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# Spatial Light Risk Mapping

## A Planning Tool to Minimise Fading of Light-Sensitive Objects Exhibited in Daylight Exhibition Spaces*

*The Preservation Department of the Royal Library in Copenhagen, Denmark has long since been involved in exhibition activities. So far, these activities have been set in designated exhibition areas and at a changing rate, which the conservators could keep up with. Nowadays, other areas of the library have been designated as areas where ad-hoc exhibitions take place. The exhibition areas have a huge range of values of visible light and UV radiation, while the library exhibits a variety of objects having a wide range of light sensitivities. In order to deal with the risk for fading associated with the new exhibition approach, a tool for curators and exhibition editors has been developed to ease and enhance the decision making process. The emphasis is placed on identifying the objects that can be exhibited and the maximum allowed exhibition time in different building locations with the goal of reducing the risk of experiencing a just noticeable fade. This light risk map has been developed using meteorological information about hours of daylight during the seasons, measured maximum light levels in different locations and taking into account the light sensitivity of different materials compared to the ISO Blue Wool Fading Standard scale. The map gives an easy understandable overview of the time each type of material can withstand perceivable colour change in different locations. The calculations and the resulting light map have been received with interest and goodwill since they provide a useful tool for curators allowing them to better understand the possible impact of exhibition lighting. This means that instead of just being restrictive, conservators and curators can work together on identifying risk for light sensitive materials, which are planned to be exhibited, in order to take preventive measures.*

### Introduction

When the new library building, The Black Diamond of The Royal Library in Copenhagen, Denmark, opened in 1999 the main objective was to expand the existing facilities and to open up the research library to a wider audience. Visitors typically consisted of researchers who had specific academic reasons for accessing the collections. The spectacular building, the general atmosphere and the huge entrance hall serve as an open invitation to the general public.

Two new exhibition halls in the basement of the building resulted in a large improvement as the old library building only had two showcases. The approach for the new exhibition rooms was traditional with exhibition of objects in showcases and on the walls of rooms and with controlled light exposure. Unfortunately, it was difficult to attract random library users down into the basement; only dedicated visitors with the intention to see the exhibitions descended the steps. Therefore, a new vision on how to exhibit the collections for a wider audience was developed in 2008, in parallel with the traditional exhibition scheme. It was established that the large number of library users and other visitors, who visit the library every day without ever looking at the exhibitions in the basement, should experience the cultural heritage objects on their way through the library in an open and light atmosphere with little references to the traditional design of exhibition rooms and without paying an entrance fee (Fig 1).

As a result of this approach, conservators were more often faced with situations in which precious objects were planned to be exhibited in bright public areas mainly lit by daylight. The light sensitivity of the objects was typically considered in a very late phase of the planning. Consequently, decisions such as the use of copies or selection of less sensitive objects led to perpetual struggle between curators/exhibition designers on one side and conservators on the other when attempting to reach a balanced solution without compromising the exhibition idea, access to the collections and long-term preservation. As the vision from the library was clear, conservators were faced with the challenge of combining exhibition of light sensitive objects with extreme daylight conditions in a helpful and responsible way facilitating the discussions regarding sensitivity and light damage of heritage objects.

From exhibiting at 50 lux in incandescent light to displaying in daylight, for instance at 300 lux, the lighting guidelines used by the conservators were challenged. To avoid loss of value caused by fading the idea was to map and quantify the risk associated with exhibition in the day-lit areas. The concept of a graphically simple light risk map of the exhibition areas emerged which could be a helpful tool for exhibition designers and collection managers. This tool should summarise the risk of fading by combining illumination, sensitivity of specific materials and the many possible locations of an object and thereby help

**1** The entrance hall of the Black Diamond with daylight glaring in.

the exhibition producers to display the objects in a more resourcefully and less risky way.

The light risk map at The Royal Library was created in 2009 but similar approaches have since been made by other cultural institutions (del Hoyo-Meléndez et al. 2011) as exhibiting in daylight has become a trend – not the least in modern buildings with large glass facades. Also various authors (Colby 1992; Ashley-Smith et al. 2002) have made practical guidelines in order to improve management of risk related to light exposure, and risk mapping combining vulnerability and environment in an institution has among others been published by Bradley (Bradley 2005).

## Impact of Light

The impact of light is cumulative and builds up in the object exposed which makes it important to manage the exposure continuously.

Light doses and variety of artificial light levels are challenges faced in any exhibition with light sensitive exhibits. By exhibiting in day lit areas, it was in addition necessary to deal with the damaging effect of daylight in comparison to that of the incandescent light sources (traditional and quartz halogen) employed in traditional exhibition rooms. As the Royal Library always display artefacts in UV protected exhibition cases this form of radiation is not a concern.

