IAQ 2016:
Heritage Research to Conservation Practice

Indoor Air Quality - in heritage and historic environments

12th International Conference
Birmingham, Thinktank, 3 - 4 March 2016

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General Information

Registration Desk/Venue

Thinktank Events Suite
3rd Floor
Millennium Point Building
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Registration Hours

Wednesday 2nd March	17:00-20:00
Thursday 3rd March	08:00-09:00

Number for emergencies
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Registration Fee includes
Admission to the presentation sessions
Conference Booklet including abstracts of presentations and posters
Evening Registration and Reception on 2nd March including wine
Tea & coffee morning and afternoon 3-4th March
Lunch 3-4th March
Free admission to Thinktank 3-4th March

Travel

Millennium Point Car Park is on Jennens Road
Postcode for carpark is **B4 7AP**
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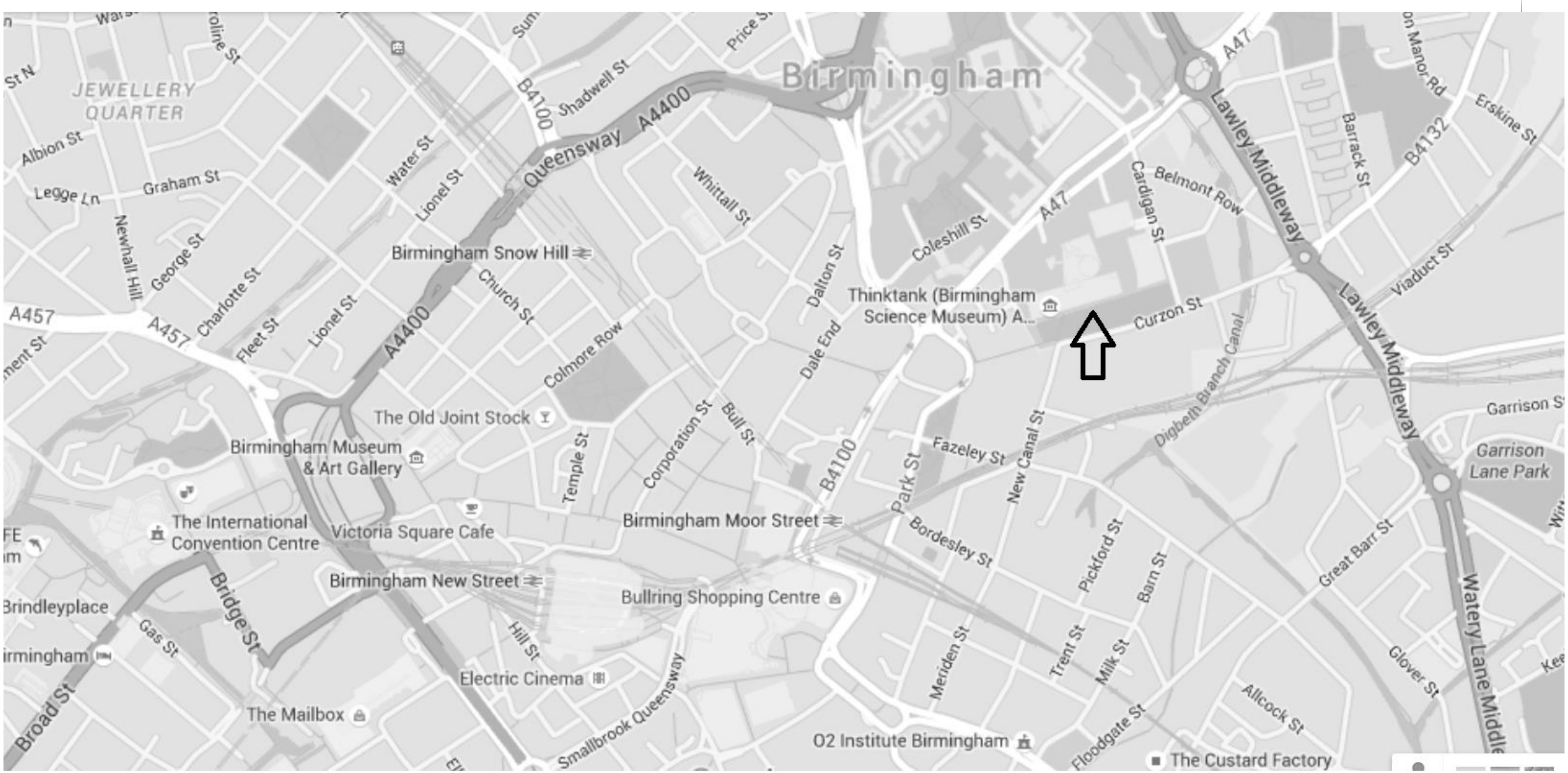

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The Custard Factory
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Allcock St
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Thursday 3rd March

0800-0900 Registration

0900-0905 Opening Remarks & housekeeping		**Jane Thompson Webb**
0905-0910 Session 1 Welcome and Chaired by		**Jean Tetreault**
0910-0940	Alexandra Schieweck	After 50 years of pollution research - Where do we stand today?
0940-1010	Dave Thickett	Unexpected dangers in emission testing
1010-1040	BREAK	
1040-1110	Alexandra Schieweck	Emission testing – an unsolvable mystery?
1110-1140	Paul Lankester	Pollution measurement – designing representative measurements and interpreting the results
1140-1210	Giulia Bertolotti	Investigating the performance and suitability of various coatings as barriers to off-gassing from medium density fibreboard (MDF)
1210-1240	Fabienne Meyer	Volatile organic compounds in collections of drawings and prints – an assessment with reference to the collection of Karl Friedrich Schinkel at the Kupferstichkabinett Berlin
1240-1400	LUNCH	
Session 2 part 1 Chaired by		**Dave Thickett**
1400-1430	Constantina Vlachou - Mogire	Tudor tapestries environmental protection project: when risk mapping and analysis informs innovative mitigation measures
1430-1500	Joseph Grau-Bové	Simulation of visitor-induced dust deposition in Hampton Court palace
1500-1530	Jiří Smolík	Behaviour of indoor coarse particles in the Baroque Library Hall, Prague
1530-1600	BREAK	
Session 2 part 2 Chaired by		**Jiří Smolík**
1600-1630	Allyson Smith	Patterns of soiling in the Old Library, Trinity College Dublin
1630-1700	Alison Lister	A Preliminary Investigation into the Environmental Conditions in Coventry Cathedral Associated with the Preservation of the 'Christ in Glory ' Tapestry
1700-1730	Marcin Strojecki	Particle deposition and sources in the indoor environment of historic churches
1730-1800	Derek Brain	Engaging with demolition and construction companies whose activities threaten your museum collection
1800-1805	Jane Thompson Webb	Closing remarks for the day

Friday 4th March

0855 Opening Remarks		**Jane Thompson Webb**
Session 3 Chaired by		**Alexandra Shieweck**
0900-0930	Jean Tetreault	Evaluation of moisture sorbents and guidelines for optimizing their use
0930-1000	James Crawford	Evaluating & increasing the airtightness of passive display cases with sorbent compartments: a collaboration between academia & industry
1000-1030	BREAK	
1030-1100	Willemien Anaf	A promising monitoring kit to evaluate air aggressiveness
1100-1130	Johanna Diehl	Preventive conservation strategies in the reopened collection of the Kunstkammer of the Kunsthistorisches Museum Vienna: Theory versus Practice
1130-1200	Helen Ganiaris	Hazing on display case glass: a review and progress on prevention
1200-1230	Mark Ormsby	Experiments with reducing energy usage at National Archives and Records Administration
1230-1400	LUNCH	
Session 4 Chaired by		**Morten Ryhl-Svendsen**
1400-1430	Rukshala Anton	Monitoring beacon for early or hidden fungal development detection dedicated to heritage conservation
1430-1500	Naomi Luxford	Inherent pollution risk: Darwin daguerreotypes and their travelling cases
1500-1530	Christian Baars	Corrosion of specimens and equipment in a Mineral Store
1530-1600	BREAK	
1600-1630	Ciarán Lavelle	A Study of the Environmental Conditions in Birmingham Museum and Art Gallery's Civic Silver Store
1630-1700	Jean Tetreault	Degradation of paper under adverse environmental conditions: modelling considerations and calibration with experimental data
1700-1730	Marianne Odlyha	Effectiveness of damage assessment and novel nano-particle based conservation treatment of collagen based artefacts, in particular leather.
1730-1800	Matija Strlič	Final discussion and Conference Conclusion

Abstracts

After 50 years of pollution research - Where do we stand today?

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After a first review published in 1965 [1], first detailed looks at pollution in indoor environments were increasingly taken during the 1990s and initial research campaigns were carried out [2, 3]. In the following years, different trends in research could be observed: from fundamental considerations about the composition of environmental atmospheres to the discussion of single airborne pollutants [4, 5]. In the beginning, there was a special focus on outdoor air pollutants as these were considered as one of the main factors impacting museum collections. Whereas carbonyl compounds such as formic and acetic acid were increasingly analysed and discussed within the 1990s [2, 3], it changed to a special focus on formaldehyde [6, 7] and so called volatile organic compounds (VOCs) [8] around the turn of the century. Special attention was paid to material emissions, mainly wooden products, and the pollutant aspects within tight environments, such as showcases and microclimate frames [9-12]. Recently, scientific analysis of material degradation processes which might contribute to a better understanding of involved chemical processes can be observed which might lead to an improvement of conservation mechanisms [13, 14].
Even though there seems to be a nearly overflowing abundance of literature targeting on pollutants in museum environments, it still remains one of the most challenging and unsolved problems. The most practicing conservators do not know how to deal and manage this topic during every-day work. They are often unsure if pollutants are a topic on their site, how to monitor and handle it, especially facing construction works and the purchase of new enclosures.
Therefore, the question must be asked how can we ensure a feedback of the scientific results into practice? And how can conservators and stakeholders in this field benefit from the knowledge obtained by research?
The oral presentation will give a critical review about what scientific research has already achieved during the last decades, where we stand today and what needs to be taken into consideration from this for future research?

