THE ARTIFACT, ITS CONTEXT AND THEIR NARRATIVE:
MULTIDISCIPLINARY CONSERVATION IN HISTORIC HOUSE MUSEUMS

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Environmental Management Challenges and Strategies in Historic Houses

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Abstract

Historic Houses interiors are often rich in textile, wood and stone sculpture artifacts. The nature of the buildings and their presentation can be challenging for preventive conservation. In situ monitoring of object deterioration can provide the evidence base for informed decisions. The impact of local radiator heating and under-floor heating have been assessed. Wall mounted control sensors have been shown to deviate substantially from room conditions. Acoustic emission has significant potential to assess micro-cracking on furniture, but the monitoring is complicated by high background levels when visitors are present. Existing cracks in furniture have been shown to respond only to longer term fluctuations. In situ measurements of colour change and micro-fading have proved invaluable in assessing suitable light exposures. Measurements of soiling of marble statues have improved the management regime in a property suffering from very high levels of traffic pollution.

Keywords

Furniture, sculpture, silk, monitoring, preventive conservation

Introduction

English Heritage has in its care 17 very different historic houses and is planning to refurbish four others. Historic house interiors are often rich in wood and textile artefacts. Sculpture forms a significant part of the collections at Apsley House, Chiswick House and Brodsworth Hall. Interiors were often produced by a single designer or company and furnishings were specially commissioned for many houses and rooms.

The environment within an historic building is often strongly influenced by the external climate as window construction and the presence of open chimneys allow ready ingress of the external air. Historic doors can be difficult to open and close and are often left open for visitor ingress. Hence the relative humidity can undergo wide and rapid fluctuations and pollution levels can be high. Whilst such a climate is obviously not conducive to the preservation of sensitive wooden artefacts such as inlaid furniture and textiles, much material has survived several centuries in these conditions and appears to be in reasonable condition.

Within an historic building it is necessary to balance the needs of the building with the requirements of the associated collections, following the provisions of the New Orleans Charter [APT, 1992]. Within English Heritage presentation projects are run by multidisciplinary teams including collections conservators and curators, building curators, mechanical and electrical engineers, interpretation professionals and historians. This multidisciplinary approach allows dialogue about potential problems at the early stages of project formulation and realistic budget setting. The presentation approach to historic houses often tries to recreate interiors as they were, based on inventories, descriptions or images. This determines the location of objects within certain rooms or locations within a room. This combined with the climate presents significant challenges for preventive conservation of the collections that form the interiors.

Basis for Target Conditions

The environmental conditions specified for each room within a property are derived from three elements:

- Published materials science for the materials that make up the collections or previous research. The complexity and aged nature of materials and composite nature of many objects makes interpreting the materials science a challenge. As a profession, conservation has developed very good limiting arguments for conditions that would cause very little change to materials, ie 50 + 5% RH. What is only just beginning to develop is an understanding of the risk of going outside of these tight, 'safe' bands. Managing a collection within an historic building often requires a knowledge of how much more risk there is at different levels outside the safe bands, for example at 35% RH and at 30% RH.

- Experience of the collections response to the present conditions. The complex and aged nature of objects means it is difficult to extrapolate laboratory studies, often carried out on new materials, to predict object response. Condition monitoring of objects can provide valuable information. However, most surveys have a degree of subjectivity and when damage is observed it is often difficult to assign to a particular event, as many collections are not closely observed. Advances in scientific techniques have produced several non-invasive, non destructive methods that have the potential to provide objective information about chemical and physical rates of change on objects and could be used for periodic monitoring. No damage in the present environment is very strong evidence and has been accepted as a European Standard [CEN, 2009].

