Indoor Air Quality 2012

10th International Conference

Indoor Air Quality in Heritage and Historic Environments

"Standards and Guidelines"

Book of Abstracts

UCL Centre for Sustainable Heritage

London, United Kingdom

17th – 20th June, 2012

Scientific Committee

Dario Camuffo, CNR-ISAC, Italy
Christian Degrigny, SARL Germolles, France
Lorraine Gibson, University of Strathclyde, UK
Martina Griesser, Kunsthistorisches Museum, Austria
Cecily Grzywacz, National Gallery, USA
Morten Ryhl-Svendsen, National Museum of Denmark, Denmark
Alexandra Schieweck, Fraunhofer Wilhelm-Klauditz-Institute - WKI, Germany
Matija Strlič, UCL Centre for Sustainable Heritage, UK
Jean Tétreault, Canadian Conservation Institute, Canada

Organisation Committee

Hénoc Agbota, UCL Centre for Sustainable Heritage, UK
Katherine Curran, UCL Centre for Sustainable Heritage, UK
Catherine Dillon, UCL Centre for Sustainable Heritage, UK
Ann Fenech, UCL Centre for Sustainable Heritage, UK
Lorraine Gibson, University of Strathclyde, UK
Josep Grau-Bové, UCL Centre for Sustainable Heritage, UK
Naomi Luxford, UCL Centre for Sustainable Heritage, UK
Eva Menart, UCL Centre for Sustainable Heritage, UK
Gianluca Pastorelli, UCL Centre for Sustainable Heritage, UK
Matija Strlič, UCL Centre for Sustainable Heritage, UK
David Thickett, English Heritage, UK
Giovanni Verri, UCL Centre for Sustainable Heritage, UK

In collaboration with

Programme

Sun 17/06/2012, Roberts Foyer

15:00-18:00 Registration
18:00-20:00 Opening address & reception

Mon 18/06/2012, Anatomy JZ Young Lecture Theatre

Session	Name	Surname	Title
Session 1 09:00-10:40 Session Chair: M. Strlič	**Nancy**	**Bell**	Rising environmental standards: A prospective view
	Catherine	**Dillon**	Implicit and explicit time preferences in collections care and conservation
	Marie	**Vest**	Practical usage of standards and guidelines for indoor air quality
	Andrea	**Cavicchioli**	Indoor air quality in heavily polluted cities: Ozone and nitrogen dioxide contamination in the indoor atmosphere of two museums of São Paulo, Brazil
	Konstantinos	**Ntanos**	Research to practice: What has changed at the National Archives environmental control in storage
10:40-11:10	**Coffee Break**		
Session 2 11:10-12:30 Session Chair: M. Ryhl-Svendsen	**Morten**	**Ryhl-Svendsen**	Acetic acid in air: A review
	Eva	**Menart**	The effect of indoor pollution on historic paper
	Jean	**Tétreault**	The impact of carbonyl vapours and hydrogen peroxide on cellulose degradation
	Giovanna	**Di Pietro**	The limited impact of acetic acid in libraries and archives
12:30-14:00	**Lunch Break**		
14:00-17:30	**Conference Workshops** Please see the conference website http://www.ucl.ac.uk/iaq2012/index for details and locations.		

Tue 19/06/2012, Anatomy JZ Young Lecture Theatre

Session	Name	Surname	Title
Session 3 09:00-10:40 Session Chair: L. Gibson	**Alexandra** **Fenella** **Alexandra** **Elise** **Katharina**	**Schieweck** **France** **Jeberien** **Spiegel** **Wiegner**	Standardisation of emission testing of materials for use in museum environments Defining data collection for assessing and monitoring visual storage environments Re-inventing standards in the development process of display cases for cultural institutions in Germany A quality label for low-emitting display materials and showcases as possible instrument for emission control Guideline for assessment of emissions from materials for museum equipment
10:40-11:10	**Coffee Break**		
Session 4 11:10-12:30 Session Chair: A. Schieweck	**Lorraine** **Arja** **Masahiko** **Alexandra**	**Gibson** **Koskinen** **Tsukada** **Schieweck**	Heritage smells: Vapour sensing around heritage objects The importance of measuring the air quality in a showcase containing rubber material Air sampling in Oddy test vessels and its analysis with SPME-GCMS Performance of adsorbent media for sustainable mitigation of organic pollutants
12:30-14:00	**Lunch Break**		
Session 5 14:00-15:40 Session Chair: D. Thickett	**Jean-Louis** **Paul** **Iain** **Andrea** **Constantina**	**Bigourdan** **Lankester** **Stewart** **Luciani** **Vlachou - Mogire**	Understanding temperature and moisture equilibration: A path towards sustainable strategies for museum, library and archives collections The impact of climate change on historic interiors Investigating relative humidity and its control in the National Trust Carriage Museum The influence of air exchange on the stability of the indoor climate in Skokloster Castle Monitoring environmental risks to historic tapestries – A holistic approach
15:40-16:10	**Coffee Break**		
Session 6 16:10-17:50 Session Chair: N. Luxford	**Marianne** **Stephen** **Robyn** **Elena** **Ferhat**	**Odlyha** **Hackney** **Hodgkins** **Badea** **Karaca**	Damage assessment of organic-based heritage materials in monitored locations Refinement in the use of ad strips for the measurement of organic acid vapours Effect of environmental pollutants on the deterioration of the Daguerreotype image Thermal microscopy and analysis for identifying environmentally sensitive parchment and leather documents and artefacts Evaluation of indoor air quality in Dolmabahçe Palace and risk assessment
Tue 19/06/2012 19:00-21:30	**Conference Dinner** **Royal Society of Chemistry,** Burlington House, Piccadilly, London W1J 0BA		