Daylight holds more energy than light from incandescent lamps, traditionally used in exhibitions, because it has higher levels of energy rich blue wavelengths. Therefore, 50 lux of incandescent light does not have the same degrading effect as 50 lux of daylight. To quantify the degrading effect of visible daylight the standard 'CIE 157:2004 Control of Damage to Museum Objects by Optical Radiation' (CIE 2004) was used. In this publication, daylight (behind glass and without UV) has been estimated to be twice as aggressive on sensitive materials compared to incandescent lamps. However, this may be a simplified statement as daylight has a variety of behaviours depending on whether the object receives direct sun light or not (Padfield <www.conservationphysics.org>). Also, each material reacts differently depending on the spectral power distribution of a given source making the estimation of degradation a complex task. And in addition to that temperature, relative humidity, oxygen and air pollution are known to affect the colour stability when exposed to any light.

Natural daylight has on the other hand advantages over electric light as the colour rendering may be more pleasant due to its spectral power distribution. Besides, daylight is a more sustainable option since it allows reducing $CO_2$ emissions. The difference in spectra and colour rendering between quartz halogen light and daylight in the library building is illustrated in (Fig 2a, b).

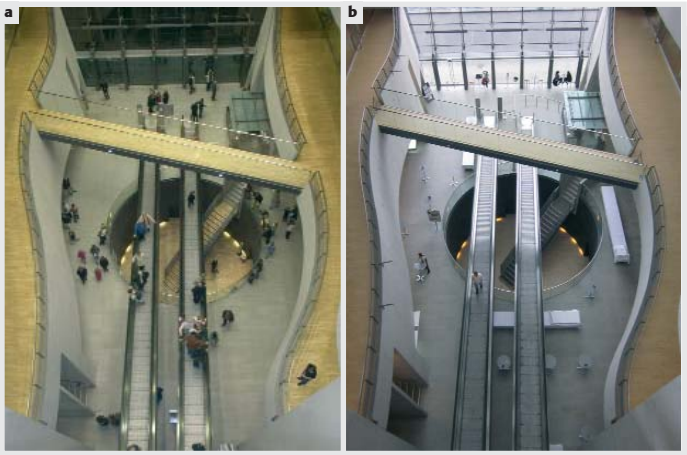
## Sensitivity of Materials

To libraries and archives the colour stability of paper is highly relevant. Launer and Wilson (1943), Lee at al. (1989) and Vávrová et al. (2008) have examined the light stability of different kinds of paper and all found that lignified paper is sensitive to light whereas paper without lignin is quite stable. Even paper with optical brighteners is only moderately sensitive to the visible light spectrum (Connors-Rowe et al. 2007). Pioneer work in light fastness of natural dyes was done by Padfield and Landi 1966 and several sensitivity tables have derived from this work.

A well-known classification of materials in terms of their light responsitivity has been made by Michalski (Michalski 1987) and adopted in the international guideline for museum lighting (CIE 2004) to quantify the amount of light that a coloured material can receive before a just noticeable fade (jnf) occurs. This classification table is still viable (Michalski 2011) with a division of materials into four categories; 'high sensitivity' (ISO Blue Wool 1-3), 'medium sensitivity' (ISO Blue Wool 4-6), 'low sensitivity' (ISO Blue Wool 7-8), and 'no sensitivity'. The high and medium sensitivity categories in this table represent many materials in the Royal Library, but to cover the majority of library materials it was necessary to expand the otherwise useful table. Vegetable and chrome-tanned leather as well as parchment are considered low sensitive materials belonging to the Blue Wool –7-8 category (CIE 2004) and therefore were not included in the light risk mapping.

The table was thus supplemented according to recommendations and research made by Colby (1992), Reissland and Cowan (2002), Vávrová et al. (2008) and CIE 2004 regarding iron gall ink, paper and other materials. To this a new category, namely 'extremely sensitive materials' was added with the aim of including materials that have extremely low colourant stability identified by the authors. Based on colour measurements made before and after a exhibition period (Tab 1) some modern coloured leather bindings and glazed paper have been found to be 'extremely sensitive' and are thus placed in this category (Figs 3a, b). Other colourimetric measurements conducted by the authors have shown colour changes in the range 2-3 $\Delta E$ for blue-green and green leathers, which were exhibited for less than 1Mlx·h. These leather dyes have also proven to be light sensitive having similar properties to those of the tinted paper listed in the category 'high sensitivity'. The materials relevant to the library are categorised and presented in Tab 2.