- The capacity for each room to hold a particular environment or be controlled to it. This depends on the building fabric, usage (open doors, windows), external environment (T, RH, wind velocity), and any internal water or heat sources. Both interior room finishes, and the collections themselves, can have a significant RH buffering capacity, for example wooden panelling, and in particularly libraries. The capacity is generally determined from past measurement. Building simulation can derive the potential internal conditions under a number of different scenarios. For accurate results a degree of expertise is required as well as a very in depth knowledge of the building fabric. Historic materials properties are often not well known and need to be added to many building simulation packages for accuracy.

The approach adopted at English Heritage to managing these environments encompasses enhanced monitoring of the collections, in situ, to determine real rates of change; scientific research to understand the exact vulnerability of the collections and how the risk increases outside of the tight specifications often developed for museum collections. Research has been undertaken into methods to improve the environment and their carbon footprint.

RH Control

The limits of RH control required for collections has been subject to much debate. Many historic rooms can only maintain wider RH ranges. All instances of observed damage are recorded at English Heritage properties along with the date when they were first observed. An estimate is made of the last time they were observed without the damage. The environmental data for the previous year is collected. This organisation wide database of damage is then used to verify proposed damage functions, for example there are at least three published algorithms to predict the extent of mould growth [IPI, 2012; Killian, 2007; Isaksson et al, 2010]. In particular the data is used to determine if a particular algorithm would have predicted the damage observed. Direct monitoring of several pieces of furniture has been developed in the AHRC / EPSRC Science and Heritage program funded post doctoral research, 'Change or Damage' [Luxford and Thickett, in press]. Several monitoring methods were assessed in laboratory experiments and then applied to furniture in Kenwood House. This property has issues with low winter RH due to inadequately controlled heating. Preliminary results have been published [Luxford, 2010] and a fuller paper is in press, [Luxford, in press].

Acoustic emission sensors were trialled in English Heritage properties with several wooden pieces, mainly furniture, but also musical instruments and a panel painting. Industrial equipment is quite bulky and quite obtrusive in an historic room setting. Equipment designed for conservation use (Hanwell Woodwatch) has been tested. Unfortunately, there is a lot of background acoustic emission generated from visitor activity in properties. The Woodwatch only has a single sensor and its routine for avoiding background signals (removing low frequency signals) was found to be inadequate. Other researchers have used correlation methods with two sensors to identify background noise. Comparison with an industrial acoustic emission equipment, Physical Acoustics Pocket AE2 with two R15α (1kHz to 1MHz, + 1.5dB) sensors allowed a sensible background threshold to be set. Data could then be used from overnight when the properties were closed and through out the winter period when there were less visitors. Acoustic emission generally uses a contact gel to ensure transmission of the emission to the sensors. This was obviously not appropriate with historic objects. Experiments with a variety of inert materials showed Melinex sheet (50µm, non coated) gave the best results (closest to a commercial contact gel, Sil-Glyde©), and this was used between the wooden surfaces and the acoustic emission sensor weighed down to ensure good contact. Acoustic emission was only observed for long term (over a period longer than 16 days and generally around 30 days) drops in RH exceeding 25%. This is in agreement with other researchers using acoustic emission on furniture. [Łukomski et al, in press]

The response time of objects is important as the high air exchange rate of many historic buildings means a significant portion of the large external diurnal RH cycle propagates indoors. Linear voltage displacement transducers were used to measure crack widths of a gilded wooden, marble topped table [Knight and Thickett, 2007]. The crack width did not respond to short term daily RH fluctuations, Figure 1. Monitoring the cracks occurring in panelling of a wooden bed and mass of a small table gave comparable results, with both only responding to longer term RH fluctuations.

Conservation (humidistatic) heating is frequently used in historic houses. Existing heating equipment can be modified, but wet heating systems have a high thermal inertia and sometimes cannot respond rapidly enough to changing conditions propagating indoors. This is a particular issue when properties are open in the winter. Single electric radiators can respond more rapidly, but can also be overcome by rapid RH changes.