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Unexpected dangers in emission testing

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Emission tests such as ISO16000-6 and the BEMMA scheme are increasingly being used to validate showcase materials. This paper will contrast these tests with the more established 'Oddy' tests.

The ISO16000 series emission tests were designed to assess the health effects of new materials in inhabited buildings. There has been massively more research on health effects of emissions than on effects on artefacts. The tests require the setting of levels for known compounds. The present BEMMA specification does not include several compounds known to damage certain artefact types. Additionally it would be surprising if there were not other damaging compounds in the average 200-400 found inside showcases that we presently do not know about. Accelerated corrosion tests require no knowledge of which compounds are causing the corrosion, just observation of corrosion on the test pieces. The test has always suffered from the limited metal materials used as test coupons (commonly silver, copper lead, but iron, zinc, magnesium and tin have been reported). Assessing results for especially organic materials was difficult. It has recently been extended to paper and a new protocol for silk will be presented. Interpretation of the level of corrosion on metal coupons has been traditionally by eye. This is mainly because the tests ethos was that it could be carried out in any reasonably equipped conservation laboratory. Standard photos and descriptions were published to try and make this less subjective. Further work with reference images can improve this. Instrumental analysis has been reported with image analysis, XRD, SEM and electrochemical approaches. Cathodic stripping has been found to be a very effective way of quantifying corrosion on copper and silver coupons, with moderate equipment costs and little technical training required.

ISO16000 sets the flow rate, chamber dimensions and sample size for room settings. A material passing the 10ug/m3 level for formic acid, could generate damaging concentrations towards certain glasses in certain showcase geometries and air exchange rates. These tests have no acceleration, and both emission and accelerated corrosion tests have shown late emission/corrosion from several materials. The main advantage of emission tests is their speed, unfortunately the delayed emission/corrosion observed in accelerated tests shows there is a risk of materials passing an emission test and then going on to cause corrosion during the long life time of many showcases. Indeed, many of the compounds reported to cause damage to artefacts are degradation products of materials. The emission test results can also be used to model compound concentrations in showcases with known surface areas of materials, volumes and air exchange rates. They are, unfortunately, significantly more expensive than Oddy tests and unlikely to be adopted beyond showcase manufacturers and the very most well-resourced museums. A recent UK survey has found that showcase manufacturers very rarely supply dressing and interpretation materials inside showcases.

Emission tests, at present, do not provide a guarantee of material suitability for showcases. Very significant additional research will be required to identify the likely additional damaging compounds.

Emission testing – an unsolvable mystery?

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Whereas the corrosion tests are specifically developed for museum purposes, emission testing was established for hygienic reasons in order to avoid adverse health effects for building occupants. Thus, in the
context of the ongoing European harmonization process of emission testing, fundamentals for a uniform and reproducible health-related evaluation have been established within several European countries and in some regard also in Asia and the USA. Those materials are of course also in use within museum environments. Museum staff might be therefore confronted with certifications according to these evaluation schemes. Chamber emission testing and sophisticated air analysis provide
a detailed qualitative and quantitative evaluation about the emission behaviour of building materials and air composition, e.g. within showcases. They are currently increasingly included into public calls regarding museum furnishing and equipment including showcases. However, good knowledge and experiences about the appropriate measurement strategy are important requirements in order to transfer these methods to museum purposes and in order to obtain usable results.

The talk will give therefore an introduction about emission testing, types of
Test chambers and experimental conditions to be considered
as well as into testing conditions and sample preparation requirements laid down in the ISO 16000-serie. It will moreover explain established evaluation schemes for indoor rooms, such as AgBB (Germany) and Grenelle (France) and will present the pros and cons of a first assessment scheme for the selection of materials for museum equipment(BEMMA scheme) which was recently derived from common chamber emission testing.

In order to give a clear and substantive guidance concerning the important issue of emission testing for museum professionals, a concise explanation of emission testing, existing schemes and the standard serie ISO-16000 is necessary. In addition, it is also important to illustrate by comprehensive test results that chamber emission tests are not comparable with corrosion tests.

An overview of necessary demands and responsibilities regarding emission testing and air analysis will be provided, which are highly required in order to establish a reliable quality assessment for museum environments in future and which cannot be fulfilled by single corrosion testing.

Pollution measurement – designing representative measurements and interpreting the results

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Two main methods of pollution measurement exist, active and diffusive sampling. Heritage environments are often complex and highly variable with location and time.
ISO 16000-1:2004 "Indoor Air Part 1: General aspects of sampling strategy" states that we should know a lot about what we are measuring, in order to produce representative results. This is often an issue in conservation. This paper aims to help design pollution measurements in conservation scenarios. Factors that can have an impact on pollution measurements will be summarised to present the full picture of how to effectively measure pollution
The effect of different variables on pollution measurement will be explored, for example it is known that measurements at different times of the year can give different results and potentially falsely paint the picture of a safe environment. The effect of time of day for shorter measurements will be investigated.
Pollution measurements at different locations within picture frames and showcases have been undertaken, the effect of location on measurement will be explored.
The air exchange rate of an enclosure is a critical factor in the concentration of pollutants. It is known to vary for a single enclosure and this will be explored. Experiments will also investigate the effect of sampling pumps on the air exchange rate of showcases.
Previous work has shown that air movement over surfaces can increase pollutant emission rates due to the disruption of boundary layers. Experiments will determine if the air movement generated by sampling pumps alters emission of pollutants from materials.
The environmental factors are not the only variables that can alter the measured results of pollutant concentrations. Recent experiments will be presented that show variations in pollutant uptake rate due to passive sampler preparation.

Investigating the performance and suitability of various coatings as barriers to off-gassing from medium density fibreboard (MDF)

Giulia Bertolotti, Capucine Korenberg and Rebecca Stacey, The British Museum

Presented by Giulia Bertolotti,
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Although timber components are known to emit volatile organic compounds (VOCs) that are harmful to museum objects, medium density fibreboard (MDF) is still used in showcases by many institutions because of its low price and workability. To reduce off-gassing, MDF is usually either wrapped with a barrier foil or "sealed" with a liquid coating. Liquid coatings do not perform as well as barrier foils (Tétrault 1994), but they are often favoured by designers as they are easier to apply and allow the use of a paint finish. Tests comparing the effectiveness of different liquid coatings were conducted at the British Museum in the late 1990s (Thickett 1998). Since then, new products have become available on the market and it was decided to investigate their suitability as barriers to MDF off-gassing.

Coatings were chosen based on their formulation, recommendations from coatings' manufacturers and information published in the literature. As part of the project, a survey on the strategies for sealing MDF employed by museums and other cultural heritage institutions was also conducted and suitable products identified in the survey were included in the study. The list of test products included water-based two-part epoxy, water-based two-part polyurethane and ethylene-vinyl acetate. All the selected coatings were screened using the Oddy test and those ranked as suitable for permanent use were tested using solid-phase micro-extraction (SPME) coupled with gas chromatography mass spectrometry (GC-MS). The use of SPME-GC-MS to complement the Oddy test was aimed at identifying the specific compounds that off-gassed.

The barrier effectiveness of the suitable coatings was then evaluated by SPME-GC-MS by comparing the emission of VOCs from coated MDF samples with uncoated MDF samples.

In parallel to the evaluation of liquid coatings, powder-coated MDF was also tested. Traditionally employed for metals, powder-coating has relatively recently become available to coat MDF. Although powder-coating cannot be done in-house and its effectiveness as a barrier to wood off-gassing has not been fully investigated, our survey has revealed that some institutions have already embraced this technology.

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Volatile organic compounds in collections of drawings and prints – an assessment with reference to the collection of Karl Friedrich Schinkel at the Kupferstichkabinett Berlin

Fabienne Meyer (1), Antje Potthast (2), Gerhard Volland (3)

(1)Kupferstichkabinett (Museum of Prints and Drawings), Staatliche Museen zu Berlin (National Museums in Berlin); (2)University of Natural Resources and live Sciences, Vienna, Division of Chemistry of Renewable Resources; (3)Materials Testing Institute, University of Stuttgart (MPA Stuttgart, Otto-Graf-Institut)

Presented by Fabienne Meyer
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Numerous collections with paper based objects in museums, archives and libraries are housed or exhibited in wood-based furniture. These can act as emission sources for volatile organic compounds (VOCs). The collection of drawings and prints of Karl Friedrich Schinkel (1781-1841) at the Kupferstichkabinett was investigated regarding the VOC-concentration in its existing storage situation. The emission potential of current and future storage materials was also tested, as well as the effect of the identified VOCs on artworks on paper.
It was shown that, while acetic acid was present in the highest concentration, the risk formic acid poses for paper-based objects is more severe. It was further demonstrated that different papers adsorb different levels of volatile organic acids; their alkalinity is of special influence. In-situ analysis of original artworks on paper and additionally of samples charged with acetic acid showed that the accumulation of VOCs is hardly avoidable when storing the papers stacked and inside folders either of archival cardboard or of polyester film. In any stacked storage situation, the limitation of air exchange between the folder interior and the surrounding air has a greater effect on the VOC-concentration in the object´s environment than the permeability and alkalinity of the folder materials.
The Schinkel collection was transferred into a new storage system involving adapted furniture and new housing that reduces the VOC concentration in the artworks surroundings, protects them from further mechanical damage, and facilitates the handling and viewing especially of objects that are large in format.