Wagner et al. (2000) have proposed an extensive list of light sensitivity properties of photographs which has not been




**2** The entrance hall lit with quartz halogen light sources **(a)** and with daylight **(b).**

**Tab 1** Colour measurements by spectrophotometer Gretag MacBeth SpectroEye (illuminant D65, angle 10°, No filter, Abs. white). Five measurements taken before and after exhibition period. Spectrophotometer lifted after each measurement and new measurement taken in another spot close by. CIELab ΔE calculated from the average of *L, *a, and *b respectively.

| *Object* | *Lux hours* | *Colour change (CIELab ΔE)* | *Material* |
|---|---|---|---|
| Hans Christian Ørsteds Billedbog (1869) made by Hans Christian Andersen | < 25,000 | 3.8 | glazed orange paper |
| Paul Bonet bound by Ole Olsen in 1974 | 800,000-1,000,000 | 10.7 | turquoise maroquin (goat skin) |

included in the table. In this list a category for extremely light sensitive materials has also proven to be necessary.

The use of published heuristic light sensitivity tables has limitations as they may contain vague information such as 'many cheap synthetic colourants' which it is not easy to decide which is the case. Also, many coloured objects have already been exhibited and thus may in some cases no longer fade as fast as indicated in these tables where the colour loss is calculated from pristine condition. Another trap is if conservators and exhibition designers do not sufficiently consider the qualities of individual objects because they think the light map is sufficient to provide reasonable protection. In order to estimate the right sensitivity the current best method is the use of micro-fading technique which is getting more and more use in the field of exhibiting cultural heritage.

## Mapping of Light Levels

Measurements of the visible light in all possible exhibition areas of the library were carried out in sunny summer days around noon with the aim of indicating the maximum exposure level. Showcases in the library are heavy and only occasionally and randomly placed in the public areas so therefore no systematic measurements were taken from behind a case glass. However, for comparison, one pair of measurements were taken outside/inside an exhibition case (Fig 4) with a 1.3 cm glass thickness and UV-filter, which gave the out/in lux readings 350/317. This specific glass filtrates out around 10% of the light. We decided not to deduct 10% in general as some cases have thinner glasses. Measurements were taken horizontally and in many cases also vertically at usual exhibition height with an Elsec Environmental Monitor 764.

Electric light automatically takes over when the sun is absent and little or no light is coming in through the windows. Therefore, the light levels in the evening were also measured as it is a contributing factor that needs to be taken into account when calculating the total amount of light reaching the exhibition areas.

The single-measured light levels are only indicative due to differences in light levels during the day and throughout the year and reflections due to the shiny facade and the sea. More thorough measurements were thus also performed in one place by logging the light levels registered in a preinstalled exhibition case to get a realistic idea of the annual exposure level by taking into account illumination changes during the day and large reflections (Fig 5). Logging was performed with a Hanwell ML 4703 light and UV logger every 30 min during two quarters on the back wall of the exhibition case (marked as number 7 in Fig 7). The average daily illumination during winter was 2,365 lx·h which in order of magnitude corresponds to the calculated amount of 3,835 lx·h/day (320 lux x 8 hours [daylight] + 1,275 lx·h [electric light]). The items in the exhibition case will be closer to the light sources so the measured level is close to the predicted. During spring the measured and logged daily average dose was as high as 11,090 lx·h and compared to the calculated dose of 4,855 (320 lux [daylight] x 14 h + 375 lx·h [electric light]) this is more than double. This is caused by surprisingly severe reflections from the glossy stone facade which occasionally results in lux levels up to 10,070 lux during springtime. To avoid this kind of unexpected deviations it is important systematically to verify the calculations with real measurements when resources are available.

## Calculation of Maximum Exposure Time

The point of reference has been to determine when 1 just noticeable fade may occur and the intention of the light risk map is to present this. This does not mean that exhibition producers can exhibit endlessly until a colour change has occurred so along with the production of the light map it was necessary to come up with a reasonable limit. As a rule of thumb it was, in collaboration with curators, decided that 20% of a cautiously predicted



**3** Hans Christian Ørsteds Billedbog (1869) made by Hans-Christian Andersen with an orange glased paper cutting **(a);** a book bound in turquoise maroquin by the Danish bookbinder Ole Olsen in 1974 **(b).**

**Tab 2** Sensitivity of library materials held in the Royal Librarys collections categorised based on Michalski 2011, Reissland and Cowan 2002, Colby 1992, Vávrová et al. 2008 as well as CIE 2004. With regard to lignified paper, it may be more correct to refer to colour change as it becomes yellow. ⬭ Chosen sensitivity to be representative for the whole category.