The defined position of objects in an historic interior can mean they are close to radiators or other heat sources. There has been some observed correspondence with damage, cracking of veneer or panels and proximity to radiators. An experiment was undertaken at Fort Brockhurst to determine the likely impact. Wooden panels were fitted with surface temperature sensors (platinum 100) and resistance based moisture content sensors (measured between two screws placed 10 mm apart). The air temperature and RH in front of each panel was also measured. The panels were placed at different distances from an oil filled electric radiator set with a surface temperature of 60ºC in a cold room. Results are shown in Table 1.

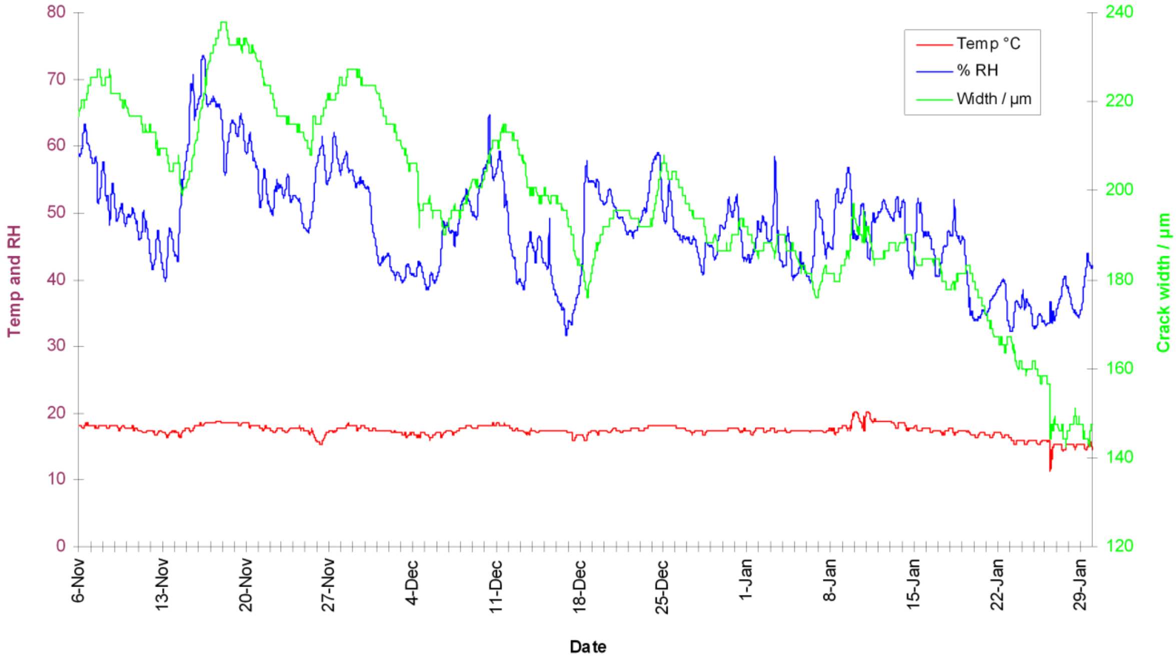

Fig. 1. Crack width on wooden frame of marble top table. © English Heritage

Distance (cm)	Surface temperature rise (°C)	Moisture content decrease (% wt/wt)	Interpretation
10	7.51	2.3	Above plastic deformation limit
20	5.67	1.8	Above plastic deformation limit
30	4.25	1.4	Above plastic deformation limit
40	2.50	0.8	Above plastic deformation limit
50	1.18	0.3	Below plastic deformation limit
60	0.53	0.2	Below plastic deformation limit
70	0.37	0.1	Below plastic deformation limit

Table 1: Effect of proximity to oil filled radiator at 60°C.

Eltham Palace, the home of the Courtaulds, was fitted with all modern conveniences in the 1920s. The heating being concealed in the floors or ceilings. The hall has under-floor heating and contains several pieces of medieval furniture. Concerns about the furniture sitting directly on the heated floor were investigated by measuring the temperature and moisture content of wood placed directly on the heated floor. A piece of oak was fitted with sets of surface temperature and moisture content sensors as described previously at 10 mm internals above its base. Results from the monitoring in situ on the hall floor are shown in Figure 2.