Wed 20/06/2012, Anatomy JZ Young Lecture Theatre

Session	Name	Surname	Title
Session 7 09:00-10:40 Session Chair: J. Tetreault	**Chris**	**Muller**	Is it time for a reactivity monitoring standard for museums?
	Tomas	**Prosek**	Application of automated corrosion sensors for corrosivity assessment of model indoor atmospheres contaminated with organic acids
	Terje	**Grøntoft**	Evaluation of pollutant impact on cultural heritage objects in enclosures Measurement, modelling and guidelines
	Michel	**Dubus**	Normalized environmental assessment of cultural heritage by electrical resistance measurements
	Alejandro	**Schrott**	Smart sensor platform for preservation of cultural heritage
10:40-11:10	**Coffee Break**		
Session 8 11:10-12:30 Session Chair: H. Agbota	**Jiři**	**Smolík**	Behaviour of particulate matter in the indoor environment of the National Library in Prague
	Francesca	**Vichi**	Measurement of nitric and nitrous acid in archives with a "multipollutant" diffusive sampler
	Dafni	**Kyropoulou**	Carbon and oxygen isotopes for environmental degradation of historic mortars
	Maria José	**Alcayde Palanca**	Museum pollutants and preventive conservation: Review and future perspectives
12:30-14:00	**Lunch Break**		
Session 9 14:00-15:20 Session Chair: J. Smolík	**Hannelore**	**Roemich**	Standards and guidelines – Understanding consequences and implementation
	John	**Havermans**	Natural history collections affecting the indoor environment
	Carlota	**Grossi-Sampedro**	Changes in indoor climate and pollution in Brodsworth Hall (Doncaster, UK) during the 21st century
	Peter	**Brimblecombe**	Indoor air quality in the future
15:20-15:50	**Coffee Break**		
Session 10 15:50-17:30	**Round Table** 'Standards and guidelines – Hindrance or help?' Moderated by **May Cassar**, UCL Centre for Sustainable Heritage Keynote: **David Grattan,** formerly of Canadian Conservation Institute Panellists: **Nancy Bell,** The National Archives (UK) **Vasco Fassina,** Superintendency to Artistic and Historical Cultural Heritage of Veneto **Jerry Podany,** International Institute for Conservation of Historic and Artistic Works **Frances Halahan,** Halahan Associates		
Wed 20/06/2012 17:30-17:50	**Conference Conclusion**		
18:00-20:00	**Farewell Reception**		

Posters

Poster Session 1

Name	Surname	Title
Maria Inmaculada	**Martínez Garrido**	Wireless sensor networks for monitoring microclimatic conditions in architectural heritage
Ludmila	**Mašková**	Aerosol particles in the National Museum of the Czech Republic
Gemma	**Mitchell**	Can emissions from polymeric materials be used to evaluate their condition?
Alenka	**Možir**	Development of a dose-response function for parchment
Alexander	**Nimmo**	Computational modelling of the role of volatile organic compounds in the degradation of 3D paper objects
Laura	**Roberts**	Applications of wireless IAQ monitoring systems
Maria Dolores	**Romero Sanchez**	TiO_2 with different dopants for self-cleaning natural stone
Iain	**Rushworth**	Vapour-phase detection of biocides in cultural heritage environments
Kristie	**Short-Traxler**	The application of standards in the design of the Weston Library
Jiři	**Smolík**	Methodology of evaluation of the effect of air quality on library and archival collections
Michelle	**Taube**	Real-time monitoring of air quality at the National Museum of Denmark
Lucia	**Toniolo**	Evaluation of the effect of relative humidity and temperature on the corrosion rate of gilded bronzes by means of galvanic sensors
Manfred	**Torge**	Evaluation of protective glazing for medieval stained glass windows
Manfred	**Torge**	Determination of wood protective agents in a world heritage church
Tanja	**Trafela**	Systematic investigation of interferences in the use of SPME fibres in studies of degradation of organic materials
Ludmila	**Tymińska-Widmer**	Digital image correlation (DIC) as a novel tool for monitoring response of canvas paintings to variations in environmental conditions
Petra	**Vávrová**	Monitoring of the indoor environment in the National Library of Czech Republic and other Czech libraries
Lai-ming	**Wu**	Monitoring and control of the conservation microenvironment at the EXPO 2010 Shanghai, China
Fang-yuan	**Xu**	Characterization of airborne particles at Shanghai Museum, China
Isla	**Young**	Instrument development for the measurement of atmospheric species: Adapting to a cultural heritage environment
Bogdan Filip	**Zerek**	Microbiological control of the indoor air in the National Library of Poland

Poster Session 2

Name	Surname	Title
Henoc	**Agbota**	A new multi-pollutant sensor for remote indoor and outdoor heritage environment monitoring
Maria José	**Alcayde Palanca**	Measurement of environmental pollutants using diffusive cartridges. Practical case in Picasso Museum, Barcelona
Willemien	**Anaf**	Characterisation of airborne particles and gaseous pollutants in the Museo Nacional do Azulejo, Lisbon
Elena	**Badea**	How collagen-based materials respond to temperature and relative humidity: A combined DSC, SEM and FTIR study
George	**Bailey**	Corrosive atmospheres inside showcases
Francesca	**Becherini**	Study of PCM technology for application to cultural heritage objects
Katherine	**Curran**	A Study of volatile organic compound (VOC) emissions during the degradation of early 20th century plastics
Elin	**Dahlin**	The MEMORI dosimeter for indoor environment
Maria	**Dmitrieva**	Comparison of two methods of assessment of airborne bio-contaminants. Questions without answers
Peter	**Dyment**	Heritage environmental protection from low energy air filters
Anna	**Fricker**	Humidity sensitivity of inkjet prints
James	**Garvey**	Compressive catalytic air purification for preservation of collections of artistic and historic works in museums, libraries and archival collections
Miguel	**Gomez-Heras**	Microclimate in a church with a forced-air central heating system (San Juan Bautista, Talamanca de Jarama, Madrid, Spain)
Josep	**Grau Bove**	Modelling particulate matter as a threat to cultural heritage indoors
Hanna	**Grossmannová**	Pollutant concentrations in the Technical Museum (Brno) – Monitoring, evaluation, strategy
John	**Havermans**	Emission of VOCs after gamma- and ethylene oxide disinfection of cellulose materials
Kristina	**Holl**	The historic furnishing of Linderhof Palace - in-situ investigation of the state of preservation with regard to the indoor climate
Vera	**Hubert**	Internal testing of real-time corrosion monitoring at the Swiss National Museum
Irena	**Kralj-Cigić**	Are hypoxic conditions beneficial for parchment documents?
Sonja	**Krug**	Reference samples for the XRF investigation of museum objects
Dafni	**Kyropoulou**	Stable isotope (^{13}C and ^{18}O) analysis for investigation of dust cementation in historic libraries

Oral Presentations

Rising environmental standards: A prospective view

N. Bell

The National Archives, UK

nancy.bell@nationalarchives.gov.uk

In the last six months several new publications setting out revised environmental standards for cultural heritage collections have been launched including British Standards Institute sponsored *Publically Available Standard 198: Specification for managing environmental conditions in cultural heritage collections.* This new environmental standard was developed in response to collection environment research that has grown significantly over the last ten years, as well as a growing international debate that environmental standards should reflect the need to reduce reliance on fossil fuels, yet at the same time provide responsible stewardship of cultural collections. Making explicit the key research references underpinning the assumptions set out in the standard, as well as the significant research gaps is one of the key features of PAS: 198. This marks a significant departure from previously published guidance and provides an opportunity to critically assess collection environment research and the value it plays in underpinning the development of environmental standards for cultural heritage collections. Against this background this paper will comment on collection environment research currently, and will offer a prospective view of the relationship between environmental standards, research, opportunities as well as emerging professional challenges.