Reference:

Meyer, F: Flüchtige organische Verbindungen in Graphischen Sammlungen.
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Tudor tapestries environmental protection project: when risk mapping and analysis informs innovative mitigation measures

Constantina Vlachou-Mogire, Ian Gibb, Kate Frame, Historic Royal Palaces

Presented by Constantina Vlachou-Mogire
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Four years ago Historic Royal Palaces (HRP) launched a multi-phased research project to establish a scientifically based strategy for the preservation of the Tudor tapestries in the Great Hall (GH) and the Great Watching Chamber (GWC) at Hampton Court Palace. These spectacular tapestries are nearly five hundred years old and have been on open display for over a century; in recent years they have been exposed to higher environmental risks due to increased activities in these rooms to generate income and extend visitor access. This paper will discuss how scientific evidence informs HRP to establish a strategy for the protection of these rare tapestries, whilst displayed in their original setting and balance conservation judgement with 'use' of the collection.
During the first phase of the project a comprehensive environmental monitoring campaign, deploying a large number of sensors, was established for a year in each of the two rooms. The monitors were positioned in front of the tapestries at three different heights, every 2.5m collecting temperature, relative humidity and light (visible / UV, direct / indirect) data. At each monitoring point, two microscope slides were also positioned to collect dust deposition data. The strategic positioning of the sensors in a matrix enabled data visualisation using mapping which revealed accurately the variation of the environmental parameters over the surface of each tapestry - thus highlighting significant risk hot-spots. During the course of this project we also had the opportunity to establish several cross-disciplinary research projects, including the development of a non-invasive analytical method for measuring fibre degradation in historic tapestries, modelling of dust deposition in the GH and the GWC, strain monitoring of the tapestries' exposure to temperature and relative humidity fluctuations as well as a biodegradation study.
We have now moved into the next phase of the project using our significant research outcomes to define targeted protection measures. Each measure is being evaluated with regard to the level of protection provided, its impact in the use or interpretation of these important historic spaces, and of course its cost and feasibility. Only the successfully selected options then proceed to further development and possible onsite trial. One initial example for the GWC to provide protection to our tapestries from light exposure and temperature fluctuations is the replacement of incandescent lamps in candelabras with new technology LEDs. Also, an innovative method to reduce light dosage and direct sunlight, currently being trialled, is the use of SmartTint liquid crystal film on the windows. This innovative technology film switches instantly between transparent and opaque states by application of electricity, and could thus be a "smart" method to control light (especially direct sunlight) into this significant historic space, whilst having little impact on the aesthetic appearance.

Simulation of visitor-induced dust deposition in Hampton Court palace

Joseph Grau-Bové, M. Strlic, C.Vlachou-Mogire

Presented by Joseph Grau-Bové
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The deposition of coarse dust (particles larger than 10 µm) in indoor heritage depends strongly on visitor numbers and behaviour. In many situations, coarse particles are the most area covering, and contribute significantly to the loss of value of heritage surfaces, either by reducing their aesthetic value or by inducing frequent cleaning. Even though the link between visitors and dust deposition has been found experimentally in many instances [1], the deposition fluxes related to visitors are not easy to predict. Mathematical models of particulate matter deposition have been traditionally concerned with air movement [2], and are therefore only valid for small particles of outdoor origin, but not for coarse particles emitted indoors and affected by visitor movement.

We have developed the first simulations of particulate matter deposition which include the contribution of visitors to deposition. Our simulations predict the air flows generated by the movement of humans in the space, and the deposition associated with this air movement. This capability is the latest addition to the Computational Fluid Dynamics (CFD) model of particulate matter deposition developed in the Institute for Sustainable Heritage, which has been extensively validated with data collected in several indoor heritage environments [3]. In order to simulate the movement of visitors, we have introduced simple mannequins into 3D environments, which advance with a constant velocity. This simple physical system is sufficient to capture the essential elements that relate visitor behaviour with deposition fluxes, and to offer the first quantification of air movement induced by visitors and its consequences.

The rich dust deposition data collected by Historic Royal Palaces in the Great Hall of Hampton Court Palace offers an unparalleled resource for the validation of the deposition model. In the absence of relevant outdoor sources of particles, the deposition rates monitored on the tapestries of Hampton Court are known to be largely related to visitor behaviour. Our simulations show that the simulated deposition caused by the movement of visitors corresponds well with some of the features detected experimentally, such as hotspots of deposition close to the doors or the vertical gradient observed in the walls. Our model also allows the simulation of the effects of different numbers of visitors, as well as their position and grouping, in order to explore which situations minimize the visitor-induced deposition.

This research demonstrates the potential of CFD simulations to predict deposition in indoor heritage, and more generally, the ability to predict the impact of human behaviour in indoor environments. This modelling approach can be used to study any hypothetical indoor scenario, opening the door to the possibility of designing heritage exhibits that offer a passive mitigation of dust deposition, reducing cleaning costs and minimising the aesthetic impact of dust.

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Behaviour of indoor coarse particles in the Baroque Library Hall, Prague

Ludmila Mašková, Jiří Smolík, Tereza Trávníčková, Jaromír Havlica,
Institute of Chemical Process Fundamentals of the CAS

Presented by Jiří Smolík
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From 2008-2010 we performed detailed indoor air quality measurements in an old Baroque Library Hall (BLH), located in the Clementinum historical complex, Prague. The measurements involved the monitoring of indoor and outdoor airborne particulate matter (PM), gaseous pollutants and climatic parameters, and the determination of PM chemical composition. Moreover, ventilation rates and spatial variation of indoor PM were also monitored. Temporal variation of size resolved indoor and outdoor PM showed that the main source of indoor coarse PM are visitors, while fine PM infiltrate from the outdoor environment (1). Furthermore, the time behaviour of PM10 concentrations measured in various parts of the hall by 3 DustTrak instrument showed, for the purpose of modelling, that the indoor environment can be considered well mixed. The assumption of ideal mixing was verified by multi-compartment modelling (2). The time and size resolved PM number concentration data were also used to estimate particle penetration efficiency (P) and deposition rate (k) by comparing measured and modelled data. No unique solution was found (1), which was probably due to a nearly linear inverse relationship between simultaneous particle penetration and deposition (3). To determine P and k separately, indoor coarse PM concentrations were increased significantly by indoor resuspension activities, followed by period of particle decay. An exponential fit of decay curve then yielded size resolved deposition rates (k) and analysis of I/O night data size resolved penetration efficiency (P). Since coarse particles are deposited by sedimentation on horizontal surfaces facing upward, we tried to estimate total deposition area using Stokes law (4). It was found that this area is constant for all particle sizes, confirming that the simple mass balance model described the coarse particle behaviour well.

Acknowledgements
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Patterns of soiling in the Old Library, Trinity College Dublin

Allyson Smith, Susie Bioletti, and Robbie Goodhue, Trinity College Dublin

Presented by Allyson Smith
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The Old Library, Trinity College Dublin is the repository for the University's treasures of more than 300,000 rare books and 20,000 manuscripts. There are several storage areas in this historic building, but the majority of the collection is held in the Long Room and Gallery. Only a very small proportion of the collection is housed in environmentally controlled conditions. In order to monitor dust deposition, particulate matter has been passively collected for more than 10 years. The study of dust in the Old Library is part of an ongoing programme of risk analysis for the Old Library and its collections. The findings of this study provide evidence which will inform Library policy and its risk based strategic planning.
This paper presents some of the unexpected findings of dust monitoring. The dust has been traditionally attributed to the large visitor numbers passing through the Long Room (650,476 people in 2014), therefore that space was expected to experience larger deposits of dust. The data shows that this is not the case. Patterns of soiling in the Old Library are widely variable between and within storage areas. It is evident that several factors are at play in terms of particle deposition. In order to assess these findings in context, a parallel experiment was carried out in a nearby historic library – the Royal Irish Academy. After a year of monitoring, comparable dust levels were founds in the reading rooms and meeting rooms of the RIA, and in the Long Room, Gallery and Fagel of the Old Library. While there are differences between the libraries in terms of their size, structure and number of visitors/users it allows important assessments to be made.

A Preliminary Investigation into the Environmental Conditions in Coventry Cathedral Associated with the Preservation of the 'Christ in Glory ' Tapestry

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This paper will present the findings of ongoing research into the environmental conditions that are impacting on the preservation of the Christ in Glory in the Tetramorph tapestry in Coventry Cathedral. The tapestry was designed by Graham Sutherland in the 1950s and installed in 1962 when the cathedral was consecrated. It is an integral and highly significant element of the interior design of this iconic 20thC building. Made of undyed cotton warps and dyed wool wefts and measuring 23 m high by 12 m wide it is also the largest continuously woven tapestry in the world.

The tapestry is mounted on a permanent scaffold fixed to the east wall. The scaffold has 10 lifts spaced 2 m apart with walkways 0.6 m wide that give access to the reverse. The tapestry is attached to the scaffold at the top and sides with fabric strips, nails and staples. It is also attached across its width by bands of cloth that are stitched to the tapestry and fixed to the boards at the edge of every walkway using carpet grippers and nails. The tapestry is unlined.

In 2014 a full condition assessment and cleaning treatment of the tapestry was carried out by Textile Conservation Limited and May Berkouwer Textile Conservation. The assessment included a survey of the causes and effects of the large amounts of surface and embedded sooty particulate dirt that was present on both faces. The dirt had collected in wide bands across the tapestry, the location of which matched the position of the walkways on the scaffold. On an aesthetic level, the dirt dulled the appearance of the dyed colours and reduced the definition of the overall design. The acidity of the dirt had degraded the wool fibres. Fluctuations in air moisture and temperature are likely to contribute to the consolidation of the dirt, making it impossible to remove fully.

