An early warning system for light damage in museums and exhibitions

M. Bacci[a], C. Cucci[a], S. Gerlach[b], H. Roemich[b], A.-L. Dupont[c], B. Lavedrine[c] and G. Martin[d]

[a]Istituto di Fisica Applicata "Nello Carrara"-(IFAC), Via Panciatichi, 64, I - 50127 Firenze
[b]Fraunhofer- Institut für Silicatforschung, Bronnbach Branch, D – 97877 Wertheim
[c]CNRS / CRCDG, 36, rue Geoffroy-Saint-Hilaire, F - 75005 Paris
[d]Victoria & Albert Museum, South Kensington, SW7 2RL London

Introduction

Light is one of the most powerful parameters in altering colour and so causing irreversible damage in works of art.[1] On the other hand, it is quite clear that works of art cannot be appreciated without light, so a compromise has to be found that can balance visitor's requirements and object's safety. It is known that the damage increases with the length of exposure and the irradiance. Rather than limiting the time of exposure for each object, it is advisable to monitor the lighting conditions on site. A continuous monitoring program for a number of objects with data loggers would be rather expensive and applicable only for selected examples. As an alternative for extensive measurements, here new light indicators, **LightCheck® Sensitive** (LCS) and **LightCheck® Ultra** (LCU), are proposed as an early warning system for light damage.

At this point the following consideration is needed. Indeed, at a first glance, it could appear quite strange to speak about light in a meeting on the air quality. However, a question is in order: can light affect the air quality? The answer cannot be other than yes, as the everyday experience itself teaches to all of us: in fact, every summer concern about the amount of ozone due to solar radiation is more and more increasing. In particular, as regards works of art, it is by now widely recognised that several photo-induced deterioration mechanisms are enhanced, or accelerated through a co-operative action, by different physico-chemical factors (temperature, relative humidity, pollutants).[2,3]

The concept of Equivalent Light Dose and evidence of co-operative effects

Co-operative effects cannot be correctly evaluated by a separate measurement of each environmental parameter. Moreover, it is not possible to take into account all the factors, which might affect the conservation state of the different objects of art. Therefore, we have introduced the concept of Equivalent Light Dose (ELD), which can be defined as: *the light-dose which is capable of producing, in a given material in an uncontrolled environment, the same spectral variation as that measured in the same material exposed under well-defined and controlled environmental conditions*. It turns out that ELD is always greater than (or equal, for no environmental effect) the effective light exposure (ELD ≥ total light dose). Therefore, the luminous exposure limits reported in the literature for the different classes of artefacts[2] are probably over-estimated, if factors other than light are not considered. Actually, in the past years tempera-based mock paintings, which were exposed for nine months to natural conditions inside several museums, did show alterations corresponding to more than 50 years of exposure to lighting of 200 lux.[4,5] Successively, an instrumentation was set up to automatically monitor for long periods both the effective light dose and the ELD.[6,7] Even in this case the effects produced on photosensitive materials, suitably calibrated with given light doses in standard conditions, were always greater than those expected on the basis of the total luminous exposure.

The LiDo project

From what has been said above it is clear that a simple measurement of the light dose could be not sufficient to assess a possible risk. So, it would be necessary a device, which, in some way, could integrate the effect of the different environmental factors. To this purpose the "LiDo" project (Key action "The City of Tomorrow and Cultural Heritage", reference EVK4-CT2000-00016) was

proposed with the aim of developing, testing and transferring to market a light dosimeter for monitoring cultural heritage. The project was carried on through five main steps:

- Selection of dyes/matrices/substrates
- Laboratory experiments
- Field application
- Standardisation of the preparation method
- Calibration