Implicit and explicit time preferences in collections care and conservation

C. Dillon[1]*, J. Taylor[2], W. Lindsay[3], M. Strlič[1]

[1] UCL Centre for Sustainable Heritage, University College London, UK
[2] University of Oslo, Norway
[3] The National Archives, UK

*Corresponding author: catherine.dillon@ucl.ac.uk

This paper presents a review of the literature relating to time preferences and discounting in decision making, with an application of the findings of the review to collections care and conservation. Data is presented illustrating the expected service life of paper typically found in historic libraries and archives, given a range of environmental controls recommended in standards and guidance. This is presented alongside data from a questionnaire distributed to visitors to historic libraries and archives, who were asked about their expectations about the future of the documents they came into contact with. The paper proposes that implicit and explicit time preferences are reflected in current rates of change in collections and stakeholders' judgements about unacceptable change and lifetime. The extent to which a decision maker discounts future outcomes and prefers positive outcomes to occur sooner rather than later is their 'time preference'. Examples of decisions that involve a time preference include financial, health economic and environmental decisions, such as choosing between energy saving devices that differ in terms of initial costs and long terms savings. Such decisions can be influenced by assumptions about future value, perceptions of risk to long term outcomes, trade-offs between different types of outcome and judgements about the needs of current and future beneficiaries. Decisions about collections lifetime, such as environmental control, may also reflect time preferences. New guidance is in preparation which asks organisations to consider the intended lifetime of their collections when making decisions about storage and use [1]. Integrating research into environmental control and material change with public engagement in decisions about what constitutes unacceptable change and the time period of which this should be allowed to occur could help inform discussions around collections lifetime.

This research is being conducted as part of the Collections Demography project, which is funded by the AHRC/EPSRC Science and Heritage Programme.

1. British Standards Institute. PAS 198 *Specification for environmental conditions for cultural collections,* 2012.

Practical usage of standards and guidelines for indoor air quality

U. Bøgvad Kejser*, M. Vest, B. Vinther Hansen, C. Bruun

The Royal Library, Denmark

*Corresponding author: ubk@kb.dk

The Royal Library in Denmark (KB-DK) is planning a new purpose built repository for long-term preservation of archive and library materials of significant national value. The facility will provide approximately 7,500 m^2 of storage of which 2/3 will be fitted for cold storage of unstable paper and photographic materials. During the planning phase engineers, conservators, collection managers, security and administrative staff at KB-DK have worked with consulting engineers to define requirements for the new building. These included requirements for the indoor air quality, which is the focus of this presentation. As a starting point we wanted the pollution targets to reflect the sensitivity of the collections, and at the same time, be measureable (controllable). To define the tolerable levels of air pollution we consulted experts in the field and analysed current standards and guidelines [1-7]. Among other things, we found that the specific pollutant targets are not always properly referenced and that it is not always stated how the targets are derived; are they based on empirical data on the adverse effect of pollutants on materials, or on limitations from practical implementations, such as pollutant detection limits or current air filtering technology, or are they simply a qualified guess? We ended by specifying the pollution levels listed in Table 1. They are within the limits recommended by ASHRAE [1] for sensitive materials except ozone, which we relaxed in order to be able to measure it. The presentation will describe the decision-making process, which has involved discussions and compromising between requirements for use and preservation; between ideal technical solutions and practical ones; and between the perceived benefits and the total costs of ownership of the repository. We conclude that standards and guidelines are essential tools for defining requirements for indoor air quality. However, their usability in the decision-making process is closely linked to the quality of the references.

Pollutant	Targets (µg/m^3)
Sulphur dioxide, SO_2	≤0.2
Nitrogen dioxide, NO_2	≤0.1
Ozone, O_3	≤1
Acetic acid, CH_3COOH	≤12
Formic acid, HCOOH	≤6
Formaldehyde, HCOH	≤6
Fine particles, $PM_{2.5}$	≤0.1

Table 1. Specified pollution targets for the new storage facility at KB-DK.

1. ASHRAE, ASHRAE Handbook – HVAC Applications (SI), Chapter 23, Museums, Galleries, Archives and Libraries, 2011.
2. BSI, BS5454, Recommendations for the storage and exhibition of archival documents, 2000.
3. C. M. Grzywacz, Monitoring for gaseous pollutants in museum environments in Tools for Conservation, Getty Publications, 2006, 109-110.
4. ISO 11799:2003, Information and documentation – Document storage requirements for archive and library materials.
5. J. Tétreault, Airborne Pollutants in Museums, Galleries, and Archives: Risk Assessment, Control Strategies and Preservation Management, Canadian Conservation Institute, Ottawa, 2003.
6. G. Thomson, The Museum Environment, Second edition, Butterworths, London, 1986, 268-269.
7. W. K. Wilson, Environmental guidelines for the storage of paper records: a technical report sponsored by the National Information Standards Organisation (USA), NISO Press, Bethesda, 1995.

Indoor air quality in heavily polluted cities: Ozone and nitrogen dioxide contamination in the indoor atmosphere of two museums of São Paulo, Brazil

A. Cavicchioli[1]*, R. O. C. de Souza[1], G. Ranieri Reis[1], A. Fornaro[2]

[1] School of Arts, Sciences and Humanities, University of São Paulo, Brazil
[2] Institute of Astronomy, Geophysics and Atmospheric Sciences, University of São Paulo, Brazil

*Corresponding author: andrecav@usp.br

This paper discusses ozone and nitrogen dioxide concentration data collected in the indoor environments of two important museums of the city of São Paulo: the History Museum of the University of São Paulo and the Art Museum of the State of São Paulo. Both museums are located in the central urban area and, therefore, in heavily polluted outdoor atmospheric conditions. Only the Art Museum has an air filtration system in its storage area. Two techniques were used to obtain the target information: continuous monitoring and passive sampling. The measured indoor concentrations were compared with outdoor data obtained from the official monitoring stations of the São Paulo State Environment Protection Department. Passive sampling was carried out using tubular collectors adapted from previously described models. For ozone, the indigotrisulfonate discoloration technique was used, whereas nitrogen dioxide was quantified measuring the formation of nitrite in an ethylene glycol/sodium carbonate/methanol impregnation medium. In the History Museum, both pollutants are found at concentrations that are only slightly lower than outdoor concentrations, with some visible differences between more or less internal areas. External fluctuation does reflect in indoor variations in the levels of both pollutants, which shows the direct influence of outdoor sources in the presence of these substances inside the museum. Lower i/o ratios for ozone were detected in the storage area during the weekends, likely due to the closure of these parts of the building where offices are also located. In a gallery near an administration area, signs of indoor ozone source were found – possibly associated with the use of electronic devices. This scenario confirms that the museum exhibits a high air exchange rate which leads to potential risks for the collection and ought to be regarded as a priority in the museum environmental management strategies. In the Art Museum, filtration and air conditioning systems do result in improvements in the air quality in terms of ozone and nitrogen oxide, especially in the storage area. Yet, the safety standards for this type of microenvironment are not always maintained.