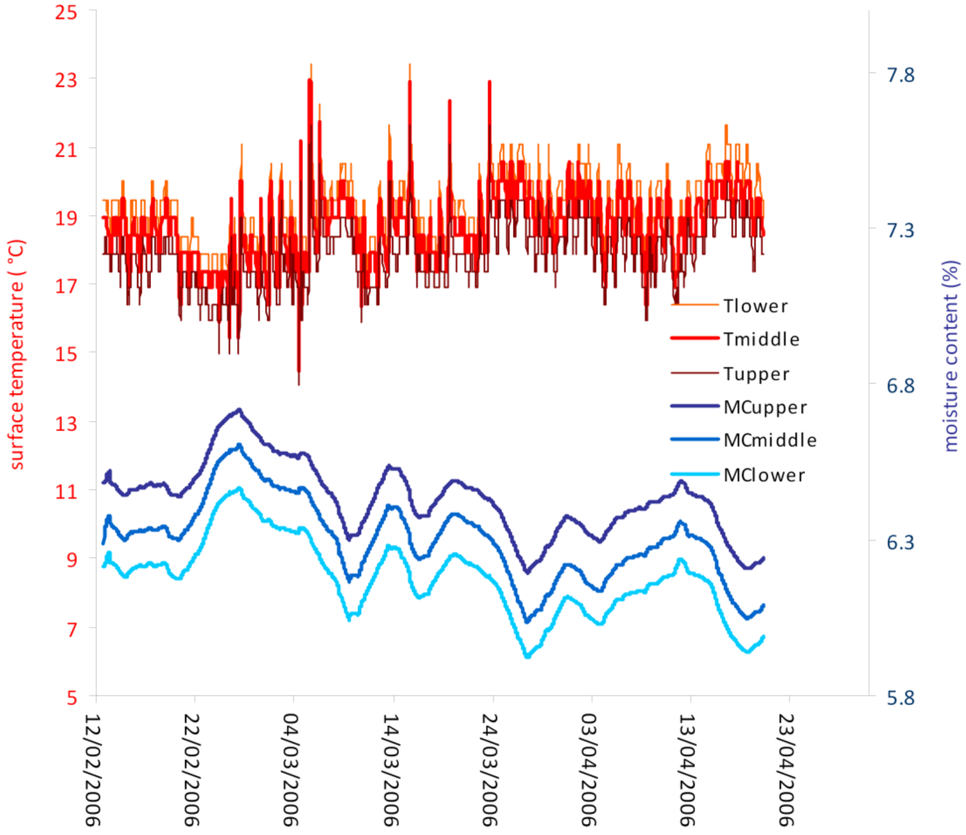

Fig. 2. Surface temperature and moisture content profile up a simulated oak leg on heated floor. © English Heritage

Despite there being a gradient in moisture content vertically throughout the oak piece, the moisture content differences are not sufficient to cause stress levels from dimensional change to overcome the plastic limit of deformation of oak [Erhardt and Mecklenburg, 1994].

Many large houses use some form of Building Management System (BMS) to control existing wet radiators. Sensors for BMS systems tend to be wall mounted. In static conditions a layer of still air exists next to surfaces and the surface has a strong effect on the layers temperature and RH. The differences in measured temperatures and RHs between wall mounted sensors and those deployed in rooms besides the collections were assessed in a particular property.

Calibrated Rotronic Hygroclip probes were placed in several rooms at Brodsworth Hall, on top of the BMS sensor housings and at points in the room next to important objects. From April to October there was little significant difference between the two sets of probes. However, during the winter the probe RHs diverged considerably with the wall mounted probes reading anything up to 15% higher than those besides objects. This is almost certainly due to the cold walls. This has significant ramifications for controlling heating systems with such sensors. If the collection is predominantly wall hung paintings or prints the system would be sensible, but in many conditions it will provide too dry conditions for objects in the room. English Heritage has worked with our main radiotelemetry supplier (Meaco) and BMS engineers to allow the radiotelemetry signals to feed into the BMS and control the heating from these room based sensors. This also has the advantage of reducing the calibration load, as only one set of sensors are required.