In collaboration with Tobit Curteis Associates LLP and the cathedral architect further research is being undertaken into the relationship between the display structure, the environmental conditions and the patterns of soiling and degradation. A better understanding of airflow within the cathedral envelope and of the transportation methods for particles is essential if rates of deposition, and thus frequency of expensive and potentially damaging cleaning, are to be reduced. The impact on dirt accumulation of alternative hanging mechanisms and the addition of a lining is also being investigated.

The paper will include a summary of the assessment and cleaning processes and a detailed description of the environmental monitoring currently being carried out within the cathedral as part of the development of a conservation plan for the long term care of this unique and important tapestry.

Particle deposition and sources in the indoor environment of historic churches

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The study reports on detailed examination of the particle sources and deposition in the indoor environment of historic churches in Poland, differing in size, construction, ventilation rates, and heating strategies. The particle concentrations indoors and outdoors were monitored for at least one year. The air exchange rate was determined by fitting exponential decay curve to recorded concentration of visitor-generated CO2 after the visitors left the church. The two-parameter mass balance equation, taking into account the particle sources and sinks in the indoor environment of churches was used to determine the particle deposition velocities and penetration factors in the indoor environment of the churches. Large indoor and outdoor concentration variability helped to separate the effects of penetration and deposition losses. Liturgical services regularly generated high indoor particle concentrations, owing to burning of incense. During the particle concentration decay after the services, losses due to deposition could be reliably determined, whereas the events of high outdoor aerosol concentrations with no emission of particles indoors allowed the penetration factors to be precisely determined. The minimal AER values of between 0.1 and 0.2 1/h were observed in monumental brick churches especially during the night and in the cold periods when the natural ventilation is limited due to closed doors and windows. Typically, area-averaged deposition velocities for particles of diameters below or above 1 µm were 1.7×10^{-5} and 2.0×10^{-5} m/s. Penetration factors ranged between 0.6-0.8. For a typical church, indoor particle sources, mainly burning incense, accounted for approximately 10% of yearly deposition, the 90% being the outcome of infiltration of the outdoor aerosol. The information obtained allows various ventilation scenarios in churches to be evaluated in terms of their effect on the particle deposition providing an essential background for heritage managers and conservation professionals to planning measures optimally reducing soiling of church interiors.

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Engaging with demolition and construction companies whose activities threaten your museum collection

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From 2015 Birmingham Museum and Art Gallery will be affected by the redevelopment of the adjacent Paradise Forum area of the city. The old Central Library building to be demolished is within meters of the museum and at one point the buildings join at a link bridge. Concerns over damage to the collection through dust and vibration lead to projects to monitor and manage the damaging effects of the work. This paper describes how the risk of damage due to dust was managed.

Dust was monitored in two ways. Firstly a simple and cheap method for monitoring and collecting dust samples using sticky back plastic and plastic petri dishes is described. The dust collected was examined and identified by Birmingham City Labs. Secondly Dustbugs supplied by the IMC group were used at four key locations. These devices give dust deposition by measuring the percentage of the glass window that is covered by dust. The data from these devices was recorded daily by the museum's Gallery Enabler Team. In this way the baseline dust deposition rates prior to building works starting were measured and recorded. It allowed the definition of trigger values for dust deposition above which an abnormal dust event can be said to have occurred.

A framework document, which takes into account not only the findings at Birmingham Museums but also data gathered independently by the contractors, will be drawn up to set out the agreement between the museum and the contractors. The framework will define what constitutes a dust event, what remediation actions might be required and who will be responsible for their funding. Incorporated into this agreement will be the trigger values for the daily increment of dust deposition and these, in conjunction with a visual and microscopic examination of the dust, will provide the necessary evidence and leverage needed to activate remediation actions from the building and demolition contractors. Included in the framework document will be the provision of real-time monitoring of concentrations of dust emitted from the demolition/building site which will act as a prompt warning system to allow dust remediation actions to be put into place promptly.

This project has increased the awareness of conservation and the potential for damage to collections amongst the staff at Birmingham Museums. The museum's Enabler Team have had direct involvement in monitoring the dust, while the wider staff has been kept informed via briefing sessions. It has also been an opportunity to engage with the main contractors involved in the Paradise Forum redevelopment in order to influence how the project is carried out and to ensure the best outcomes for the preservation of the collection and for the continuing enjoyment of visitors to the museum.

Evaluation of moisture sorbents and guidelines for optimizing their use.

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Relative humidity (RH) plays an important role in the degradation process of many types of objects. It has always been a challenge for museums to maintain a low or a specific RH set-point as part of a preservation strategy for cellulose-based objects, metals, calcium-based objects, some colourants and some salt impregnated objects. RH can be controlled within an enclosure, either by active or passive systems. An active system may be a climate-control unit through which the RH of one or more enclosures can be regulated. By comparison, a passive means of RH control utilises moisture sorbents within an enclosure without any system to force air movement.

Different moisture sorbents are applied in the conservation field and their performance expectations are typically provided by the suppliers or distributors. At times, no information on the performance is available or if provided, the protocol is unknown or not standardized. A typical performance indicator for sorbents is the Specific Moisture Reservoir (M). This reservoir is the amount of water (in grams) that is gained or lost by 1 kg of sorbent for each 1% change in RH. The goal of this research was to determine the M for the most common commercial moisture sorbents and to provide some guidelines on how to optimise their use in enclosures.

The performance of seven moisture sorbents (Artsorb, Desipack [bentonite clay], orange silica gel, Prosorb, regular silica gel, RHapid gel, and Zeolite [molecular sieves 4A]) were tested under 3 different scenarios: 10% fluctuation around an RH set point, keeping the enclosure dry in the zone of 20 – 30% RH, and keeping the enclosure humid in the zone of 50 – 60% RH when the average humidity is lower in the room. The bentonite clay and molecular sieves were found to underperform in all circumstances, while the performance of the silica gels varied from underperforming to very good, depending on the scenario.

The use of moisture sorbents in enclosures is an important mitigation strategy and very sustainable when the climate control of the room cannot be achieved easily. This paper will present practical tools such as an equation for the determination of the quantity of sorbents needed, as well as fast and easy methods for conditioning sorbents.

Evaluating & increasing the airtightness of passive display cases with sorbent compartments: a collaboration between academia & industry

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Airtightness & accessibility are desirable yet conflicting design requirements for many microclimates built for heritage collections. Passive display cases feature sorbents for modifying internal relative humidity or scavenging air pollution. Sorbent compartments are routinely located below the exhibit compartment, enabling separate access to sorbents. However, they are a source of several air leakage routes and their location extends the height of cases; increasing *stack-potential*. Air leakage by *stack-effect* in cases is driven by ultra-low pressure differentials (˜0.1 – 0.01 Pa). For many microclimates, it is the main mechanism causing air exchange with the macroclimate. The location of sorbent compartments in confined plinth- or kickboard-spaces obstructs their gap inspection & remediation following case manufacture.

To begin resolving the airtightness weaknesses of passive cases and their sorbent compartments, a pair of industry-made cases (0.9 m^3) of identical design was investigated in a university laboratory. Each case had a pair of sorbent compartments. An appraisal of factors decreasing case airtightness was made via gap inspections, geometric surveys, pressure testing of the sorbent compartment components, etc. Airtightness measurements of the cases as-received – & after gap-remediation & leak-proofing – were made using two techniques:

1) tracer gas decay

2) constant pressurization and depressurization

In their as-received condition, the causes & spatial distributions of the gaps were consistent between the cases. The sorbent compartments on each case featured the largest gaps. These were distributed around three features:

1) wall seams

2) door-gasket

3) door-lock

For each case, the total size of the gaps in the sorbent compartments was significantly larger than for the exhibit compartment ceiling & the exhibit compartment door-gasket combined. A 3-fold difference in total gap-size between each pair of sorbent compartments had little effect on the air leakage rates for the cases – as determined by tracer gas decay. In contrast, this 3-fold difference in gap-size was detectable & proportional to the air leakage rates of the cases when measured by constant de/pressurization. This inconsistency between results of different test methods is explainable through the physics of air movement under natural and forced conditions.

The sorbent compartments were modified *ex-situ* with devices for limiting leakage. They were then leak-proofed by applying low positive and negative air pressure differentials: ˜100 Pa. Each sorbent compartment sustained these pressure differentials over a nominated duration; proving that they do not leak at pressures significantly greater than those driving stack-effect. Installation of the pressure-proofed sorbent compartments & closure of gaps in the exhibit compartment increased the airtightness of these display cases by up to 10 times & brought them to the microbarometric limit – as determined by tracer gas decay.

To help counter display case leakage by stack-effect, it is recommended that case manufacturers inspect, remediate & pressure-proof sorbent compartments prior to their installation on cases. For periodic maintenance checks, the practicality of *in-situ* pressure-proofing is being investigated. Some procedures & technologies developed during this collaboration between academia & industry are being implemented during manufacture of display cases. The risks of enclosing incompatible materials in microclimates with low exchange rates are recalled.