Research to practice: What has changed at The National Archives environmental control in storage

K. Ntanos

The National Archives, UK

kostas.ntanos@nationalarchives.gsi.gov.uk

The National Archives (TNA) is the official archives of the UK government. It holds almost 1000 years of recorded history at its site in Kew, London. One of the main aims of TNA is to preserve and protect its 11 million records making them accessible to all. The environment in storage is controlled by a vast air conditioning (HVAC) system, which is both complicated and increasingly costly to operate and maintain. Managing environmental conditions is a complex task given the, sometimes, contradicting imperatives of preservation, access, and environmental responsibility. The approach taken by TNA is informed by conservation research outcomes and its progress systematically monitored and assessed against current specifications and government targets. This talk will present the progress made in implementing the outcomes of the Building Environment Simulation project [1, 2], a highly complex computer model that simulates environmental conditions in TNA's repositories delivered in collaboration with UCL Centre for Sustainable Heritage. Since the completion of the project, various elements of the HVAC system have been upgraded or replaced in order to provide increased control, though without that predicating tight control bands and fixed set points. The main difference has been a shift in environmental control strategy, which aims to deliver appropriate preservation environment in storage, whilst meeting the organisation's sustainability targets. The impact it has had on targets for reduction of energy use and CO_2 emissions to date will be reported and the resultant storage environmental conditions accessed based on TNA's Annual Environmental Assessment methodology [3].

1. S. H. Hong, M. Strlič, I. Ridley, K. Ntanos, N. Bell, M. Cassar, Climate change mitigation strategies for mechanically controlled repositories: The case of The National Archives, Kew, Atm. Env., In Press, Available online 16 December 2011.
2. S. H. Hong, K. Ntanos, M. Strlič, I. Ridley, M. Cassar, N. Bell, Monitoring and Modelling the Storage Environment at The National Archives, Institute of Conservation (ICON) Conference CF10 Conservation in Focus, Cardiff, 2010.
3. K. Ntanos, S. VanSnick, Environmental Assessment without Limits at The National Archives, In: ICOM-CC Graphic Documents Working Group, Interim Meeting, Copenhagen, 2010.

Acetic acid in air: A review

M. Ryhl-Svendsen

Department of Conservation, National Museum of Denmark, Denmark

morten.ryhl-svendsen@natmus.dk

This paper will summarise work on atmospheric acetic acid in museum environments: its sources, typical quantities in air (room scale and micro-environments) and effects on materials, as has been reported in numerous papers during the previous nine IAQ conferences. Special emphasis will be placed on interactions with materials (deterioration mechanisms) and a discussion on thresholds or exposure limits. The paper will be in two parts: first, a general state-of-the-art review, and second, a report of new findings by the author. Traditionally for museum environments, acetic acid has been associated with corrosion of metals and deterioration of calcareous objects. However, more attention will be given to a review of recent research, which focuses on acetic acid's interaction with organic polymeric materials, including paper, plastics, and proteinous materials such as leather and parchment. Deterioration mechanisms within organic materials initiated by acetic acid (and other carboxylic acids) can be quite complex, as some materials may be degraded by atmospheric acetic acid, and at the same time be the source of the acid(s). Finally, a report on a new study by the author on the dynamics of acetic acid in air on a room scale will be given. A general mass-balance model has been derived from tests in an environmentally-controlled room-sized chamber. The model describes the typical dynamics of a museum room: the acid's sources (material emissions) and sinks (passive removal by sorption on the building interior or museum collection objects), influence of climate (temperature) and air exchange rate. The findings will be related to the deposition mechanisms of atmospheric acetic acid onto material surfaces with the presentation of deposition velocity values valid for a number of typical building and heritage object materials.

The effect of indoor pollution on historic paper

E. Menart[1]*, G. de Bruin[2], M. Strlič[1]

[1] UCL Centre for Sustainable Heritage, University College London, UK
[2] Nationaal Archief, The Netherlands

*Corresponding author: eva.menart.09@ucl.ac.uk

It is well known that loss of mechanical stability and colour change of paper are influenced by different environmental factors. In environmental management of library and archival collections, quantitative knowledge of dose-response functions is essential, however, some factors, including pollution, have been researched less extensively and quantitative knowledge is still missing. Indoor- and outdoor-generated pollutants accelerate paper degradation, as they often increase its acidity or lead to direct material oxidation. To investigate this, samples were exposed to the most abundant archival pollutants: acetic acid, nitrogen dioxide and formaldehyde [1]. To represent the contents of a real-life repository six different paper types (five real samples + one model) were selected and exposed to 80 °C, 60% RH and 1000 ppb of each pollutant [2]. Experiments were performed in a purpose-built set-up, with a dynamic flow of polluted and humidified air flushing reactors with samples continuously. Samples were analysed using viscometry (BS ISO 5351:2004) and colorimetry (ΔE 2000). Acetic acid and nitrogen dioxide, especially the latter, had the most effect on both DP loss and colour change and were therefore selected for further experiments. These are performed at 3 different temperatures (80 °C, 70 °C, 60 °C) and 43% RH to obtain quantitative data on the temperature dependence of pollution-related degradation. On the basis of experimental data, the concept of pollutant dose and its suitability as a measure for damage accumulation will be investigated.

1. A. Fenech et al., Volatile aldehydes in libraries and archives, Atmos. Environ., 44, 2010, 2067-2073.
2. E. Menart , G. de Bruin, M. Strlič, Dose-response functions for historic paper, Polym. Degrad. Stab., 96, 2011, 2029-2039.