A recent review of environmental control within EH properties assessed each room where the environment is controlled (conservation heating, background heating, dehumidifiers, humidifiers, smart ventilation). The necessity for that control was assessed and, in several instances with robust objects or reasonable environments, the control measures were removed. Monitoring after the removal confirmed the validity of the assessment. The remaining measures now have energy monitoring attached to determine the exact energy usage. Stand alone devices have energy meters. The total usage for wet heating systems is monitored and surface temperature sensors are used to indicate the amount of time conservation heating radiators are turned on compared to comfort heating in occupied zones of the buildings. Three years of data is now available for a range of property and room types to inform future decisions about installing environmental control.

Results from a recent collaborative doctoral thesis strongly indicated that hygrothermal aging is much more important for the chemical degradation of silk than exposure to light [Luxford, 2009]. Light exposure causes extensive fading of dyes, but does not appear to chemically degrade the silk. Monitoring behind tapestries is now carried out in six locations to assess their hygrothermal degradation rates from isoperms developed in the thesis. A series of small samples of silk were taken from a range of objects across six locations and five properties (one set of material in store). The samples were analysed with gel permeation chromatography, Thermo Scientific Finnigan Spectra with BioSEP-SEC-S4000 column. The method had been developed to reduce the sample size to 0.1mg. Results are shown in Figure 3. Analysis with tensile testing indicated an absolute end point of 30,000 Dalton (Da), when the silk would not be able to hold its own weight. Discussion with curatorial colleagues indicated that samples with an Mw slightly above 100,000 Da would not be considered suitable for display without additional conservation or support.