A promising monitoring kit to evaluate air aggressiveness

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Heritage institutions traditionally evaluate and follow-up their indoor air quality by monitoring temperature, relative humidity, and -more rarely- light. However, smart use of technology enables monitoring other parameters that give a more complete insight in environmental 'air aggressiveness'.
To evaluate the indoor air aggressiveness, the Belgian AIRCHECQ-project* develops a new monitoring kit that is modular (collection dependence) and transportable (space dependence), and generates continuous information (time dependence). The basis of the AIRCHECQ monitoring kit comprises a multipurpose datalogger to which a range of sensors can be connected. In this way, the kit simultaneously and continuously measures (1) environmental parameters and (2) material behaviour. The generated data enables the investigation of 'cause-and-effect' relationships. Software (under development) summarizes the data into a single Indoor Air Quality-index (IAQ-index), and graphical and intuitive tools allow heritage caretakers to manage the indoor air quality themselves. In addition, plotting the IAQ-index over time enables an efficient follow-up of mitigating actions.
The kit monitors several environmental parameters continuously, e.g., temperature, relative humidity, CO2, air flow, air pressure, light, particulate pollutants, amount of visitors, etc. However, gaseous pollutants are more complicated to continuously monitor because the concentrations present in heritage contexts are below detection limits of commercial sensors.
Few commercial sensors are designed to monitor the material behaviour over time. Most known reactivity monitoring devices make use of metal sensors. They monitor the metal corrosion rate. Due to selective metal sensitivity, they additionally give an indication of the presence of certain gaseous pollutants (e.g., silver is sensitive to sulphides, and lead to organic pollutants) (e.g. Musecorr (Prosek, Kouril et al. 2008), Onguard (Purafil), ECMTM (Cosasco)). Moisture content sensors monitor the moisture content of materials such as paper in books (van der Burg, Hijnberg et al. 2014). To extend the material monitoring possibilities, the AIRCHECQ-project intends to develop additional (inexpensive) sensors for other heritage-related materials. The team is currently developing a new sensor to monitor the dimensional response of wood to environmental change. The sensor consists of a strain gauge that is applied on a (historic) wood block. Preliminary results are promising. Preliminary results of the first measurement campaigns will be presented.
*AIRCHECQ: Air Identification & Registration for Cultural Heritage: Enhancing Climate Quality (https://www.uantwerpen.be/en/projects/airchecq/)

Prosek, T., M. Kouril, L.R. Hilbert, Y. Degres, V. Blazek, D. Thierry and M. O. Hansen (2008). “Real time corrosion monoitoring in the atmosphere using automated batter driven corrosion loggers. “ Corrosion Engineering, Science and Technology 43 (2): 129-133.

Van der Burg, J., W. Hijnberg, M. Martens and M. Nagel-Stuart (2014). It’s all about objects. The impact of moisture content measufements. Zoeterwoude, Helicon Conservation Support.

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Preventive conservation strategies in the reopened collection of the Kunstkammer of the Kunsthistorisches Museum Vienna: Theory versus Practice

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After years of intense planning and implementing the presentation of the collection of KK/KHM WIEN, the new permanent exhibition was reopened for the public in 2013 and the museum returned to some kind of routine. Sensitised by the increasing number of publications dealing with damages to museum objects due to inappropriate reconstruction and exhibition measures, great emphasis was and is placed upon preventive conservation strategies during the last few years until today. The concept of the HVAC system of the exhibition rooms as well as the design and technical construction of the showcases were already presented at the last IAQ conference, the first problems arising were also already indicated there.

The vision to realise an ideal environment to sustain the precious objects for the future and present them gloriously to the public was rapidly diminished by the economic reality. Due to limited budget, the realisation of internal air circulation and pollutant filtering in all showcases could not be executed; so about one third of the overall 294 showcases – containing less sensitive objects made of bronze, terracotta, and stone – were built as airtight enclosures (AER about 0.,1 per day) without further air conditioning and pollutant filtering. Unfortunately, exactly those showcases revealed to be a big problem after a short period of operation: a glittering film with crystalline structure was noticed firstly only on metallic, later on also on terracotta objects. This colourless deposit – easy to remove since not highly adhering to the objects' surfaces – was analysed and first results confirmed by further investigations.

All analyses detected the crystals to be derivatives of piperidine; slightly different molecules were identified by different methods (1,2,2,6,6-pentamethyl-4-piperidinol, 1,2,2,6,6-pentamethyl-4-hydroxy-piperidine and 2,2,6,6-tetramethyl-4-piperidinol). First considerations about the source of these contaminants were taken, in order to find out which parts of the showcase construction materials emit piperidine and to plan appropriate measures.

Another focus of our study was laid on the effects of the contaminants on the safety of objects as well as humans inside the museum. On the one hand the crystalline layers on the surface of the objects pose an aesthetic problem, but much more important seems to be danger for the objects and the health of museum workers. Simple tests were carried out to estimate the chemical interaction between the piperidine derivatives and metal surfaces. The results help to decide whether and how fast it will be necessary to remove the contaminant layer from the objects' surfaces.

Research on the implementation of pollutant filtering for upgrading the showcases originally built without internal air circulation were carried out in parallel. For this measure, chemical analysis of air pollutants clearly proved the affectivity of the newly installed filtering system. Additionally, many of the showcases showed dull layers on the inner glass surface. These were also analysed by different labs and the results confirmed the presence of mainly fatty acids.

Due to in-house controversy about the general climate, ventilation, and filtering procedures in the display area, complementary investigations were performed to learn about the influence of different HVAC operation modes on air quality in the exhibition rooms. The results are a basis for developing a general long-term climatic concept in cooperation with the facility management of the museum that should also help implementing standards for other in-house collections.

Hazing on display case glass: a review and progress on removal and prevention

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Museums around the world have reported smearing and residues on the surfaces of glazing in display cases made by a number of different manufacturers. This has occurred in cases with a wide variety of contents and conditions. These residues, referred to here as hazing, are unsightly and can detract from the displays. Display cases are a large investment for museums and anything that detracts from their appearance is a concern. In addition, resources to clean the internal surfaces of cases are limited and put the contents, vulnerable museum exhibits, at risk.

Initial investigations on this phenomenon using SEM-EDX, XRD and Tof-SIMS by Imperial College London have indicated a wide variety of compounds but consistently sodium-based. Some of the compounds can be attributed to the contents of the case but it has become obvious that the hazing is caused by other factors. The consistent presence of sodium indicates that there may be migration of sodium ions out of the glass network. Analytical work on identifying the haze has also been carried out by several institutions (Metropolitan Museum, New York; Canadian Conservation Institute) but causes are yet to be confirmed.

The Museum of London raised this problem with several display case manufacturers. One of them, ClickNetherfield, tasked their engineering and innovation team to work on a system to clean, renovate and inhibit the formation of the haze. Initial research focused on the gel layer of the glass with the goal of eliminating surface marking. After nine months, proof of concept was achieved and a full time scientist was recruited.

A process was developed that systematically removes the surface contaminants. Once this film is removed the gel layer can be reset using a paste containing inorganic and organic chemicals and finally the newly exposed glass is treated with a gel containing chemicals that react with the gel layer to form a barrier that reduces the activity of the surface, inhibiting future haze formation.

Testing included intensified pollutant exposure, which showed a significant resistance to haze formation compared to the untreated substrate twenty months post-treatment. Several empty cases at the Museum of London were treated, one with exceptionally severe haze resulting in a dramatic improvement in the transparency and appearance of the glass. Results so far are positive and the treatment has passed the Oddy test. ClickNetherfield hopes to make this product, known as Renew Vitrine, available in November 2015 and are looking for demanding cases to test the product.

The paper will describe the haze reported on display cases and the development and application of the ClickNetherfield product. It will also review analytical work to date to identify the haze and present the results of an international survey of museums that have reported this phenomenon. Although the causes of the haze are still uncertain, progress on prevention has been made. This positive result is a good example of collaboration with industry to achieve a solution to a problem that has been widely reported in museums.

Experiments with reducing energy usage at the National Archives and Records Administration

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The National Archives and Records Administration holds several million cubic feet of records at over 60 U.S. locations, the largest of which is the Archives II building outside Washington, D.C. From 2003 to 2013 the agency reduced its energy intensity (BTU per gross square foot) by nearly 40%. Over the past few years electricity use at Archives II has been cut an additional 20% through new efficiency initiatives, including night and weekend shutdowns of air handler units. At the same time the long-term storage environment has improved based on the Time-weighted Preservation Index model. Even with the shutdowns the storage areas have maintained surprisingly low humidity throughout the year. Experiments with shutdowns are being tried at other buildings, and pollutant specifications and filtration are being reconsidered in light of new research in the field.

Monitoring beacon for early or hidden fungal development detection dedicated to heritage conservation

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Fungi are common biocontaminants of indoor environments, and numerous studies have demonstrated how they can degrade the materials they colonise (e.g. wood, textiles, paper, pigments, varnishes, etc.), which can even result in total destruction of these substrates. Today, fungal contamination is an increasing problem not only in houses and working places. Objects of art in museums and their depots are seriously threatened by fungal contamination (Sterflinger 2010).
At present, heritage conservation organisations can implement corrective measures (Bousta et al., 2008) in order to restore damaged materials, but no efficient preventive strategies are available, nor are any systems that would trigger a warning so that contamination can be halted before any major damage is observed. This situation results notably from problems inherent to the metrology of biocontaminants (Madelin, 1994 and Flannigan, 1996).

Current techniques are unable to detect mould at an early stage in their development or hidden contaminants. Moularat et al., in 2008 has established chemical fingerprints of mouldy development from Volatile Organic Compounds (VOCs) arising specifically from fungal metabolism. This approach has the advantage of detecting fungal development both reliably and rapidly before any visible signs of contamination could be detected. Since the development of this Fungal Contamination Index (FCI), other specific indexes have been developed to monitor works of art in terms of mould development risks. Their applications constitute a new approach for diagnosis (Moularat 2007; Moularat and Robine 2011; Moularat and Robine 2011).