The impact of carbonyl vapours and hydrogen peroxide on cellulose degradation

J. Tétreault[1]*, A.-L. Dupont[2], P. Bégin[1], S. Paris[2]

[1] Canadian Conservation Institute, Canada
[2] Centre de Recherche sur la Conservation des Collections, France

*Corresponding author: Jean.tetreault@pch.gc.ca

The aim of this research was to quantitatively assess how VOCs can impact the long term stability of cellulose. Little is known about how VOCs produced by paper during ageing can affect its stability. It has been shown previously that among six carbonyl compounds tested, formic acid was the major reactant on pure cellulose Whatman No. 1 paper [1]. In this continued programme of research, pure cellulose paper with a higher degree of oxidation (Whatman No. 40) was used, as it was expected to be more prone to react with VOCs and would also better represent the state of oxidation of historic papers. The VOCs were acetic acid, formaldehyde, formic acid and furfural. They were generated by vapour/water/salt solutions at an approximate concentration of 50 ppm each, at 75% RH and 21 °C in closed vessels in which the paper samples were placed for 52 days. The VOC concentrations were measured using Dräger and Gastec detector tubes. In order to estimate their long term stability, the exposed paper samples were then subjected to accelerated heat and humidity ageing for 5 days at 100 °C. They were subsequently analysed by different means. Molar masses of cellulose were determined using size-exclusion chromatography with multiangle light scattering detection and viscometry. Colour, pH, copper number and zero-span tensile strength measurements were also carried out. In agreement with previous findings, a significant degradation was found only for the samples exposed to formic acid vapours. However, all VOCs produced an increase in the copper number values. Formic acid was found to be the most oxidative, followed by acetic acid, formaldehyde and furfural. To compare the impact of the VOCs with that of a strong oxidant on paper, samples of Whatman No. 1 and 40 were exposed to hydrogen peroxide vapour, alone and combined with formaldehyde. The results will be presented at the conference.

1. J. Tétreault, P. Bégin, A.-L. Dupont, S. Paris, *Carbonyl vapors and their impact on paper degradation,* 9th Indoor Air Quality Meeting, 2010, Chalon-sur-Saône, France, 71. http://iaq.dk/iap/iaq2010/2010_contents.htm

The limited impact of acetic acid in libraries and archives

G. Di Pietro[1]*, F. Ligterink[2]

[1] Hochschule der Künste Bern, Forschungsschwerpunkt Materialität in Kunst und Kultur, Switzerland
[2] Rijksdienst voor het Cultureel Erfgoed, The Netherlands

*Corresponding author: giovanna.dipietro@hkb.bfh.ch

In the last twenty years much attention of conservation scientists has been focused on the measurement of concentration levels of indoor generated air pollutants in libraries and archives, and on the investigation of their harmful effects on paper-based objects. Although these studies provide only parts of the pathway puzzle, they have essentially fuelled a fear of air pollutants. The prospect of embrittled and yellowed paper-based collections has led archives and libraries to implement conservation measures like chemical air filtration. In libraries and archives the most abundant, potentially harmful indoor generated pollutant is acetic acid, which is a vapor given off by degradation of cellulose [1-3]. Few studies have investigated the effect of acetic acid on paper. The results of these studies are partly contradictory. In 2000 Dupont and Tetreault [4] published a paper showing relevant depolymerization of Whatman paper exposed for 40 days at 8 ppm of acetic acid at ambient temperature and 54% RH. This result has been later questioned by the same authors [5]. Strlič et al. [6] have reported a 20% decrease of the degree of polymerization for Whatman paper aged at 50 °C for one year in a vial containing 1.4 μl of acetic acid. A prediction of the long term effect of typical acetic acid exposure levels on paper depolymerization is required for managers to take better decisions about preventive conservation measures.

In this talk we will present a mathematical model to predict the depolymerization of paper exposed to acetic acid. The model assumes that the paper content of acetic acid is in equilibrium with the environmental concentration according to the recently published partition coefficient [7]. The pH change of paper after equilibration with environmental acetic acid can be calculated for simple model papers. The resulting change in depolymerization rate is then given by the Zou expression for the acid hydrolysis rate [8] and the Ekenstam equation. The model is straightforward and can reasonably explain the accelerated aging results of Strlič et al [6]. The contribution to paper depolymerization in 100 years due to absorption of ambient concentrations of acetic acid is predicted as negligible in comparison with the natural depolymerization.

1. J. Havermans, M. A. de Feber, W. J. Genuit, G. J. van Velzen, Emission of volatile organic compounds from paper objects affected with iron-gall ink corrosion, in J. Bridgland, Ed., Proceedings of the ICOM Committee for Conservation, 12th Triennial Meeting, Lyon, 1999, 513-516.
2. A. Lattuati-Derieux, S. Bonnassies-Termes, B. Lavedrine, Identification of volatile organic compounds emitted by a naturally aged book using solid-phase microextraction/gas chromatography/mass spectrometry, J. Chromat. A, 2004, 1026, 9-18.
3. C. J. Shahani, G. Harrison, Spontaneous formation of acids in the natural aging of paper, in: V. Daniels, A. Donithorne, P. Smith, eds., Works of Art on Paper, Books, Documents and Photographs, Techniques and Conservation, Congress of the International Institute for Conservation, London, 2002, 189-192.
4. A. Dupont, J. Tetreault, Cellulose degradation in an acetic acid environment, Stud. Conserv., 2000, 45, 201-210.

5. J. Tetreault, A. Dupont, Carbonyl vapors and their impact on paper degradation, 9th IAQ conference, 21-23 April 2010 Chalon-sur-Saône, France, 2010.
6. M. Strlič, I. Kralj-Cigić, A. Možir, G. de Bruin, J. Kolar, M. Cassar, The effect of volatile organic compounds and hypoxia on paper degradation, Polym. Degrad. Stab., 2010, 96, 608-615.
7. J. L. Pedersoli Jr, F. J. Ligterink, M. van Bommel, Non-Destructive Determination of Acetic Acid and Furfural in Books by Solid-Phase Micro-extraction (SPME) and Gas Chromatography-Mass Spectrometry (GC/MS), Restaurator, 2011, 32, 110-134.
8. X. Zou, T. Uesaka, N. Gurnagul, Prediction of paper permanence by accelerated aging 1. Kinetic analysis of the aging process. Abstracts of Papers of the American Chemical Society, 1996, 212:42–POLY.

Standardization of emission testing of materials for use in museum environments

A. Schieweck

Fraunhofer Wilhelm-Klauditz-Institut (WKI), Germany

alexandra.schieweck@wki.fraunhofer.de

Even though the need for emission testing of materials for use in museum environments is often discussed, it remains unclear so far how this emission testing should be carried out. From the literature, there are a lot of methods available for performing air sampling and emission testing, especially concerning passive sampling devices. The diversity encompasses standardized methods from the field of indoor air hygiene, commercially available passive samplers which have to be analysed by a laboratory after exposure, direct reading sampling devices, microchemical tests and tests which have been especially designed for museum purposes, such as corrosion tests. The question arises whether the results obtained by different methods are comparable and what are their limits and possibilities? For clarification, tests have been performed, both in the laboratory using materials for showcase construction and on-site within several showcases, using different methods [1]. Standardized techniques give precise data which might be difficult to interpret with regard to the potential corrosive impact on cultural assets. Passive devices mostly cause an underestimation of pollutant levels. Other systems are too insensitive to detect low concentrations, which are of high importance in museum environments. Also, results obtained by corrosion tests cannot always be explained by standardized material emission tests. The talk will present the results and, based on this, will discuss the requirements for standardizing emission testing in the museum sector. The importance of appropriate test conditions, especially regarding the almost static conditions inside museum enclosures, will also be considered. The same applies for first approaches to evaluating analytical results concerning the selection of materials, as in this context there are often uncertainties.