| *Extremely sensitive* | *Highly sensitive* | *Medium sensitive* |
|---|---|---|
| | **ISO Blue Wool 1-3** | **ISO Blue Wool 4-6** |
| *Glazed paper, some 20th century leather dyes (turquoise)* | Most plant extracts, hence most historic bright dyes and lake pigments in all media: yellow, oranges, greens, purples, many reds, blues.<br>Insect extracts, such as lac dye and cochineal (e-g- carmine) in all media. Many cheap synthetic colourants in all media.<br>Most felt tip pens including blacks.<br>Most red and blue ball point inks.<br>Most dyes used for tinting paper.<br>Most colour photographs with 'colour' (or 'color') in the name, e.g. Kodacolour, Fujicolour.<br>Iron gall ink.<br>Watercolours, gouaches, coloured prints.<br>Bistre, sepia, complex black inks.<br>Wood pulp paper.<br>Some modern leather dyes. | A few historic plant extracts, particularly madder-type reds containing primarily alizarin, as a dye on wool or as a lake pigment in all media. It varies throughout the range of media and can reach into the low category, depending on concentration, substrate and mordant.<br>The colour of most furs and feathers.<br>Most colour photographs with 'chrome' in the name, e.g. Cibrachrome, Kodachrome.<br>Rag paper and sulphate pulp paper. |
| 0.025 Mlx·h to jnf | 0.3-3 Mlx·h to jnf | 10-100 Mlx·h to jnf |

dose could be used for one exhibition. This approach was chosen as a way of reducing exposure without having to maintain a database with strict documentation of exposure for all exhibited items and their numerous possible openings. Objects being especially vulnerable and/or of special significance will be followed continuously by documentation of light dose and sometimes even with colour measurements as the simple '20%' light map approach might be inadequate for long-term preservation for these items. In that way a dual approach is applied.

The actual colour of the object is the point of reference for using the light risk map. It does not take earlier exposure into account, but only relates to future colour changes.

When calculating the exposure limits (1 jnf) for each sensitivity group the lowest Blue Wool sensitivity, belonging to the head category (including three Blue Wool numbers), was chosen to represent all objects in the category. This approach was used to counteract for the uncertainty regarding the actual light sensitivity which is not straight forward to predict. So even if a certain colour may be as stable as a Blue Wool 3 it is regarded as sensitive as Blue Wool 1 (red rings in table 2).

The next step was to calculate how many hours of daylight public areas can possibly receive under the most unfavourable lighting conditions measured earlier. Data on the maximum number of hours of sunshine per month was obtained from the Danish Meteorological Institute (Fig 6) and was used to calculate the maximum average time of sunshine for each quarter of the year (instead of each month).

**4** Photometric measurement at the Bigger Queen exhibition case. Measurement taken without glass to be compared with measurement when the glass front is closed.

**5** Reflection of sunlight from the shiny stone facade results in lux levels of more than 10,000 in a preinstalled showcase (not visible but behind the back of the photographer) for a short while during the daytime.

| Jan | Feb | Mar | Apr | Maj | Jun | Jul | Aug | Sep | Okt | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 240 t | 268 t<br>279 t | 369 t | 427 t | 505 t | 523 t | 521 t | 464 t | 381 t | 322 t | 249 t | 221 t |

**6** Data from the meteorological institute showing the possible amount of sunshine month by month <www.dmi.dk/dmi/hvor_meget_kan_solen_skinne>. 't' stands for hours.

For example, an autumn day will have 10 hours of daylight in average and an exhibition case with a measured maximum of 320 lux might thus receive 10 hours x 320 lux resulting in 3,200 lx·h per day. Assuming that the degrading effect of daylight is twice as high as the one observed for incandescent light (CIE 2004) these 3,200 lx·h can be estimated as 6,400 lx·h. Whenever the sun is absent (light level < 600 lux outside) the electric light is automatically turned on between 6.30 and 23.00 h (16.5 hours). Therefore, the number of lx·h associated with the electric light component was added to obtain the total exposure. After considering the example above, it can be seen that there will be 6.5 hours of electric light at a measured level of 150 lux adding 975 lx·h to the previously estimated value of 6,400 lx·h resulting in 7,375 lx·h per day. A material belonging to the category 'highly sensitive' category may experience a colour change after 300,000 lx·h (0.3 Mlx·h) resulting in an exposure limit of 41 days before the risk of experiencing a just noticeable colour change. The single measured photometric values will in general lead to overestimation of the actual exposure (if no serious reflections are decisive) since lower levels will be the case when the sun is not shining or is shining from a position with less impact. Although this is a disadvantage, this method still provides useful information (with a limited effort) since the overestimated values may count up for unintended extension of display, wrong sensitivity predictions, etc.

Lux measurements from representative locations in the public areas were registered in a table together with the degradation factor of daylight. In Tab 3, some examples are listed with the degradation factor, measured lux level (in sunny conditions) and number of hours to reach a just noticeable colour change—in this case for 'highly sensitive' materials, which may reach this level after an exposure of 300,000 lx·h. These data are followed by the number of hours of daylight and electric light divided by the number of days during different seasons of the year to finally get a number of how many days a specific item can be exhibited before undergoing a noticeable colour change. A number in red means that the item can be exhibited for less than three weeks or rather not recommended for exhibition. A number in yellow corresponds to an exhibition time of less than three months, while a number in green indicates that the object can be on display for more than three months. Fig 7 shows a representative part of the full light table forming the basis for the light risk map.