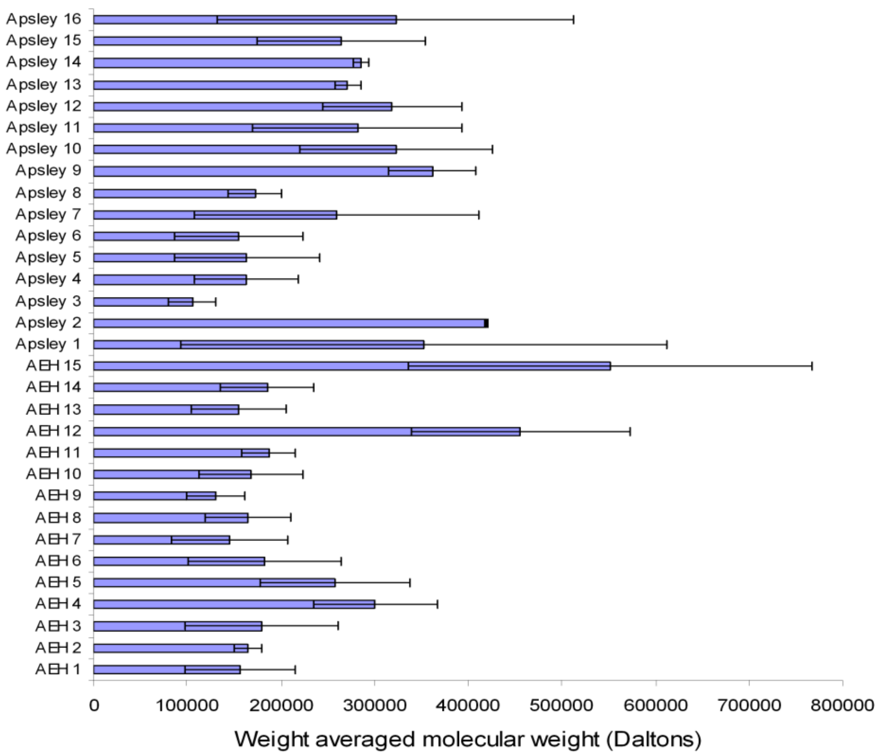

Fig. 3. Molecular Weights of silk samples from objects. © English Heritage

Light Control

Many historic houses rely heavily on natural light from windows, with little artificial lighting present. Windows have UV filters applied and double blinds are often used to control visible light levels with light plans to control the blind positions [Thickett et al, 2007]. This approach can produce annual doses around 584 klux hours suitable for medium sensitivity objects. Manually adjusted blinds are very unlikely to be able to produce doses around 146 klux hours for more sensitive objects depending on opening hours. Comparison of the data from 35 continuous light loggers with light plans indicated that doses were generally between 20 and 45% under those specified on the light plan within English Heritage properties. A series of long term colour monitoring experiments was initiated for a range of object types.

The 3 mm diameter colorimeter head was repositioned using either the pattern on the object or with holes cut in a Melinex mask that then was positioned using the pattern. The ability to view through the colorimeter was of great benefit for this. Repositioning errors were calculated for each point by repeated measurements. The colorimeter calibration was checked before each annual set of measurements using standard colour tiles. Results from three points from the inlaid wooden cabinet at Rangers House are shown in Figure 4. The colour changes slowly for all three points (and similar results were obtained for the other five points monitored on the cabinet). If a linear progress of the reaction is extrapolated then a perceptible change (ΔE_{00}>1.7) would occur in just over 26 years for the fastest changing plot.

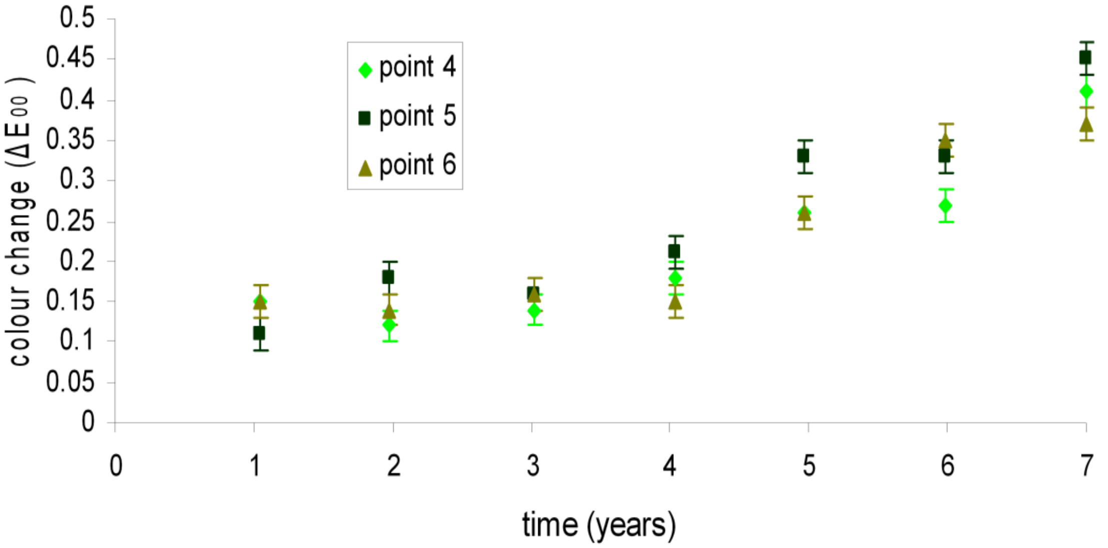

Fig. 4. Colour change of three monitoring points on veneered cabinet. © English Heritage