1. A. Schieweck, Comparison of test methods for indoor air analyses and material emissions in the museum environment. Possibilities and limits, submitted for publication.

Defining data collection for assessing and monitoring visual storage environments

F. G. France

Library of Congress, USA

frfr@loc.gov

Standardized monitoring of controlled environments in visual storage encasements to assess the environment and air quality poses challenges for cultural heritage institutions [1]. Since the mid-twentieth century, institutions have used cases with controlled microclimates to retard the deterioration of artefacts. Significant developments in the design and construction of anoxic and hermetically sealed cases over the past 50 years support preservation of cultural heritage materials [2]. Sensors measuring a variety of environmental parameters are critical for long-term monitoring to maintain stable preservation environments for significant items of cultural heritage. Appropriate sensors for monitoring parameters are integral to the design, development and fabrication of effective visual storage systems. Even more essential is standardization of the quality, quantity and type of data collected. This is often dependent on the sensors purchased, with long-term consideration of calibration and data interpretation issues frequently omitted from initial case design. The integration of sensor data into information technology and security systems with alerts and notifications requires collaboration with information security, and building management, further emphasizing the need for standardized guidelines on data collection.

The Waldseemüller 1507 World Map is a large anoxic encasement system installed at the Library of Congress in 2007. The Library has monitored a range of environmental parameters in this encasement in real-time for four years. The ability to monitor the effectiveness of the encasement over time has allowed calculation of the leakage rate, with data illustrating the hermetic seal having an effective potential lifespan of 150 years. Collecting data emphasized the challenges of integrating such a sophisticated system into existing institutional IT systems and policies. This also highlighted the need to standardize data collection in order to best understand interactions between environmental parameters – relative humidity, temperature, pressure, and oxygen levels – inside and outside the encasement, including the composition of the internal environment.

1. F. France, Best Practices and Standards in Environmental Preservation for Cultural Heritage Institutions: Goals, Knowledge, Gaps, in Advances in Paper Conservation Research: Developing Conservation Research at the British Library, British Library Conference Centre, London, UK, 2009. http://www.bl.uk/aboutus/stratpolprog/ccare/events/France.pdf.
2. S. Maekawa Ed., Oxygen-free Museum Cases, The Getty Conservation Institute, Research in Conservation, Los Angeles, 1998, 71.

Re-inventing standards in the development process of display cases for cultural institutions in Germany

A. Jeberien*, H. Heine

Class of conservation and restoration, University of Applied Sciences Berlin (HTW Berlin), Germany

*Corresponding author: Alexandra.Jeberien@htw-berlin.de

During 2010 the *University of Applied Sciences Berlin* (HTW), *conservation and restoration class*, got involved in the development process of a sustainable display system for museums institutions. HTW is accompanied by two research institutions and four companies. All partners deal with different aspects of objects' display in museums and collections. Therefore the working group unifies specific conservation knowledge and broad research competence, as there is scientific analysis of construction materials, innovations in climate measurements and relative humidity buffering systems, energy-saving lighting and the development of construction materials. HTW covers the challenge of materials testing, which is done in cooperation with one of the other research institutions.

The system is based on state-of-the-art preventive conservation requirements and the latest materials testing research results. At the same time it is adjustable and re-useable for differing exhibition situations. As a result, the system meets current pollution-reducing and energy-saving demands as well as the financial needs of small institutions.

Since a lot of museums and collections cannot afford to analyse display materials in emission test chambers, they often rely on the Oddy test. The test has been discussed on a broad and controversial basis [1] though is wide spread in the museum world. The HTW team applies it within the project, but combines it with the research partner's test chamber results. Being aware of the Oddy tests' pros and cons, part of HTW research, covers the evaluation of the Oddy tests' conditions: the test set-up as well as the interpretation of the test outcome. As a result, guidelines for the conditions in which the Oddy test needs to be run and interpreted will be developed. Additionally, the research team is examining options to accelerate the Oddy test parameters (e.g. time, temperature, humidity) and trying to broaden the variety of indicators.

For IAQ 2012 it is planned to present the results of the indicator research as well as the guidelines for the test procedure. The following institutions and companies are involved: *Fraunhofer*-Institut für Holzforschung / Wilhelm-Klauditz-Institut (WKI), Brandenburgisches Landesamt für Denkmalpflege und Archäologisches Landesmuseum, museumstechnik GmbH, long life for art, heddier electronic, VOMO.

1. C. Grzywacz, Monitoring for Gaseous Pollutants in Museum Environments, Getty Conservation Institute, Los Angeles, 2006.
2. J. Tétrault, Airborne Pollutants in Museums, Galleries, and Archives: Risk Assessment, Control Strategies, and Preservation Management, Canadian Conservation Institute, Ottawa, 2003.
3. P. Hatchfield, Pollutants in the Museum Environment - Practical Strategies for Problem Solving in Design, Exhibition and Storage, Archetype Publications, London, 2002.

A quality label for low-emitting display materials and showcases as a possible instrument for emission control

E. Spiegel

Otto-Friedrich University of Bamberg, Germany

elise.spiegel@gmail.com

One serious problem in museums – particularly in showcases – is the entry of pollutants and the resulting damage of art and cultural heritage due to unsuitable display and storage materials. The focus of the present work deals with the question of whether or not a quality label for low-emitting display materials and showcases is an appropriate instrument for emission control.

The presentation summarizes the results of the author's doctoral thesis, which pursued the following three objectives:

- The analysis of the current situation concerning pollutants in German museums;
- The assessment of a quality label from the point of view of conservation science;
- The assessment of a quality label from an economic point of view through the estimation of the economic viability of the project by exploring the acceptability of such a label by museums and/ or producers.

The empirical survey indicated that German museums should seek help in terms of dealing with pollutants and the development of instruments to limit the entry of pollutants [1]. Regarding the feasibility of a quality label from the point of view of conservation science, the author was able to show that it would be possible to develop a quality label based on the existing state of research (even if for the specification of target values more extensive studies would be required). From the economic point of view the results show that, in particular for providers of high quality museum showcases, competitive advantages would arise due to such a quality label. It was found that a quality label for low-emitting display materials and showcases could be economically viable and that its feasibility can be classified as perfectly possible. In summary, it can be said that a quality label for low-emitting display materials and showcases is a suitable instrument for emission control in museums.

