix ballpoint ("BP").
2. Pilot Fineliner liquid ink ("LI").
3. Pilot BP.
4. Quink (fountain pen ink).

Blue Ink Pens:

1. Penline BP.
2. Parker BP.
3. Staedtler Stick BP.
4. Bic BP.
5. Fisher #PRI Medium BP.
6. Walker BP.

Red Ink Pens:

1. Staedtler Stick 430F BP.
2. Artline Fine LI.

Green Ink Pens:

1. Staedtler 430F BP.

The unexposed section of the ink line was used as a control ink line for those pages exposed to sunlight and fluorescent tube light. Those pages bearing ink lines, in the folders labelled three, were placed inside a drawer and not exposed to any direct light, in order to act as an extra control.

The purpose of the controls for both the paper and ink tests was to detect any effects other than those caused by exposure to visible/UV light, such as the effects of higher temperature, natural degradation of the paper or ink line, dehydration etc.

Papers and inks were examined visually and with a Foster and Freeman Video Spectral Comparator (VSC-1) equipped with an FS1A barrier filter and UV light source.

Results

The documents exposed to fluorescent tube light displayed no detectable changes in paper and ink visual appearance (apparent optical absorption), UV stimulated visible fluorescence, red or infrared luminescence, or infrared absorption, nor did the control inks and papers show any change in these responses.

Sunlight affected both papers and inks dramatically, with one week of exposure often sufficient to change the optical properties of both paper and ink. Figure 1 shows the effect of sunlight exposure on the inks tested, displayed in black and white.

The results of the tests involving sunlight are expressed in Tables 1 through 4 below.