A common issue with historic houses is that they were designed within their landscape setting, and many windows have important views of that landscape. Views at several English Heritage sites are retained whilst the inner (white) blind is above a certain level, on bright days the blind needs to be lowered to control the lux level, impeding the view. Neutral density films on windows allows the blinds to stay at a higher level. Films with greater than 35% transmission do not appear to affect the view out through the window (results of visitor surveys). Although the lower transmission films are a definite grey colour and fitting to only some windows on an elevation will be visually intrusive. At Kenilworth Castle a window with historic view is fitted with a screen developed by the Victoria and Albert Museum that retains the view through the window whilst reducing light levels to 50 lux, 1.5 m from the window. [Pretzel, 2006]

Low light levels were an issue for a major representation project at Audley End House. The light plans for many of the rooms are set to produce annual doses of 146 klux hours. This is equivalent to 150 lux with the small number of hours the house is open. A micro-fading research project was developed with Nottingham Trent University to anticipate fading rates if the light levels were increased. Many of the objects of interest were large, such as the State bed furnishings, or the 30 m carpets, and the measurements were performed in situ. Vibration was a problem, particularly with old wooden floors and measures had to be taken to minimise it to allow useful measurements. The results from this study are tabulated below. The light sensitivity categories devised by Reuss et al are included for comparison and their recommended annual light doses [Reuss et al, 2005].

Object	Location	Number points measured
Boule cabinet	Kenwood House	6
Cabinet	Kenwood House	14
Cabinet	Rangers House	12
Lacquer cabinet	Rangers House	8
Lacquer cabinet	Rangers House	8
Lacquer cabinet	Rangers House	8
Lacquer screen	Marble Hill House	8
Silk Carpet	Osbourne House	36
Silk wall hanging	Brodsworth Hall	4
Silk wall hanging	Brodsworth Hall	4
Watercolour	Down House	8
Piano	Down House	8

Table 2: In situ fading measurements.

All three objects contained generally relatively stable dyed colours, but each had a very light sensitive colour present. The present light doses at Audley End from the Meaco system are included for comparison. The data was used to generate a series of colour altered images of the carpet showing the effect of different lighting levels. The images were printed and the colours checked with colorimetry. Scenarios with the windows open and with just sun curtains in place were developed, as this had been suggested to improve ventilation in the property during summer. The images were very powerful in the discussions about the differing options. The project team had proposed opening the blinds and windows to increase ventilation. The very dramatic fading this would induce convinced against this scheme. There were also proposals to increase light levels in rooms containing the objects measured, the evidence was key in demonstrating the level of fading that would occur, which was deemed unacceptable by the project team.

	ISO blue wool equivalent	Category (Reuss 2005)	Recommended annual light exposure, klux hours	Present annual light exposure
State bed				
Blue	Equal to 3	Sensitive 2	146	140
Green	Less than 1	Sensitive 1	29	140
Red	Equal to 2	Sensitive 2	146	140
Yellow	Between 2 and 3	Sensitive 2	146	140
Saloon Carpet				
Brown background	Greater than 3	Sensitive 2	146	103
Light blue	Equal to 3	Sensitive 2	146	103
Pink	Greater than 3	Sensitive 2	146	103
Green	Equal to 1	Sensitive 1	29	103
Banner				
Grey	Almost 1	Sensitive 1	29	239
Red	Equal to 3	Sensitive 2	146	239
Background white	Equal to 3	Sensitive 2	146	239

Table 3: Micro-fading results

Pollution

Apsley House is in central London on an extremely busy traffic junction. The house, unlike most of English Heritage's estate, is extremely close (4 m) to the road. Pollution levels in the house are very high and diesel particulate is a particular problem leading to extremely high soiling rates for a variety of object types. Airborne levels have been measured at between 2000 and 6000 particles per cubic meter for the 0.3-2 micron equivalent diameter range. A series of 19th century marble busts are present in the inner hall, in the room next to the entrance. The soiling rate has been measured with a Minolta 2600D colorimeter over the past seven years since English Heritage took over management of the property. The busts were cleaned six months after the monitoring began. The colorimeter head (3 mm diameter) was relocated onto the side of the bust using a melinex mask with a hole. The edges of the mask were lined up with the edges of the bust base. The relocation error was estimated at $0.2\Delta E_{00}$. Colour difference using the CIE 2000 system was calculated from the initial measurement. The soiling of the busts produces a slight yellowing of the surface and the 2000 system was used as the CIE 1976 system is reported to underestimate yellowing, despite its widespread use in conservation. Results for one bust are shown in Figure 5.