**Tab 3** A section of the light table illustrating the number of days a highly sensitive item can be exhibited in different library areas before a noticeable colour change is expected to occur.

| | *Degradation factor* | *Measured lux* | *UV (i µW/lumen)* | *Lux hours to reach 1 jnf (300.000 )* | *Spring (14h/day)* | *Summer (16 h/day)* | *Autumn (10h/day)* | *Winter (8h/day)* |
|---|---|---|---|---|---|---|---|---|
| By wall in front of T20 (5) | x2 | 900 | 670 | 167 | 12 | 10 | 17 | 21 |
| At the back wall by road (6) | x2 | 400 | 830 | 375 | 27 | 23 | 38 | 47 |
| Smaller Queen Exhibition case (8) | x2 | 140 | – | 1,071 | 77 | 67 | 107 | 134 |
| Entrance gallery close to window (9) | x2 | 1,300 | 500 | 115 | 8 | 7 | 12 | 14 |

## Creation of the Light Risk Map

A visual light risk map was developed from the dataset shown in Fig 6 as a straightforward tool to be used during the exhibition planning stage by curators and exhibition designers. The aerial photo (Fig 8) of the Royal Library gives an overview of the building. The old red brick building has a few skylights in the roof whereas the new building, 'The Black Diamond', shows the new trend of 'opening up' the library to a wider public and letting light come into the building through large windows facing the sea front as well as skylights located on the roof. In Fig 9 an overview is given of the photometric measurement points throughout the public areas.

The data allows devising a floor plan for which exhibition areas could be classified using red, yellow and green colours to illustrate the differences in exhibition capacity in terms of light exposure according to the previously described material categories. Similar to the light table, red markings indicate that exhibition is recommended less than 20 days in this specific location. The yellow markings show locations with a threshold of 21-90 days, while the green markings illustrate areas with threshold from 91 days and upwards. The green category has a wide spread in threshold; from 91 days up to 83 years. This is specified in the table printed on the opposite side of the light map where specifications for each location, light sensitivity category and season of the year are presented.

The light risk map for 'extremely sensitive' objects (Fig 10a) shows mainly red areas and a few areas in yellow. In the category of 'highly sensitive' objects (Fig 10b), exhibition is not a reasonable option in the front hall area or close to the windows. However, red markings turn into yellow in the inner areas of the building with the exception of locations underneath the skylights. Some locations are suitable for longer exhibition periods and are thus marked in green. With regard to the 'moderately sensitive' objects (Fig 10c) the majority of the public areas are shown in green and classified as safer zones.

It can be seen that the light risk map allows making informed decisions during the exhibition planning stage taking into account the light sensitivity of each object. For instance, the map gives useful information for making important decisions such as moving a sensitive object into a darker position as well as choosing a less sensitive item to be exhibited in a brighter zone.

## Experiences with the Light Risk Map

It is evident from the light risk map that illumination of many objects must be restricted in some way in order to exhibit the collections for a reasonable period.

The light map was used during the planning stage of the exhibition Carsten Niebuhr and the Arabian Journey in 2011. In the early planning of the exhibition, the light map was introduced and the exhibition architects became aware of the effect of daylight and the importance of placing the exhibition cases

away from the highly illuminated areas. To reduce or avoid exposure of some light sensitive drawings, these objects were duplicated, printed on transparent film and adhered to the glass wall. In this innovative way the daylight was included in the exhibition design (Fig 11) reducing the light levels as the photostats had an overall darkening effect in the exhibition area. Another solution, to lower the light levels, was to install huge awnings that help to reduce the light coming from the upper parts of the building (Figs 12, 13). In addition, a part of the horizontal top component of the exhibition cases was covered with dark felt to supplement the light protection by the awnings. Some of the exhibition cases were built up with deep, dark inner boxes for providing additional protection to the more sensitive objects and a group of original items were repositioned in darker exhibition areas.

Design of exhibition cases in the library has, as a result of the work with the risk from light, developed into incorporation of magnetic removable side covers to be used as flexible light shielding or to be attached when the library is closed.