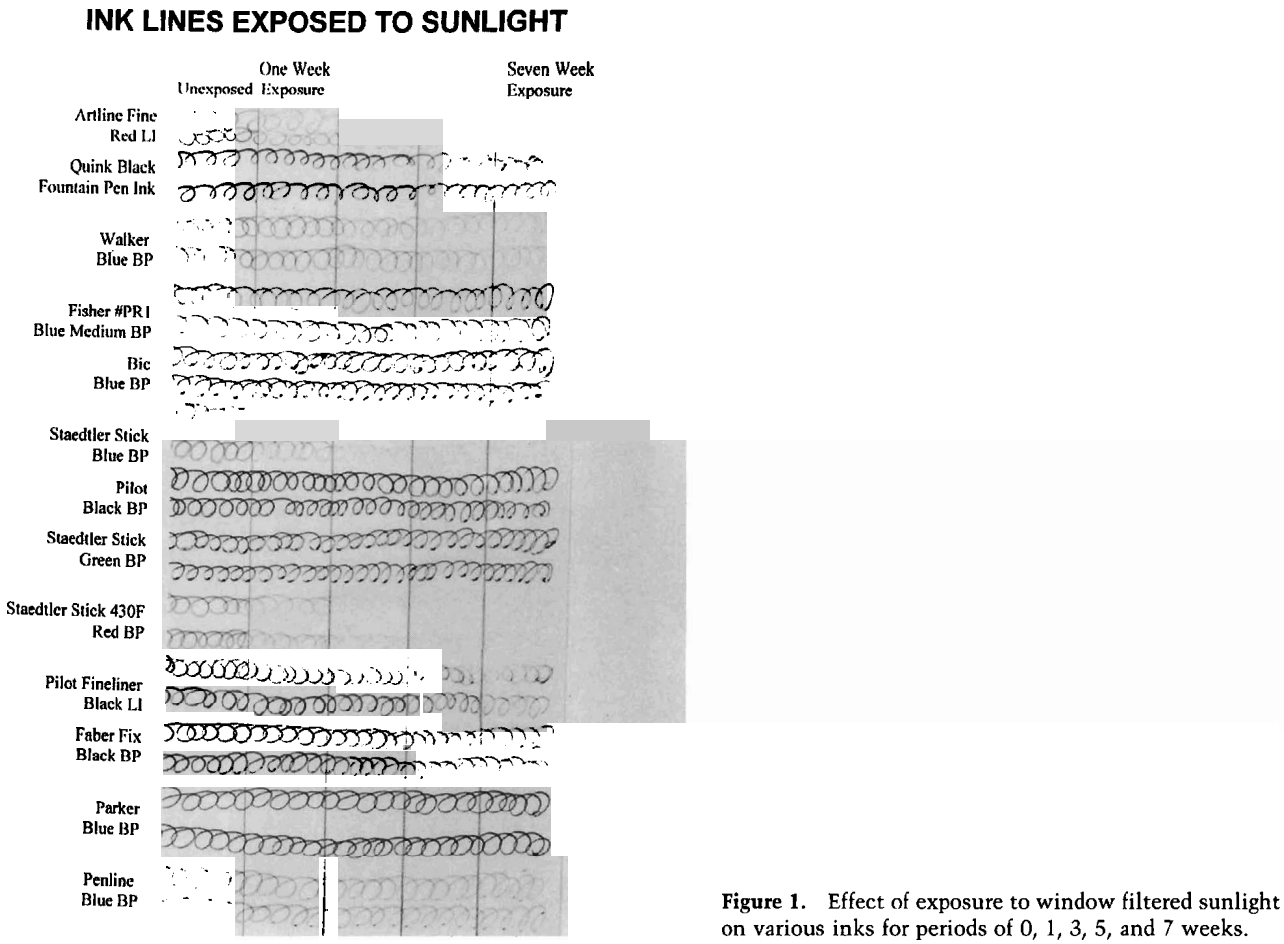

Figure 1. Effect of exposure to window filtered sunlight on various inks for periods of 0, 1, 3, 5, and 7 weeks.

Table 1. *The effect of sunlight on papers when observed visually with UV(A) illumination and with white light illumination*

Paper Type	Reaction of Exposed Paper
60gsm Typewriter Paper	Initially very dull, dulls progressively over 5–7 weeks, starting at first week (visually paper yellows slightly).
Lined Pad Paper	Initially dull, dulls progressively over 5–7 weeks, starting at first week (visually paper yellows dramatically).
Canon Brand	Initially bright, dulls progressively, starting at first week (visually, paper yellows).
Champion Brand	Initially bright, dulls progressively, starting at first week (visually paper yellows slightly).
Reflex Brand	Initially bright, dulls progressively, starting at third week (visually paper yellows slightly).
Renew Brand, Recycled	Initially dull, dulls progressively, starting at first week (visually paper yellows very slightly).
Victory Brand	Initially bright, dulls progressively, starting at first week (visually paper yellows).
Xerox Brand	Initially moderately bright, dulls progressively, starting at first week (visually paper yellows slightly).

Table 2. *The effect of sunlight on papers when illuminated with blue/green light and observed for red and infrared luminescence*

Paper Type	Reaction of Exposed Paper
60gsm Typewriter Paper	Slight dulling of paper over time
Lined Pad Paper	Paper lightens, starting at first week
Canon Brand	Some lightening of paper, starting at first week
Champion Brand	Progressive darkening of paper, starting at first week
Reflex Brand	Progressive darkening of paper, starting at third week
Renew Brand, Recycled	Some darkening of paper at first week
Victory Brand	At first week paper lightens, darkening after five weeks
Xerox Brand	Progressive darkening of paper, starting at third week

Discussion

Sunlight, even through window glass, has a dramatic effect on most of the papers and inks tested. Visually, the general effects are a darkening, or "yellowing" of paper, and fading of inks with associated changes in other optical properties. The danger for the document examiner is that when presented with a document bearing several visually different inks, the examiner might interpret these differences as arising from different pens/inks. The possibility that these differences were caused by partial sunlight exposure should be considered. However, as we have observed for eight paper types, paper is affected by sunlight in either its visual or fluorescent/luminescent properties over the period of time in which inks are affected. The presence of a clear boundary between different intensities of fluorescence/luminescence on different parts of the paper, along with differences in the inks present on these parts of the paper, should normally give a warning to the document examiner that the paper (and associated inks) may have been affected by partial sunlight. In the case mentioned in the introduction, the presence of a clear boundary around the affected area of paper, and the lack of any evidence of chemical leaching into the surrounding paper, persuaded the authors that the observed changes in ink and paper were unlikely to have