At the end of the project two indicators, LCS and LCU, were realized. These indicators can fill the present gap created by the lack of suitable materials to detect low to medium values of light doses. Actually, the well-known Blue Wool Standard, in its most sensitive formulation N.1, is suitable only for light doses of the order of several hundred of Kluxh.[1] Instead, LCS and LCU can cover the range 0 – 400 Klux hours (LCU: 0 – 100 Kluxh; LCS: 60 – 400 Kluxh) and can be used in a complementary manner because the former is especially suitable for the monitoring of very-light sensitive and fugitive objects, usually exhibited under low levels of light (ISO categories 1-3; e.g. colour photographs, watercolours, textiles, natural history specimens), or for short exposure periods, while the latter is better suited for controlling the lighting of more durable objects (ISO category 4-6; e.g. oil paintings, tempera, polychrome sculptures, bone, ivory) or for longer exposure time. The two indicators consist of photosensitive dyes, applied on a substrate with a polymer binder. LCS is constituted by a blue dye applied on glass support, while LCU consists of two dyes, red and blue, applied on a paper substrate. The fading rate of the blue dye is about twice that of the red dye. Their response to light is cumulative, as they undergo a progressive variation in colour with increasing exposure, so LCS changes its colour from blue to very light blue, while LCU, which is brilliant blue before exposure, becomes violet, purple, pink and almost whitish by increasing exposure. Accordingly, clearly discernible colour steps are reached depending on the dose of light received, so that the indicators can be used for a first, instrumentation free, easy and fast estimation of the luminous exposure that an object receives in a given environment during a given period. The working principle is quite analogous to the one of pH indicator papers: the colour of the exposed dosimeter is compared to the one of a properly calibrated scale so as to obtain a semi-quantitative information on the total light dose received during the exposure period. Therefore, the most critical point of the research is the calibration scale. In order to calibrate the light indicators, samples were artificially light aged in laboratories and, also, exposed in different real conditions in museums. Ageing experiments were performed by exposing to different light sources LightCheck® samples at high illuminance (20 - 190 Klux) in light-ageing chambers with adjustable temperature and humidity. Based on these ageing experiments, the influence of the lighting conditions was examined (type of lamp, intensity, spectral distribution of the emitted radiation). The influence of other environmental parameters on the fading rates such as thermo-hygrometric conditions was also investigated. Moreover, the exposures of the indicators, whether in the laboratory or on-site, were accompanied by continuous monitoring of illuminance, temperature and humidity with a data logger. The colour evolution was followed by means of spectrophotometric and colorimetric measurements and expressed in terms of colour change (ΔE) with respect to the non exposed sample, according to the CIE*Lab76 Colour System (D_{65} standard illuminant, 10° Standard observer). Variations of temperature and humidity were found to have some influence on the colour change, by accelerating the fading process. For this reason it was avoided to strictly define the new light monitoring systems as dosimeters. No dark recovery was observed, at least under illuminance typical of museum exhibit. A limited number of colour steps, easily distinguishable to the naked eye were selected, representing a given light-ageing stage for both indicators so that a semi-quantitative evaluation of the total light dose can be obtained by simple visual comparison between the exposed indicator and the reference scale.

Conclusions

LightCheck® systems were developed as an early warning system, providing an assessment of the risk factor related to light in museums. LightCheck® Ultra is especially suitable for the monitoring of very-light sensitive and fugitive objects, usually exhibited under low levels of light (ISO categories 1-3; e.g. colour and early photographs, watercolours, textiles, natural history specimens), or for short exposure periods, while LightCheck® Sensitive is better suited for controlling the lighting of more durable objects (ISO category 3-6; e.g. oil paintings, tempera, polychrome sculptures, bone, ivory) and/or longer exposure time. Since other parameters such as temperature, humidity and spectral distribution of the light source may have an influence on the colour change, LightCheck® systems should be considered as "integrating" environmental indicators.

1) T. T. Schaeffer, " Effects of Light on Materials in Collections" - Series : Research in Conservation, (2001) , Ed. Getty Publications, Los Angeles , California.
2) J. Tétreault, " Airborne Pollutants in Museums, Galleries, and Archives: Risk Assessment, Control Strategies, and Preservation Management", Canadian Conservation Institute, 2003.
3) M. Bacci, C. Cucci, A. A. Mencaglia, A. G. Mignani and S. Porcinai, Studies in Conservation, 49 (2004) 85 – 98.
4) M. Bacci, M. Picollo, S. Porcinai and B. Radicati, Environ. Sci. Technol., 34 (2000) 2859 – 2865.
5) M. Odlyha, O. F. Van der Brink, J. J. Boon, M. Bacci and N. S. Cohen, Preprints of the 13th Triennial ICOM Meeting, Rio de Janeiro, 2002, Vol. I, pp. 73-79.
6) M. Bacci, C. Cucci, A. A. Mencaglia, S. Porcinai and A. G. Mignani, Proc. SPIE, 5146 (Optical metrology for Arts and Multimedia), invited paper N. 22 (Munich 23-26 June 2003).
7) A. G. Mignani, M. Bacci, A. A. Mencaglia and F. Senesi, Sensors Journal, IEEE, 3 (2003) 108 – 114.