## Conclusion

The light risk map offers a new approach to communicate detailed and complex knowledge to museum professionals which has proved very effective so far. Traditionally conservators have been the messenger of restrictions, but the responsibility and the anxiety for the objects is, however, now shared among the

# Light risk table

| | | Degradation factor | Measured lux | Hours to reach 1 just (extremely sensitive) | Hours to reach 1 just (highly sensitive) | Hours to reach 1 just (medium sensitive) | Extremely sensitive | | | | Higly sensitive | | | | Medium sensitive | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Spring (14h/day) | Summer (16 h/day) | Autumn (10h/day) | Winter (8h/day) | Spring (14h/day) | Summer (16 h/day) | Autumn (10h/day) | Winter (8h/day) | Spring (14h/day) | Summer (16 h/day) | Autumn (10h/day) | Winter (8h/day) |
| | Outside (1) | UV | 100.000 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diamond A | Close to the glass facade (2) | x2 | 46.000 | 0 | 1 | 109 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 9 | 11 |
| | By sign in front of escallator (3) | x2 | 27.000 | 0 | 6 | 185 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 13 | 12 | 18 | 23 |
| | In front of elevator (4) | x2 | 18.000 | 1 | 9 | 313 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 22 | 20 | 31 | 39 |
| | By wall in front of T20 (5) | x2 | 900 | 14 | 167 | 5.556 | 1 | 1 | 1 | 2 | 12 | 10 | 16 | 19 | 1 years | | | |
| | At the back wall by road (6) | x2 | 400 | 31 | 375 | 12.500 | 2 | 2 | 3 | 3 | 26 | 23 | 36 | 42 | 3 years | | | |
| | Bigger Queen Exhibition case (7) | x2 | 320 | 39 | 469 | 15.625 | 1 | 2 | 3 | 4 | 33 | 29 | 45 | 57 | 3 years | | | |
| | Smaller Queen Exhibition case (8) | x2 | 140 | 89 | 1.071 | 35.714 | 4 | 4 | 6 | 11 | 77 | 67 | 107 | 134 | 9 years | | | |
| | Entrance gallery close to window (9) | x2 | 1.300 | 10 | 115 | 3.846 | 1 | 1 | 1 | 1 | 8 | 7 | 12 | 14 | 1 years | | | |
| | Between the pillows gacing the window(10) | x2 | 500 | 25 | 300 | 10.000 | 2 | 2 | 2 | 3 | 21 | 19 | 28 | 34 | 2 years | | | |
| | In "room" between info and lockers (11) | | 20 | 1250 | 15.000 | 500.000 | 76 | 76 | 76 | 76 | 999 days | | | | 83 years | | | |
| | In "room" NW in corner by window (12) | x2 | 840 | 15 | 179 | 5.952 | 1 | 1 | 1 | 2 | 13 | 11 | 17 | 21 | 1 years | | | |
| Diamond B | Cartoonist corridor(13) | | 140 | 179 | 1.714 | 25.000 | 6 | 6 | 8 | 9 | 104 days | | | | 4 years | | | |
| Diamond C | Loos bridge with film on windows) (19) | x2 | 500 | 25 | 300 | 10.000 | 2 | 2 | 2 | 3 | 21 | 19 | 28 | 34 | 2 years | | | |
| Holm C | Octagon showcase - horisontal (14) | x2 | 850 | 15 | 176 | 5.882 | 1 | 1 | 1 | 2 | 12 | 11 | 17 | 20 | 1 years | | | |
| | Octagon showcase - vertical (15) | x2 | 640 | 28 | 341 | 11.364 | 2 | 2 | 3 | 3 | 24 | 21 | 33 | 40 | 3 years | | | |
| | In area between the inner yards (16) | x2 | 380 | 33 | 395 | 13.158 | 2 | 2 | 3 | 4 | 30 | 25 | 38 | 46 | 3 years | | | |
| | In niche right after Hansen (17) | x2 | 300 | 42 | 500 | 16.667 | 3 | 3 | 4 | 5 | 36 | 31 | 47 | 57 | 4 years | | | |
| Holm B | Showcase outside the ladies room (18) | | 60 | 417 | 5.000 | 166.667 | 23 | 23 | 23 | 23 | 103 days | | | | 28 years | | | |

The numbers indicate days of display until just noticeable colour change may occur. **Red**: less than 3 weeks. **Yellow**: less than 3 month. **Green**: more than 3 month.

**Extremely light sensitive materials:** Glazed paper, modern leather dyes, early photographic techniques

**Highly light sensitive materials** (Blue Wool 1-3):
Most plan extracts, hence most historic bright dyes and lake pigments in all media: yellow, oranges, greens, purples, many reds, blues. Insect extracts, such as lac dye and cochineal (e-g- carmine) in all media. Many cheap synthetic colorants in all media. Most felt tip pens including blacks. Most red and blue ball point inks. Most dyes used for tinting paper. Most colour photographs with "colour (or color) in the name. E. G. Kodacolour, Fujicolour. Iron gall ink Watercolours, gouaches, coloured prints. Bistre, sepia, complex black inks. Wood pulp paper