1. E. Spiegel, Emissionen im Museum – Eine empirische Studie zur aktuellen Situation und zum Umgang mit Schadstoffen in deutschen Sammlungen. in: R. Drewello, Eds. Restaurierungswissenschaften – Beiträge zur Erhaltung von Kunst- und Kulturgut, vol. 1, University of Bamberg Press (UBP), Bamberg, 2009, 85.

Guideline for assessment of emissions from materials for museum equipment

K. Wiegner[1]*, W. Horn[1], O. Jann[1], M. Farke[2], O. Hahn[1]

[1] BAM Federal Institute for Materials Research and Testing, Germany
[2] GLASBAU HAHN GmbH, Germany

*Corresponding author: katharina.wiegner@bam.de

Modern display cases or storage containers for cultural assets must fulfil many specifications including low VOC-emissions and high air tightness within strict limits. This evaluation scheme will support users such as exhibition curators, conservators and designers to select suited construction materials for this purpose. In order to provide a realistic assessment of the amount of volatile compounds emitted from materials used in close proximity of heritage objects, a new test procedure was developed and optimised by BAM Federal Institute for Materials Research and Testing. This new test procedure was developed to address pollutants in environments with low air exchange rates, such as display cases, where low limits of detection are required for the proper evaluation of the impact of specific emitting substances. Many relevant materials used in display case constructions were tested and classified based on their potential emissions. The new assessment scheme for museum display case construction materials comprises various analytical methods and was published under the Bewertung von Emissionen aus Materialien für Museumsausstattungen (BEMMA) scheme (Assessment of Emissions from Materials for Museum Equipment). This new testing procedure was applied to single materials and not the complete display case itself. The evaluation of the emission by display cases will need to consider additional factors such as tightness, air change rate, air conditioning or ventilation and the use of display case materials.

Heritage Smells: Vapour sensing around heritage objects

L. T. Gibson*, G. Mitchell, I. Rushworth, M. Smith

WestCHEM, University of Strathclyde, UK

*Corresponding author: lorraine.gibson@strath.ac.uk

Vapour sensing experiments have been conducted to examine a range of artefacts (paper, modern materials and ethnographic materials) to help identify states of deterioration and potential contamination. A number of case studies were conducted in a range of institutions in the U.K. and indicated a need to provide more sensitive and robust methods of analysis which are now under development. In addition, laboratory simulated experiments have been undertaken to examine the three categories of materials under investigation in the Heritage Smells project:

Paper
To collect volatile organic compounds (VOCs) from paper materials, conventional indoor air sampling has been conducted in addition to collection of VOCs from the surface of the paper using siloxane elastomer sampling strips. Although the sampling strips were not as sensitive as solid phase micro-extraction fibres, when collecting VOCs from the pages of a book, they are considerably less expensive, more robust and still provided detailed information about emissions. Indeed many of the analytes collected were known cellulose deterioration products.

Modern materials
To examine volatile emissions from polymeric materials, a dynamic emission chamber has been built which allows examination of up to seven samples at a time. Samples are heated to approximately 80 °C and the VOCs emitted were collected onto Tenax TA sampling tubes and identified after analysis using thermal desorption gas chromatography mass spectrometry. Correlations between volatile species and materials were attempted.

Contaminated materials
Gas and liquid chromatographic methods of analyses have been developed to examine a range of chemical hazards (e.g. DDT, thymol etc.) which may be present on ethnographic objects and natural history specimens. Initial experiments indicated that some analytes (DDT in particular) will be difficult to trap and elute on conventional sampling tubes and that alternative sorbents will need to be sought. In addition, the possibility of identification of contaminated objects by headspace sampling was explored.

The importance of measuring the air quality in a showcase containing rubber material

A. Koskinen[1]*, U. Knuutinen[2]

[1] Tampere Museums, Finland
[2] Helsinki Metropolia University of Applied Sciences, Finland

*Corresponding author: arja.h.koskinen@tampere.fi

The elastomer collection of Tampere Museum consists of over two thousand industrially mass-produced objects, which include footwear, tyres and healthcare objects. In 2000 a rubber protection suit (code WWII) was put on permanent display. It remained there until August 2011. At the end of the display, in June 2011, air quality in the showcase was studied using VOC gas analysis. The results were used to evaluate the storage solution for the suit, which will remain permanently in the museum's new storage facility. The initial assumption was that the air quality in the showcase would be poor. The experimental procedure was very simple: inside air from the showcase was pumped into two small Tenax tubes and the samples were analyzed using gas chromatography (TD-GS-MS) in the Finnish Institute of Occupational Health. For the analysis reference limits (S1) where chosen from standards which are used to determine good air quality in homes [1, 2]. The results showed that concentrations of VOC gases were more than twice the given limits. It was evident that both the building materials of the showcase and the rubber material itself were emitting organic gases. After evaluating the results it was clear that the procedures of displaying and storing elastomer objects would have to be changed [3]. In future the storage room will be fitted with VOC measuring equipment since the whole elastomer collection will be stored in the same room. The results will be important both for the wellbeing of rubber material objects as well as for the health and safety of the people who are working with the collection.

1. J. Säteri, Sisäilmastoluokitus 2008. Sisäilmaston uudet tavoitearvot. FiSIAQ. (Finnish Society of Indoor Air Quality). www.sisailmayhdistys.fi 4.1.2012.
2. K. Villberg, K. Saarela & T. Tirkkonen, The Control of Indoor Air Quality, Sisäilman laadun hallinta, VTT PUBLICATIONS 540, Espoo, 2004.
3. A. Koskinen, A Plan for the Preservation of the Collection of Rubber Material Objects in Tampere Museums. Master's Thesis, EVTEK Institute of Art and Design Degree Programme: MA Studies in Conservation, 2008.

Air sampling in Oddy test vessels and its analysis with SPME-GCMS

M. Tsukada*, C. Granzotto, A. Rizzo

Department of Scientific Research , Metropolitan Museum of Art, USA

*Corresponding author: Masahiko.Tsukada@metmuseum.org

The Oddy test is a widely accepted screening test method in museums for the evaluation of materials for their safe usage in display and storage of artworks. Sample material is enclosed in a test vessel with metal coupons under elevated temperature and relative humidity. The test evaluates the effect of off-gassing from the sample material on the metal coupons. Since its first development, different set-ups have been published [1, 2] and refinements to overcome disadvantages of the test, such as relatively long test period and intrinsic subjectivity of the result evaluation, have been proposed [3-5]. However, the nature and extent of off-gassing that affects the metal coupons is not well studied. In order to explore this aspect, air from test vessels was analyzed with SPME-GCMS. In a previous presentation*, some considerations about test vessels and preliminary results were discussed. In this presentation, results of the Oddy test, including evaluation of visual and weight changes of metal coupons will be discussed in relation to the qualitative analysis by SPME-GCMS of the air inside the vessel. So far, ten materials were tested in three types of test vessel. In all cases, some chemical components were detected by SPME-GCMS, but not all of them seemed to be responsible for the Oddy test results. In general terms, the same chemical components were detected from the same materials tested in all types of test vessel. However, in few cases the distribution of the components changed depending on the type of test vessels. Three types of test vessel showed different extent of leakage, which may influence both the Oddy test results and the substances detected by SPME-GCMS. Although the Oddy test set-up can still be improved to prevent leakage, the characterization of the air inside the vessels studied has provided supplemental information for an improved evaluation of the sample materials.