However, even if the FCI has been widely tested (Joblin, Moularat et al. 2010; Moularat, Hulin et al. 2011; Hulin, Moularat et al. 2013), VOCs'analysis by GC/MS, which is required for index calculation, is incompatible for indoor environment real-time monitoring strategy. So having such a device, which could be set up in buildings and able to provide almost instantaneous information on prospective fungal development, constitutes a breakthrough. In this context, researches around FCI exploitation have been followed up in order to provide a monitoring device widely deployable. This device is the result of the miniaturization of an analytical chain for portable, reliable and low-cost applications (Anton, Moularat et al. 2015).
The proposed system is based on one hand on the selection and concentration of chemical compounds from the sample of interest and on the other hand on the development of an array of different sensors in order to obtain a specific footprint. Thus, the developed device has three modules validated individually: one for preconcentration of samples, one for

separation and one for detection. This innovative microsystem involving the collection, analysis, and interpretation of data replaces all these indispensable index calculation steps. This fungal contamination detection device was the subject of patent applications by the CSTB (Moularat, Joblin et al. 2010; Moularat, Joblin et al. 2011).

Inherent pollution risk: Darwin daguerreotypes and their travelling cases

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Down House, Charles Darwin's home, contains six daguerreotype portraits of his children, including the only known image of Darwin with another person. The daguerreotype image plate is silver, with a brass mount and cover glass, which forms a packet that was placed inside a travelling case, commonly of wood, paper, textile and leather. Wool velvet ribbon, identified with Fourier-transform infrared spectroscopy (FTIR), edges where the daguerreotype packet sits inside the travelling case. The daguerreotypes have been displayed in their original travelling cases, inside a showcase. However the wool velvet and leather can off-gas reduced sulphur gases, risking tarnish on the silver daguerreotype image. A double ring of tarnish, with darkening at the edge of the image plate and a further ring at the edge of the brass mount, were identified as silver sulphide using SEM-EDX.

The original cover glasses are made from glass which is probably unstable in composition, identified using X-ray fluorescence (XRF). Droplets have been observed on the inside surface of the glass obscuring the images. At low RH the droplets crystallise and deposits, identified as sodium formate using FTIR, can fall onto the daguerreotype plate causing localised tarnish to the silver surface, visible using Scanning Electron Microscopy (SEM). Additionally the wood in the travelling case is a source of formic acid, which could lead to on-going deterioration of the glass, further obscuring the image for visitors and risking localised corrosion of the image surface.

The daguerreotype packet is normally sealed with P90 tape around the edges. Whilst safe for photographic materials the P90 tape offers little barrier to pollution into the daguerreotype packet from the travelling case. Research is testing alternative materials, to improve the barrier and limit both reduced sulphur gases and formic acid entering the daguerreotype packet. Materials under consideration include aluminium foil tape, corrosion intercept and silver foil. The possibility of using absorbents, such as charcoal cloth sheets behind the packet, to mitigate the formic acid is also being assessed. To investigate differences as a result of the packet design, silver coupons, inside test daguerreotypes purchased from eBay, are being analysed with colorimetry.

Whilst improving the barrier on the edge of the daguerreotype packet would prevent pollution ingress, it may increase the glass deterioration. For unstable glass, condensation events can provide sufficient moisture for glass corrosion. To determine whether condensation events occur, temperature, RH and surface wetness sensors were placed inside the test daguerreotype packets. Microscope images of droplets and crystallisation events on the original cover glass at different RH are being used to understand the glass stability. This will complement the test daguerreotypes results using different sealing methods and microclimates. A larger mock up daguerreotype, with a diffusion tube inside to determine levels of formic acid penetration into the packet with different barrier seals will be attempted. The results will help determine if the inherent risk from pollutants from the travelling case on unstable cover glasses and silver image plate, means these can be displayed together safely and inform future conservation treatments.

CORROSION OF EQUIPMENT AND SPECIMENS IN A MINERAL STORE

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Keywords: Museum store, mineral collection, VOC, SO2

National Museum Cardiff houses the most comprehensive collection of minerals in Wales, approximately 40,000 specimens. The collection is used frequently for display, teaching and research purposes, often in collaboration with other institutions. The temperature in the Mineral Store is controlled by a stand-alone air handling unit which is situated inside the store. Air is recirculated in the store to chill the air and maintain a temperature of 20-22^{o}C. Without active temperature control, for example during breakdown and maintenance periods, summer temperatures reach 27^{o}C in the store. A large number of sulphide minerals are observed to have suffered corrosion damage in the past five years. In addition, the air handler's heat exchanger is corroded to such a degree that it requires replacement for the second time in five years. Due to evidence from the analysis of corrosion products by XRD, SEM and FTIR, and direct air analysis, organic acids and sulphurous compounds are suspected of being the causes of the corrosion observed. The precise mechanisms are unclear at present but are likely to involve a combination of elevated temperature and a build-up of airborne pollutants due to lack of fresh air supply, with one exacerbating the other. Different solutions are possible to address either of the two mechanisms, but all include a reduction of the storage temperature in conjunction with a mechanised air exchange to remove any corrosive airborne compounds and avoid their accumulation in the store. While the environmental requirements of the collection are paramount to any solution, there is also an opportunity to implement a system that improves collections care while also being low in maintenance, has low failure potential and is environmentally sustainable.

A Study of the Environmental Conditions in Birmingham Museum and Art Gallery's Civic Silver Store

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Introduction
The Conservation team at Birmingham Museums Trust are currently undertaking a project to monitor the environmental conditions in their civic silver collection store. We intend to use this information to identify the risks to the collection and to enable us to introduce methods to mitigate the potential negative effects on our objects.

Background to the Research
The project was set up to improve the storage of a significant civic silver collection which is currently stored at Birmingham Museum and Art Gallery, in a space which is considered unsatisfactory for silver storage due to environmental fluctuations resulting from external walls, historic windows and internal water and heating pipes. In addition, historic monitoring with AD strips and metal tokens indicated that the plywood storage units and original display boxes made from wood, card, leather, felt and velvet have contributed to the tarnish process.

There were constraints on the project due to:
- Limited storage on site, meaning the original storage location and wooden shelving units had to be utilised.
- The need to keep the objects in original presentation boxes.
- The requirement for curators and councillors to see objects without unpacking.
- Limited financial and budgetary resources.

Given these constraints, it was decided at the outset that passive methods were required to prevent the objects re-tarnishing. Several passive methods such as charcoal cloth, silver bags and scavengers have been used by museums; however a modern industrial product called INTERCEPT Technology™ has been used specifically for metals storage and has been trialled at several museums. The Conservation department aims to assess the potential corrosion inhibiting effects of INTERCEPT Technology™ products which can be used in environments with poor air quality, such as pollutants.

The Project So Far
Volunteers trained as part of the project have cleaned, photographed, documented, and then repackaged silver objects in clear sealed polythene bags with a piece of CORROSION INTERCEPT® foam.
Environmental conditions in the store are being monitored using Hanwell environmental monitoring systems to record the temperature and relative humidity. Hydrogen sulphide diffusion tubes are also being used to detect pollutants in the atmosphere.

Future Work

A test group of silver tokens have been strategically placed in the civic silver store and a control group have been placed in the conservation store in three different formats: in a bag with Intercept foam, in a bag without Intercept foam and exposed on the shelf. To improve the scientific viability of the project we would like to undertake further imperial experimentation through the use of photographic coupled with scientific XRF analysis of silver tokens to identify the level of sulphide formation on the token surfaces after a period of time in the differing environments.

The research will indicate both if the Intercept product is a viable means for the passive control of metals in unstable environments and also provide an analysis of the air quality of the storage environments within the Birmingham Museum and Art Gallery building.

Degradation of paper under adverse environmental conditions: modelling considerations and calibration with experimental data

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To predict the useful lifetime of paper and other polymeric materials, the classical approach is the use of accelerated ageing as a means to simulate, over short periods of time, all the changes that occur in the polymer over the long periods of natural ageing. Implicitly, in these experiments, the hypothesis is that the artificial conditions used induce the same modifications as natural ageing and that only the rate of each reaction is magnified. However, this hypothesis is not always straightforward as the conditions and processes of natural ageing are multiple and varied. Researchers are aware of this difficulty and the attempts to predict levels of deterioration of paper in natural ageing conditions based on accelerated ageing data are limited. The purpose of the present research is to explore the validity of the extrapolation of accelerated ageing data of paper to natural ageing. The novelty introduced is that besides the classical environmental parameters (T, RH), the model developed includes the presence of outdoor and indoor airborne pollutants. The equation proposed by Zou and co-workers for determining the degradation reaction rate constant k of cellulose [1] has thus been adapted to include not only temperature and relative humidity levels but also various pollutants. Different equilibrium and empirical equations were used for the determination of the two main variables in the equation, which are the hydrogen ion concentration and the moisture content in paper. The model proposed to assess paper stability is based on data from previous research [2]; in particular the protective effect of aldehyde compounds on cellulose degradation. This effect was examined further.
The experimental determination of the reaction rate k is based on the model proposed by Ekenstam for the degradation of linear polymers, which is traditionally used for the degradation of cellulose [3]. However, this model has limitations in that it is not fully applicable to cellulose over the whole range of possible degradation extents and pathways. In particular, departure from linearity has been observed over prolonged periods of artificial ageing [4]. This issue was investigated and the data obtained from artificial ageing of pure cellulose paper on a longer timeframe is discussed in view of the possible experimental artefacts playing a role. Other models, derived from Ekenstam, that have been proposed more recently were also evaluated [5, 6]. Scenarios predicting the decay over time of the degree of polymerization of cellulose will be presented, ranging from typical climates in libraries and archives to worst case situations such as old buildings in polluted urban environments. The foreseen application of the model is to assist stakeholders in making decisions that will optimize the preservation of paper-based heritage. The tool provided, which evaluates the overall impact of the environment, should help select the best cost benefit mitigation strategies adapted for each particular context and situation.