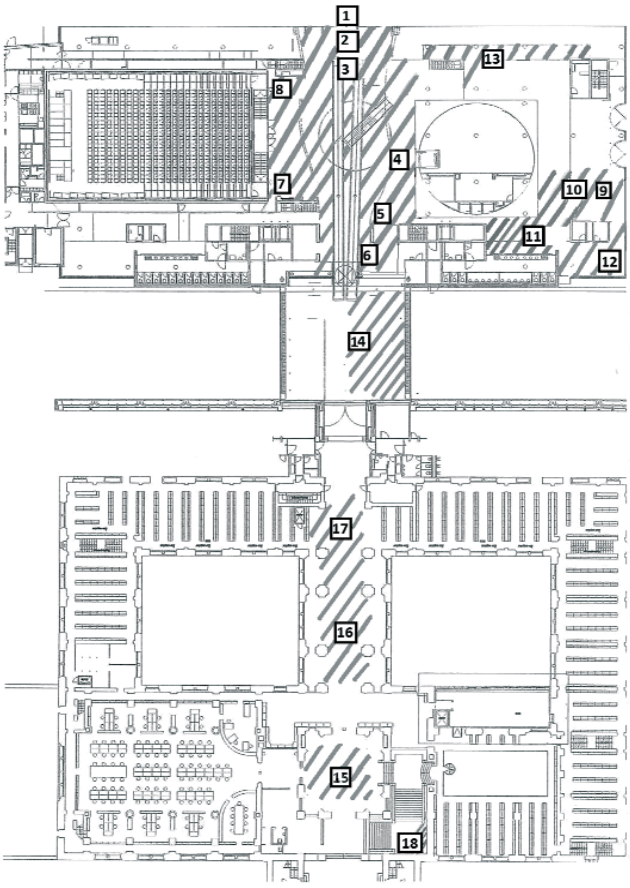
**Medium light sensitive materials** (Blue Wool 4-6):
A few historic plant extracts, particularly madder-type reds containing primarily alizarin, as a dye on wool or as a lake pigment in all media. It varies throughout the range of media and can reach into the low category, depending on concentration, substrate and mordant. Most colour photographs with "chrome" in the name, e.g. Cibrachrome, Kodachrome. Rag paper and sulphate pulp paper

**7** A representative part of the full light table. The red markings indicate that exhibition is only possible less than 3 weeks. The yellow marking allows less than 3 months (21-90 days) while the green marks more than 3 months.

museum professionals. The light risk map is taken as neutral information based on research and is encouraging the discussion between curators, conservators and the exhibition staff at a very early stage of the exhibition planning phase. Conflicts are avoided and better relations are developed between management and conservation. Preliminary experience has shown that curators are more aware of the necessary exhibition restrictions when they are confronted with the consequences of exhibition of individual objects.

The light risk map provides an adequate tool for exhibition planners helping them to lower illumination levels, choose the less vulnerable objects, show sensitive objects only during the opening of an exhibition, turning the pages according to a scheduled plan, target the sensitive objects for seasons with lower light levels or ultimately produce a copy for exhibition purposes.

**8** The Royal Library. The public areas are centred on an axis in the middle of the three buildings, which are built together.




**9** Lux measuring points throughout the public areas in the Royal Library relating to the positioning numbers in the light map table.


**10** Ground map with colour marking for the three different light sensitivity categories: extremely light sensitive objects **(A);** highly light sensitive objects **(B);** medium light sensitive objects **(C).** The red marking indicates exhibition is recommend for less than 3 weeks. The yellow markings show areas for exhibitions less than 3 months. The green markings from 3 months and upwards.

Light sensitive objects could also be exhibited on specially announced days, as part of a collection highlight event. This limitation leads into a creative process where a variety of new solutions are enforced through discussions between the different professional groups.

The map is a simple tool which can be further employed by conservators taking into account the specific vulnerabilities and risk of loss in the case of previously faded or changed colours, objects exhibiting low contrast etc.

To use the light risk map in a responsible way it is, as a rule of thumb, suggested to work with a maximum exposure allowance of 20% of the indicated amount of days in the light risk map for one exhibition. The light map will be periodically updated as new and more qualified data will be obtained by year-long light logging. It should also be taken into account that different objects have varying significance value. Some objects are more important as historic objects than others and therefore the balance between short term access in an exhibition might be less important than long-term preservation with emphasis on future generation's access to an undamaged object of outstanding national significance. Therefore the risk map should never stand alone.

