Effect of short-term simulated daylight exposure on optically brightened papers

Phil Green and Mike Honess
London College of Communication, Elephant and Castle, London SE1 6SB
pj.green@lcc.arts.ac.uk

Abstract. Two optically brightened commercial papers were subjected to 72 hours continuous exposure to graphic arts daylight simulating fluorescent lamps at 1.4 and 4.4 klux. At the higher illuminance level, a CIELAB colour difference of 1.0 was reached in approximately 3 and 50 hours for the two papers. The colour differences produced by the 1.4 klux exposure were greater than that predicted by assuming a linear relationship between intensity and colour change, by a factor of 1.8.

1. Introduction
Papemakers achieve high whiteness and brightness levels through the addition of fluorescent whitening agents (FWAs) which modify reflection from a surface by emitting visible light on excitation by photons with frequencies in the ultra-violet. The majority of commercially-available papers are optically brightened in this way.

A concern with FWAs is their stability over time, especially when irradiated with light which includes UV. Quenching of fluorescence leads to a visible colour change, which is typically a reduction in whiteness and brightness attributes accompanied by an apparent yellowing.

Test methods for investigating the effect of light exposure on prints and photographs are based on accelerated fading tests using high-intensity illumination, typically in the range 30-80 thousand lux (klux) [1]. These can be combined with exposures at lower intensities in order to determine the extent of reciprocity failures and estimate the effect of exposures in normal viewing conditions.

Of interest in the present study is the extent of fading of the optically brightened papers used in commercial printing, when displayed under graphic arts viewing conditions. For conservation purposes it is common to exclude UV from the illumination source, but the FWAs in commercial white papers require an element of UV radiation in the source to achieve the intended brightness and whiteness levels, and this is incorporated in the specification of the reference illuminant in ISO 3664:2009 [2].

This paper is part of a series of investigations into colour changes in fluorescent papers after printing which include accelerated exposure conditions, but in this study we chose to use actual graphic arts viewing booths at a typical illumination level, and at an augmented level achieved by fitting additional lamps in the booth.

2. Experimental setup
Two papers with high levels of optical brightener were selected. These were a commercial gloss art paper with 10% recycled fibre content, and a premium bond paper. They were exposed in a Verivide...
colour viewing cabinet for 72 hours to fluorescent lamps simulating a D50 illuminant, having been
selected from the middle of previously unopened packets. The lamp specifications given by the
manufacturer [3] conform to the requirements of ISO 3664:2009 with a Colour Rendering Index [4] of
98, and the lamp is also stated to conform to the metamerism index specifications of ISO 3664:2009 in
both visible and UV regions.

Two papers were exposed with 4 lamps, giving an illuminance on the paper surface of 4426 lux.
One of the papers was also exposed for the same time period to two lamps, giving 1433 lux; the
illuminance being lower than might be expected since the two lamps were further from the exposure
area and at a more glancing angle.

The lab where the test was conducted has a stable temperature and humidity, but these were not
recorded during the test.

Measurements of reflected radiance were made in-situ at 20-minute intervals over a 72-hour period
using a Jeti Specbos 1200 telespectroradiometer. Measurements were recorded at wavelengths 380-
780nm at 1nm intervals and the in-situ radiance data were converted to XYZ.

Measurements were also made of a white PTFE plaque of 10mm thickness at the same position as
the paper samples at the beginning and end of each exposure and measurement run. The reflectance
of the tile was used to normalise the in-situ tristimulus measurements of the papers to Y=100 for a
perfect reflecting diffuser. The tristimulus values of the illuminant were computed in the same way,
and the paper and illuminant tristimulus values used to compute CIELAB coordinates and colour
differences relative to the first measurement in each run.

The short-term reproducibility of the measurements was evaluated by 10 repeat measurements of
the PTFE plaque. The standard deviation under the 1433 and 4426 klux exposures was respectively
0.05% and 0.48% of the measurement.

3. Results
The resulting colour differences are shown in Figures 1-3. It can be seen that in each case there is a
relatively rapid initial change, followed by a slower continuing change. In the case of the 1433 lux
exposure, the colour change is not significant after approximately 12 hours, while at 4426 lux the
change continues throughout the 72 hours of exposure. The approximate time to 1 CIELAB ΔE*ab
colour change is 3 hours for paper A and 50 hours for paper B.

![Figure 1. Colour changes on commercial offset gloss at 4426 lux](image-url)
On the commercial offset paper the largest changes in the L*, a* and b* components are in b*, which is consistent with quenching of FWAs. Interestingly, it can be seen in Figures 2 and 3 that the proportion of colour change which is accounted for by the b* component is greater at the lower intensity, and the change in b* is almost constant between 1433 and 4426 lux.

It can be seen in Figure 3 that approximately 50% of the change in b* has occurred in the first 20 minutes of exposure at 1433 lux.
Comparing the results at 1433 and 4426 lux, the lower level of illuminance produces a much larger change than would be predicted by assuming that the exposure effects of 10klux for one hour is equivalent to 1klux for 10 hours; the change at the end of the 72 hour exposure was 1.8 times what would be expected if the colour change were linearly related to the exposure intensity.

It is assumed that the FWA quenching is permanent and that it would not recover after a period of keeping in dark conditions, but this was not tested.

4. Conclusions
Non-accelerated exposures to graphic arts viewing illumination lead to significant colour changes in optically-brightened papers over relatively short time periods. The time to reach a 1 CIELAB $\Delta E_{ab}$ colour change under 4426 lux varied greatly between the two papers, suggesting that fading characteristics of papers should be known in order to select suitable papers for different applications.

Since the magnitude of change in the $b^*$ component of colour difference, which is most associated with radiative changes to FWAs, is fairly consistent between the two exposure levels it is possible that there is a threshold level at which change occurs, and it would be interesting to investigate this further. The rapid initial change in this $b^*$ component at 1433 lux also suggests a need to investigate further at lower illuminances and exposure periods.

The magnitude of change under the lower exposure intensity was substantially greater than predicted by assumptions of reciprocity.

References
[1] ISO 18937:2010 (WD) Imaging materials — Photographic reflection prints — Methods for measuring indoor light stability, ISO, Geneva
[2] ISO 3664:2009 Graphic technology and photography — Viewing conditions, ISO, Geneva
[3] Manufacturer's data sheet for Philips TL950 lamp
[4] CIE Publication 13.3, Method of Measuring and Specifying Colour Rendering Properties of Light Sources, CIE, Vienna (1995)