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Effectiveness of damage assessment and novel nano-particle based conservation treatment of collagen bases artefacts, in particular leather

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The work reported here refers to studies performed on collagen-based artefacts (in particular leather) within the framework of two projects the MEMORI project (Measurement, Effect Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets) and the NANOFORART project (Nano-materials for the Conservation and Preservation of Movable and Immovable Artworks). The MEMORI project, as also the previous PROPAINT project (Improved Protection of Paintings during Exhibition, Storage and Transit) demonstrated the damaging effects of enhanced concentrations of volatile organic acids (acetic and formic acids) in enclosures (microclimate frames and showcases) to organic-based cultural objects , and so brought awareness to conservators of this problem [1,2]. Furthermore in the MEMORI project a Decision Support Model was developed as a tool for conservators to assess quality of microclimates surrounding cultural heritage artefacts, also organic-based heritage materials. The database for this tool included results obtained from accelerated ageing studies performed in the MEMORI project. In this paper the results for collagen-based artefacts (in particular leather) will be reported. Controlled environment dynamic mechanical analysis (DMA) was used together with atomic force microscopy (AFM) for damage assessment. The application of these techniques had been developed in the previous IDAP project (Improved Damage Assessment of Parchment) where mechanical displacement of parchment under programmed RH was correlated with extent of denaturation of the collagen. In the MEMORI project parchment and vegetable tanned leather samples (sumac,mimosa) were exposed to acetic acid ($c \leq 400$ mg/m3) and formic acid (3.3 vol. % - 56.9 mg/m3), mixture of the two, and then a blank with no acids for up to 16 weeks at 75% relative humidity (RH) . Results will be presented of the effects of such ageing on these materials, in particular leather. For collagen-based materials (parchment and leather) it was found that improper storage conditions with elevated levels of volatile organic acids can lead to surface gelatinization and lowering of pH. Fluctuations in RH and temperature can then lead to further damage with cracking of the gelatinised surface layer. The third project NANOFORART (Nano-materials for the Conservation and Preservation of Movable and Immovable Artworks) provided novel nano-formulations of nanoparticles for the protection of organic-based heritage materials. In this project part of the work involved testing the efficacy of treatment of collagen-based materials using pH adjustment based on nanoparticles. The type of nano-preparations used will be described together with their method of application and evaluation. Historical leather samples, in particular, showed an improvement in properties after treatment using calcium-based nanoparticles. Overall conclusion for pH adjustment is that the use of calcium based nanoparticles works well and appears to have beneficial effects on long term ageing [3]. This was assessed using Infra-red spectroscopy (ATR-FTIR), Xray surface analysis (XPS), and controlled environment dielectric analysis. Future testing and optimisation of nanoparticle treatment procedures is ongoing for future application for preservation of leather bookbindings in archives.

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Poster Abstracts

Poster

Impact of Visitor Traffic on the Indoor Environment of the Church St. Georg at the UNESCO World Heritage site Monastic Island of Reichenau in Germany

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St. Georg is one of the three Romanesque churches on the island of Reichenau at Lake Constance, Germany, built between the 9th and 11th century. UNESCO inscribed the monastic island of Reichenau in the World Heritage List in 2000. St. Georg has meticulously restored wall paintings which are exposed to a very humid indoor environment. In co-operation with the State Office for Monument Conservation Baden Württemberg, the Materials Testing Institute University Stuttgart (MPA) initiated a national research project funded by the German Federal Environmental Foundation (DBU). The project started in 2015 with the aim of identifying anthropogenic risks and preventive mitigation measures to reduce the environmental stress. One aspect of the research is the impact of visitor traffic on the indoor environment. Within the project a survey on particulates (time series of mass concentrations, composition of deposited particles) and VOCs (sources, concentrations) will be performed in the nave and in the crypt. The nave is open to the public, whereas the crypt is not. The surveys will provide the possibility to discriminate between the effects of visitors, other anthropogenic influences, and inherent risks due to the material condition of the building. The poster will present first results of the project with respect to this task.

Poster

Environmental Monitoring of the Mary Rose Museum

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The salvage and conservation of waterlogged archaeological artefacts are challenges faced by many museums throughout Europe. One of these museums is the Mary Rose museum in Portsmouth, which cares for a collection of 19,000 marine archaeological artefacts. The costly recovery and conservation of this large collection make conservational management a priority to ensure prolonged display lifetimes. However, the effects of air quality on such collections, which typically involve display cases with mixed materials (metals and organic materials), are currently poorly understood.

This poster reviews the sources of gaseous pollutants in the museums environment, detailing their interaction with artefacts and methods of detection. Outdoor sources of pollutants, such as ozone and nitrogen dioxide, will be absorbed onto surfaces, including those of the artefacts that are not in cabinets. Display cases protect their contents from outdoor sources of pollutants, however low air exchange rates can result in high concentrations of potentially harmful gases from the cabinet and/or artefacts within the showcase. In the marine archaeology context, it is common practice to treat waterlogged wood with Poly Ethylene Glycol (PEG), however, it has been reported that this treatment doesn't prevent the development of high acidity [1,2] and the degradation of PEG might result in the off-gassing of formic acid [3].

In this poster, the complex air chemistry present in microclimates of marine archaeological displays is juxtaposed with the relative simple methods of environmental monitoring used within museums. Diffusion tubes are commonly deployed, but these devices have long acquisition times, are expensive and have large uncertainty values.

This work aims to identify the need for improved sensors to monitor museums environments and to inform further research towards a greater understanding of acceptable concentrations of pollutants.

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Poster

Changing gas concentration in a display case using low emission materials

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In our previous study, we reported gas emissions from interior materials used in museums and estimated the gas concentrations in display cases [1]. We confirmed that relatively high gas concentrations were present in display cases that were built using low emission materials, indicating that cases are often built to be as air tight as possible to prevent effects from the surrounding environment; thus, accumulating emission gases and increasing internal gas concentrations with time. These gases can cause adverse effects on artefacts. Therefore, it is necessary to be cautious about gas concentration in display cases to properly preserve artefacts without the effect of high gas concentrations.
Various experiments were performed to confirm the actual environmental conditions within a full-scale display case, including testing the changes in gas concentrations and estimating the concentrations within the case based on initial gas concentrations. The free standing display case (size: 750 × 750 × 1920 mm^3 H and glass case size: 730 × 730 × 970 mm^3 H) was used for the tests that contained measurement holes to allow gas sampling without opening. The interior table was placed with a low emission material. The display case contained a fan for air circulation. The air change rate was 0.12 air changes per day under natural conditions and 4.64 air changes per day when the fan was operational.
Multiple gas sampling events focusing on acetic acid and formic acid were performed within a specific time cycle for 12 days. The case was kept closed during sampling. We observed slight variation in gas emissions throughout the experiment. The acetic acid emission averaged 1.6 µg/h. The emission rate was 4.7 $\mu g/(m^2 \cdot h)$. After one week, the concentration within the case was over 400 $\mu g/m^3$. The gas concentrations obtained through the prediction formula based on the initial gas concentration was consistent with the experimental results, indicating that it was possible to predict changes in the gas concentration in display cases using measurements of the initial gas concentration. These results will help in understanding the condition in display cases to develop better methods for preventing the build-up of unwanted gases.

The construction of the display case was collaborated with OKAMURA Corporation and their support is greatly appreciated.

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Poster

Gas emissions and sugar compositions of different wood species of plywood used in museums

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Gas emissions from wood products, such as plywood, pose a major challenge in museums because of the volatile organic compounds emitted [1]. Plywood is often used as an interior material in museums as it is very useful, except for its gas emissions. We have observed high acetic acid gas emissions from plywood [2]. Wood veneer is considered one of the main sources of acetic acid emissions from plywood. However, the characteristics of gas emissions from plywood remains unclear, and only a few studies have focused on improving and fabricating low-emission plywood. This study compares emissions from different species of wood veneer and investigates emissions experimentally.

Three hardwood species, Meranti (Shorea sp.), Kapur (Dryobalanops sp.), and Keruing (Dipterocarpus sp.) and one softwood species, Japanese red pine (Pinus densiflora), were used in the experiments. Emission tests focusing on acetic acid were conducted using the chamber method [3]. The acetic acid emission rates of two hardwood species were greater than that of the softwood species. The emission rate of one hardwood species was close to that of the softwood species. In addition, the emission rates were different for each hardwood species. Acetic acid emissions from wood are attributed to the hydrolysis of acetyl groups in the hemicellulose. Hardwood has more acetyl groups than softwood. Thus, acetic acid emissions from hardwood were higher.

Xylose, a monosaccharide, is one of the main constituents of xylan, a hemicellulose. The analysis of neutral sugar composition confirms that the xylose content of each hardwood species differs. By comparing these results with the results of the emission test, we find that the emission rate increases when amount of the xylose component increases. Some xylose units have acetyl groups. It can thus be inferred from these results that acetyl group content is different for each wood species and sugar composition is relevant to acetic acid gas emissions.

Choosing the appropriate wood veneer may reduce gas emissions from plywood. This study mainly focuses on acetic acid gas emissions. Other gases volatilized from wood veneer will be examined in a future study.

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Poster

Ammonia in archives

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Ammonia in indoor environments, such as libraries and archives, can damage stored materials such as pigments and metals (Grzywacz, 2006) and mediate microbial decomposition (Petushkova and Lyalikova, 1986). The measurement of indoor and outdoor ammonia concentrations was performed by Analyst diffusive samplers (Marbaglass, Italy) in four archives in the Czech Republic, representing different outdoor environments: (1) Třeboň (small town), (2) Zlatá Koruna (rural), (3) Teplice (industrial area), and (4) Prague (large city). All indoor activities in the archives were very limited. The samplings were carried out during a 12 month period at each location.