The initial soiling rate is high, with a perceptible change ($\Delta E_{00}>1.7$) within 2 years. The data shows that once the door was closed, after 12 months, the rate dropped dramatically. Cleaning had a dramatic effect on the surface colour (this occurred at 18 months). Records indicate the busts had not been cleaned since at least 1995. The soiling occurred slowly after cleaning. It is estimated that one perceptible change occurs after 8.5 years [Ashley-Smith et al, 2002]. The entrance door to the property is now closed and has to be opened by visitors.

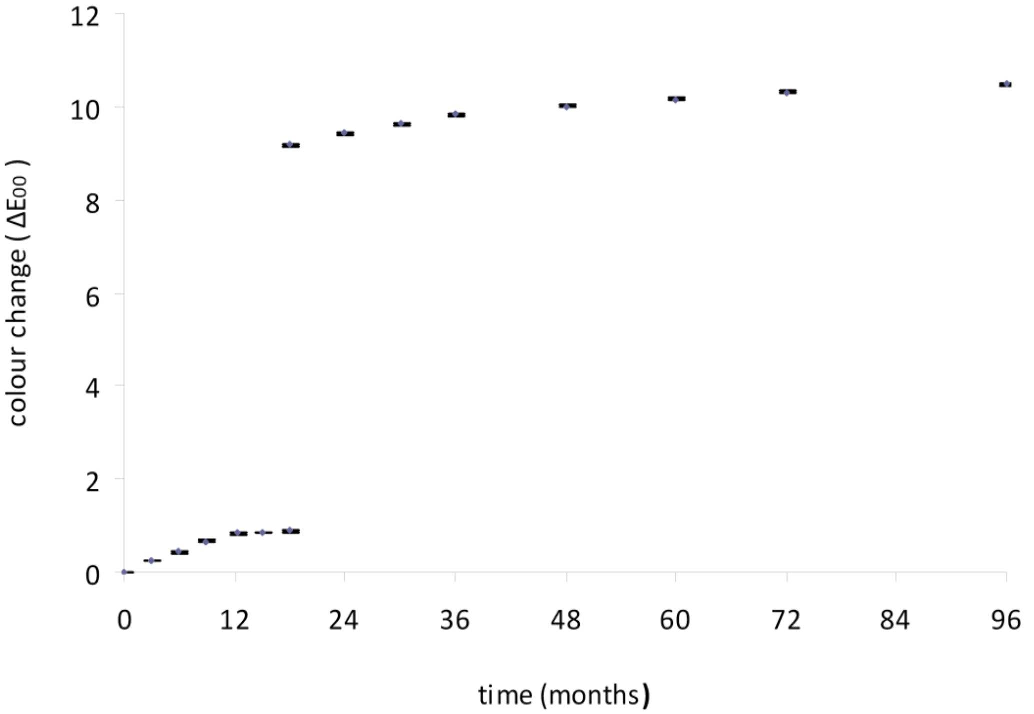

Fig. 5. Soiling on marble bust

Discussion

Scientific research and collection monitoring has been used to provide evidence for decisions and policy relating to environmental control across English Heritage's estate. As with much preventive conservation the detail is extremely important. Within historic houses, with more difficult to control environments than recent custom build museums, this evidence of how much risk exists outside of accepted safe RH bands or illuminance and pollution levels is essential to manage environments efficiently. Case studies have been presented to show the approach. Improvements in techniques and methods of direct object response monitoring can only increase the body of information on which to base environmental decisions. This provides a vital adjunct to and confirmation of laboratory studies.

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