Table 3. *The effect of sunlight on inks when observed in normal light and under conditions for detection of red and infrared absorption*

Ink Type and Colour	Visual Observation	Red/Infrared Absorption 610–1000 nm	Reaction of Unexposed Ink
Black, Faber Fix BP	Fades	Remains visible at 735–780 nm	Disappears at 735–780 nm
Black, Pilot Fineliner LI	Fades	Ink fades as the line fades visually	Nil
Black, Pilot BP	Slight darkening	Nil	Nil
Black, Quink Fountain Pen Ink	"Browns" and fades	Ink fades as the line fades visually	Nil
Blue, Penline BP	Fades	Nil	Nil
Blue, Parker BP	Darkens	Nil	Nil
Blue, Staedtler Stick BP	Fades rapidly	Ink disappears at 695 nm	Ink disappears at 780 nm
Blue, Bic BP	Darkens	Nil	Nil
Blue, Fisher BP	Darkens	Nil	Nil
Blue, Walker BP	"Greys"	Ink fades as the line fades visually	Nil
Red, Staedtler BP	Fades rapidly	No visible IR response	No visible IR response
Red, Artline LI	Fades rapidly	No visible IR response	No visible IR response
Green, Staedtler BP	"Blues"	Nil	Nil

For Tables 3 and 4, "Nil" means the ink shows no significant fading in infrared, or no luminescence observed. Furthermore, there were no changes to ink responses on exposure to fluorescent tube light, nor were there any changes to the control inks.

Table 4. *The effect of sunlight on inks when observed under blue light illumination and using FS1A barrier filter*

Ink Colour	Reaction of Exposed Ink (red and infrared luminescence [IRL]).	Reaction of Unexposed Ink
Black, Faber Fix BP	After three weeks ink luminesces at 630–645 nm; after five to seven weeks, ink luminesces at 610 nm; at 780 nm all exposed ink fades (unexposed remains luminescent)	Ink luminesces at 630–645 nm
Black, Pilot Fineliner LI	After 3 weeks ink luminesces at 610 nm approximately inversely to visual fading	Ink luminesces at 645 nm
Black, Pilot BP	Nil	Nil
Black, Quink Fountain LI	Exposed line luminesces slightly more than unexposed at 610 nm	Luminesces at 610 nm
Blue, Penline BP	Nil	Nil
Blue, Parker BP	Nil	Nil
Blue, Staedtler Stick BP	At 610 nm one and three week inks luminesce more strongly than the unexposed ink and the remainder of the exposed ink. At 715 nm the luminescence fades as the visual line fades	Luminescence begins at 630 nm
Blue, Bic BP	Nil	Nil
Blue, Fisher BP	Nil	Nil
Blue, Walker BP	At 630 nm one to three weeks, some luminescence approximately inversely proportional to the visual fading, continuing to 780–830 nm	No luminescence
Red, Staedtler BP	Luminescence increases at 610 nm one to three weeks, but fades thereafter, at 645 nm luminescence fades with the visual fading	Luminesces at 610 nm
Red, Artline LI	Luminescence fades as the visual line fades	Luminesces at 610 nm
Green, Staedtler BP	Nil	Nil

been caused by chemicals and were consistent with the effects observed in this paper of partial sunlight exposure.

This paper has been presented at the American Society of Forensic Document Examiners 55th Annual Conference (1997) in Scottsdale, Arizona, and the Third International Congress of the Gesellschaft für Forensische Schriftuntèrsuchung (GFS) (1997) in Lucern, Switzerland. No previous research citations on this topic were found by the authors.

References

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