The results showed that, in all archives, indoor concentrations of ammonia were usually higher than in the outdoor environment. A possible source of indoor ammonia could be the decomposition of infiltrated ammonium nitrate (López-Aparicio et al., 2011, Lunden et al., 2003), but the penetration of ammonium nitrate and ammonia from outdoors explained only approximately 80%, 50%, 40%, and 20% of indoor ammonia levels in Teplice, Prague, Třeboň, and Zlatá Koruna, respectively. This indicates that all four archives also had another sources of ammonia.

In order to determine this ammonia source, two passive samplers were placed on the walls of each depository. The first was exposed to the free indoor air while the second was exposed in parallel under a sealed glass cover. The results confirmed the building material as the source of ammonia in all of the archives. This was most likely caused by the degradation of organic additives used during building constructions, such as animal urine – a frequently used traditional building additive (Snow and Torney, 2014), or urea based compounds that are used as concrete additive in modern buildings (Demiborga et al., 2014).

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Poster

The Use of Solid-Phase Microextraction Gas Chromatography Mass Spectrometry (SPME-GC/MS) for analysis of plastic materials in historic collections: A case study of handbags in the Museum of London.

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The analysis and identification of plastic materials in heritage collections can be challenging. This is due to a number of factors, including the wide range of plastic formulations found in collections and the difficulty in visually distinguishing between different materials. However, this is becoming very important as plastics are increasingly present in collections of 20th century social history, costume, modern art and design works, and in archives.

Solidphase Microextraction Gas Chromatography Mass Spectrometry (SPME-GC/MS) involves the non-invasive detection of volatile organic compound (VOC) emissions from materials, using fibres with an absorbent coating. This can provide information about material composition, in addition to identifying the products of ongoing degradation reactions. Unambiguous identification of additives such as plasticisers is possible, along with characteristic markers of particular plastic types. Advantageously, the fibres can be used to accurately and non-invasively analyse difficult to reach parts of an object, as well as objects with complex surface textures.

SPME-GC/MS has been used to analyse plastic materials from eight 20th century handbags from the Museum of London's costume collection. This paper therefore demonstrates the practical application of the technique to real, naturally aged museum objects. It has been shown that for some objects SPME-GC/MS can be used to accurately identify plastic materials and provide information on composition. In other cases the results from SPME-GC/MS were inconclusive, and more established techniques such as FTIR may be a more straightforward approach to polymer identification.

Poster

Lead white blackening on graphic art

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The blackening of lead white pigments is a well-known degradation phenomenon, which previously has been reported for paintings, murals and illuminated manuscripts [1-5].

However, since the discovery of graphic art in the Statens Museum for Kunst (Denmark) collection has blackened in the last 10 years, we are in the process of investigating the extent and source of this problem. We found many occurrences on artist drawings, lithographs, and, surprisingly, even on historic photographs, where the white pigment has been used as a retouch in the highlight areas. Our survey also included parts of the collection of The Royal Library in Copenhagen. Some of the cases are reported to be in good condition on visual examinations done 10 years ago.

We will in the poster discuss various aspects of this problem, including the possible sources and decay mechanisms. Model samples of pigment on various base materials (e.g., paper, parchment, and photographic prints) are being monitored for blackening while exposed to natural (galleries and storage areas) and artificial atmospheres (elevated doses of H2S under laboratory conditions) and to low-quality storage and framing materials. As part of this program we are monitoring the level of H2S [4, 6] in collections areas of the Statens Museum for Kunst, and The Royal Library (both located in Copenhagen city centre) for one year.

Pigment samples from real drawings and prints will be taken from deteriorated areas, analysed by spectrometric methods (XRF, SEM-EDX, Raman, FTIR), and compared with the laboratory model samples. Especially the examination of the morphological layering of the blackening will reveal the process mechanisms, and help understand if the source of decay is entirely external (blackening only on pigments upper surface) or if the base material of the artwork could be a contributing source (blackening from below).

This project is ongoing and results are forthcoming.
The project is supported financially by the Danish Ministry of Culture.

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Poster

Detection of active moulds on historical objects by means of the HS-SPME GC-MS method

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Historical objects and art items are mostly made of organic materials which are susceptible to biodeterioration caused mostly by moulds. In cases when there is possibility that object may have been attacked by moulds a conservator has to decide about its disinfection. However, most historical objects are sensitive to disinfection methods (taking into account methods based on alcohols, ethylene oxide or radiation) due to their composition and because they are already naturally aged. Thus, the decision for disinfection of objects should be taken after confirmation that the moulds are indeed active. This may be investigated with classical microbiological methods, but they are time-consuming, labour-intensive and require a contact with the surface of objects. The results of these analyses give information more about the microbial contamination of the surface than the presence of active moulds. They also exclude the possibility of moulds detection if they grow inside the structure of objects. An alternative method of active moulds investigation may be the analysis of volatile metabolites that are emitted by moulds at every stage of their development. These metabolites are called microbial volatile organic compounds (MVOCs). They can be detected when moulds grow both on the surface and inside the material as they easily diffuse of the objects.

The main goal of this study was to assess the possibility of using the solid phase microextraction – GC-MS method for detection of active moulds growth based on MVOCs measurements. The analysis was carried out for selected moulds that were inoculated on the model samples of silk, cellulose, parchment and wool placed on microbial broths prepared in closed vials. One additional experiment was carried out for a historical sample of leather inoculated with Aspergillus niger prepared in a Petri dish without a broth (open system). After six days of incubation the MVOCs acquired inside the vials and emitted by A.niger growing on leather were sampled on SPME fibre and then analysed in GC-MS system. The obtained chromatograms were analysed qualitatively and quantitatively in order to determine whether among the identified compounds are markers of moulds activity that may be used for their detection in case they develop on the real historical or art objects.

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Poster

Practical Implementation of Preventive Conservation Strategies during Museum Construction Projects

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The current trend within conservation and restoration sciences is directed towards the effort of Preventive conservation strategies. A lot of new scientific approaches can be observed over several years. However, it still seems complicated and difficult to realize those recommended and postulated strategies during everyday life. Most museums suffer on the same problems, i.e. how to realize preventive conservation during building renovation projects, which persons have to be involved and consulted? How can aesthetical and conservation requirements be successfully combined, especially in regard to budget limitations? Museum conservators often report a lack of agreement between different responsible parties or the integration of conservation in decision making processes coming too late. In addition, there are uncertainties in defining clear and precise demands on environmental parameters such as climate, lighting, pollution, and the technical construction of exhibition furnishing.

For this reason, a two-year research project was carried out between two museums of different size and collection type, which are currently undergoing renovation measures and complete refurbishment, with Fraunhofer WKI as the consulting research institute. The joint project was funded by the Deutsche Bundesstiftung Umwelt (DBU). It was differentiated into two separate projects for each museums site, which are the Herzog Anton Ulrich-Museum Braunschweig and the Domschatzkammer Minden.

The Herzog Anton Ulrich-Museum is one of the oldest museums in Europe. It houses a large painting collection, including e.g. masterpieces of Rembrandt, Rubens and Vermeer, as well as a famous enamel and porcelain collection and valuable furnishing. The old listed building is closed for renovation for a few years. A totally new exhibition is planned including new furnishing of rooms, galleries, and showcases. Due to fine metal pieces showing clear pollutant induced damage, the focus of this project was on investigating the reactions of pollutant damaged objects towards large climatic cycles and further pollution impact. The objective was to specify requirements for the gallery furnishing. This included the development of policies on how to implement material emission tests, how to deal with material emissions of different product charges and especially how to combine aesthetic and conservation requirements. One main aspect was the timely agreement between all parties. Therefore, the policy also contained information about how to involve the different responsible parties and at which stage.

The Domschatzkammer Minden with a current small exhibition area will be extended and rebuilt. The valuable medieval collection houses mainly wooden sculptures, church vestments, reliquaries and precious artefacts. The planned exhibition will offer a modern and appealing presentation of the items on display. Main objectives of the renovation work

are achieving an energy efficient building and the implementation of preventive conservation measures because a wide range of museum exhibits show environmentally induced damages such as stress cracks in wood and light damages on textiles. The research project at Minden dealt therefore with the development and realization of an integrated concept based on preventive conservation and considering climatic parameters, lighting and pollution.
The project demonstrated the possibilities of realizing preventive conservation in museum facilities of different size and collection type from a very practical point of view. The poster will present results and critical evaluations of the joint project.

Poster

Modelling collections and their environments

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Significant recent advances in environmental and material modelling have accompanied the publication of a recent environmental guideline (PAS 198) that recommends institutions to develop individual environmental policies tailored to their collections. By integrating the material properties of objects, the value and expected use of the collection and the resource requirements, fixed environmental set points and thresholds can be avoided and preservation outcomes optimised.

Yet, little guidance is provided on how this could be done in practice. In collaboration with the Smithsonian's Museum Conservation Institute (US), the National Archives (UK) and the company Lichtblau e.K. (Germany), this research is working towards modelling collection change to aid the implementation of the new guidance. There are three key elements: (i) a structured stakeholder engagement programme including workshops and interviews to discuss long-term preservation horizons, acceptable degradation for different types of materials/objects, and user requirements for a decision-facilitating tool; (ii) research on material degradation as a result of indoor environmental impact through case studies. Scientific evidence will be collected through a combination of conventional analytical methods and non-destructive collection surveys. Synergistic effects of environmental impact and material properties will be described by dose-response functions established via statistical and computational modelling. The first case study is historic paper containing iron gall ink; (iii) an integrated software platform that responds to the needs of the conservation community. Such a platform will serve as a tool for data upload and interpretation, scenario evaluation as well as for development of environmental strategies for management of various collections. The poster contribution interactively explores this latter element.

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