The light mapping of the exhibitions areas was quickly done to get an idea of the order of light levels and the consequent risk in different areas. Since then we have installed light data loggers in different areas to qualify the estimated light doses. In general light levels below the estimated ones used in the light risk map are expected because worst case scenarios consistently were chosen. It is not an accurate tool but in spite of common uncertainties regarding the light sensitivity of specific materials and the light dose to be exposed to, it highlights the risk and gives an idea of the order of magnitude of the light risk in different areas. Implementation of the light risk map effectively reduces the light doses for items going into exhibition and several vulnerable objects have been spared from exhibition in the day-lit areas.

Focusing on the risk from light has derived creation of a new tool (part of the conservation documentations system) to log

**11** Transparent copies of etchings adhered to the glass wall.

**12** Awnings lowering the illumination from the skylights.

**13** Visitors enjoying the exhibition under the shade of awnings installed in the exhibition area in the library.

**14** The artificial light finds its way out through the large glass front showing a reversed picture of how the daylight is able to find its way into the building during the day.
All photos: © The Royal Library, Denmark.

exposure to very vulnerable and significant objects and a more extensive and systematic colour measurement programme during long-term or highly lit exhibitions. Also, new exhibition cases with special protection from light have been developed. The library provides digital access to an increasing amount of the collections and this trend will keep the physical objects on more or less permanent storage. As a consequence the conservators will be faced more frequently with semi-permanent exhibitions of the written heritage which are becoming museum objects. Admittedly in rooms with well controlled low light levels, but like exhibiting in the day-lit areas, this also results in significant risk regarding fading of ink and other colours because of long-term exposure. The knowledge gained from working with the risk light map has also facilitated the work with this new challenge.

## Endnotes

* This contribution was first presented as a talk during the XII IADA Congress at Berne in August/September 2011 and has been revised for publication.

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## Suppliers

Preservation Equipment Ltd, Vinces Road, Diss, Norfolk, IP22 4HQ, United Kingdom, Tel +44-1379-647400, www.preservationequipment.com (Elsec Environmental Monitor 765 with data logger [RH Temp UV & LUX]).

Tempcon Instrumentation, Unit 19 Ford Lane Business Park, Ford Lane, Ford, Nr. Arundel, West Sussex, BN18 0UZ, United Kingdom, Tel +44-1243-558270, www.tempcon.co.uk (Hanwell ML4703 Light [LUX] and Ultraviolet [UV]).

## German Title and Abstract

*Räumliche Kartierung zur Lichtbelastung: Ein Planungswerkzeug zur Begrenzung von Lichtschäden in Ausstellungsflächen mit Tageslicht*


Die Abteilung Bestandserhaltung der Königlichen Bibliothek in Kopenhagen wird schon seit langem bei Ausstellungstätigkeiten einbezogen. Bislang beschränkte sich ihr Eingreifen auf ausgewiesene Ausstellungsräume und – in Absprache mit den Restauratoren – auf den Austausch der Exponate nach Ablauf vorgegebener Fristen. In jüngster Zeit wurden zusätzliche Ausstellungsflächen für kurzfristige Ausstellungen eingeplant, die teilweise durch Tageslicht beleuchtet sind. Die Licht- und UV-Belastung in diesen Ausstellungsflächen schwankt sehr stark, ebenso unterscheiden sich auch die ausgestellten Exponate in ihrer Lichtempfindlichkeit. Um die Risiken für lichtinduzierte Schäden innerhalb der neuen Ausstellungssituation besser abschätzen zu können, wurde ein Werkzeug entwickelt, das Kuratoren und Ausstellungsplanern die Entscheidungsfindung erleichtert. Ziel ist es, ausstellungsfähige Objekte für die Tageslichtsituation zu identifizieren sowie die maximale Ausstellungsdauer für jeden Bereich des Gebäudes festzulegen, um das Risiko eines gerade noch wahrnehmbaren Lichtschadens zu minimieren. In die Kartierung der Ausstellungsflächen flossen meteorologische Daten zur durchschnittlichen Lichteinstrahlungsdauer in Abhängigkeit von der Jahreszeit ebenso ein wie die lokal ermittelten maximalen Beleuchtungsstärken und die Lichtempfindlichkeit bestimmter Materialgruppen gemessen am ISO Blauwollstandard. Die daraus resultierende Kartierung der Ausstellungsflächen ermöglicht einen leicht verständlichen Überblick, über welche Dauer eine bestimmte Materialgruppe an einer definierten Stelle ausgestellt werden kann, bevor ein wahrnehmbarer Lichtschaden eintritt. Die Berechnungen und die Kartierung fanden großes Interesse und Akzeptanz, da sie Kuratoren ein hilfreiches Werkzeug an die Hand gibt, um die Auswirkung schädlicher Lichtstrahlung besser einschätzen zu können. Anstelle von generellen Einschränkungen können Kuratoren und Restauratoren zusammenarbeiten, um Schadensrisiken für lichtempfindliche Ausstellungsobjekte zu erkennen und präventive Maßnahmen durchzuführen.

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