*M. Tsukada, C. Granzotto, A. Rizzo, Organic off-gas analysis in the Oddy test vessel with SPME-GCMS, at Meeting of Users' Group for Mass Spectrometry and Chromatography (MaSC) 2011, Cambridge, Massachusetts.

1. J. A. Bamberger, E. G. Howe, G. Wheeler, A Variant Oddy Test Procedure for Evaluating Materials Used in Storage and Display Cases, Stud. Conserv., 1999, 44, 86-90.
2. L. Robinet, D. Thickett, A New Methodology for Accelerated Corrosion Testing, Stud. Conserv., 2003, 48, 263-268.
3. R. Chen, L. Moussa, H. R. Morris, P. M Whitmore, Silver Nanoparticle Films as Sulfide Gas Sensors in Oddy Tests, in: P. Vandiver, F. Casadio, B. McCarthy, R. H. Tykot, J. L. R. Sil, Eds. Materials Issues in Art and Archaeology VIII, Materials Research Society Symposium Proceedings 1047, Materials Research Society, Warrendale, 2008, 287–297.
4. M. Strlič, I. Kralj-Cigić, A. Možir, D. Thickett, G. de Bruin, J. Kolar, M. Cassar, Test for Compatibility with Organic Heritage Materials – a Proposed Procedure, E-preservation Science, 2010, 7, 78-86.
5. S. Wang, L. Kong, Z. An, J. Chen, L. Wu, X, Zhou, An Improved Oddy Test Using Metal Films, Stud. Conserv., 2011, 56, 138–153.

Performance of adsorbent media for sustainable mitigation of organic pollutants

A. Schieweck

Fraunhofer Wilhelm-Klauditz-Institut (WKI), Germany

alexandra.schieweck@wki.fraunhofer.de

The impact of organic pollutants in museum interiors and especially in museum showcases is still of great concern for museum conservators. In the context of the ongoing MEMORI project, which is funded under the seventh framework programme [1], laboratory trials have been performed in order to evaluate the applicability of absorbent media inside of museum enclosures for improving microclimates within preventive conservation strategies. A range of different kinds of activated charcoal, charcoal cloth, zeolithes and silica gel has been subjected to test series under active and passive conditions (with/without air exchange) in order to identify the most effective adsorbent materials. Formaldehyde, formic acid, acetic acid, toluene and alpha-pinene have been selected as target substances due to their known corrosive impact on cultural assets as well as due to their frequent occurrence in museum environments [2, 3]. The experimental set-ups have been designed in such a way as to answer open questions concerning the chemical and absorbing properties of the selected adsorbent media for the target substances. During these experiments, it was also of interest if undesired reaction products might be generated by contaminant-adsorber interactions and if used adsorbent media might act as potential secondary emission sources because of desorption processes. The results revealed clear differences between the adsorption capacities of the media tested, and also concerning the filtration of specific target substances. The performance of adsorbent media that proved to be good in laboratory trials will also be checked in museum enclosures. Therefore, recommendations will be given for their installation. Air quality inside the enclosures will be checked before and after installation in specific time intervals.

The talk will present the results of laboratory trials, an evaluation of adsorbent media and first recommendations for their utilization in museum enclosures.

1. Measurement, Effect Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets. Innovative Research for Market Transfer - MEMORI (no 265132), funded by the European Commission within the 7th Framework Programme (FP7), duration: 2010-2013.
2. A. Schieweck, T. Salthammer, Indoor air quality in passive-type museum showcases, J. Cult. Her., 2011, 12, 205-213.
3. S. Lopez-Aparicio, T. Grøntoft, M. Odlyha, E. Dahlin, P. Mottner, D. Thickett, M. Ryhl-Svendsen, N. Schmidbauer, M. Scharff, Measurement of organic and inorganic pollutants in microclimate frames for paintings, e-PS, 2010, 7, 59-70.

Understanding temperature and moisture equilibration: A path towards sustainable strategies for museum, library and archives collections

J-L Bigourdan*, K. M. Smith, J. M. Reilly

Image Permanence Institute, Rochester Institute of Technology, USA

*Corresponding author: jxbpph@rit.edu

In 2010, the Image Permanence Institute (IPI), a department of the College of Imaging Arts and Sciences at Rochester Institute of Technology, NY received funding from the U. S. National Endowment for Humanities, to investigate new methodologies for sustainable management of collection environments. Collections of enduring research value and cultural significance reside mainly in libraries, archives and museums that are under pressure to reduce their use of energy. While is widely recognized that providing a proper environment is the most important element for preservation, HVAC operations are under scrutiny. In response, institutions are considering a variety of strategies to minimize energy use, such as moving from a static environmental management approach, where macro-environmental temperature and humidity settings remain stable and constant, to a dynamic approach involving methodical nightly, weekend, or seasonal settings adjustments. IPI's current research addresses the lack of systematic study of what happens to collection materials when short-term climate changes occur. Looking to common material-enclosure configurations, such as books on shelves, prints and photographs in boxes, maps in flat-file cabinets, IPI's research explores several key questions: How do temperature and humidity changes propagate through objects and collections? How do seasonal changes affect collections? How can collection managers assess the risks or benefits of dynamic environmental changes that occur in a repetitive pattern over long periods of time?

The thrust of this presentation is to report for the first time new findings regarding thermal and moisture transfer between materials and collection environments. These results will be based upon extensive laboratory testing and field experimentation. IPI's research will provide new and significant insights into the dynamic relationship existing between the changing conditions of the macro-environment, the micro-environment surrounding a collection object, and the object's core. It is believed that the gained knowledge will enable and support profound changes in the way HVAC operations are managed.

The impact of climate change on historic interiors

P. Lankester[1, 2]*, P. Brimblecombe[2]

[1] English Heritage, UK
[2] University of East Anglia, UK

*Corresponding author: Paul.Lankester@english-heritage.org.uk

It is well known that our climate is changing. Previous work on the impact of climate change on heritage has usually focussed on the impact of climate change outdoors, but more recently there has been a shift to research the impact indoors, on historic collections and interiors. Here we present a rapidly applicable method that allows for the prediction of temperature and relative humidity in unheated historic interiors. This can be used both in the short term (i.e. days to weeks), and in the long term (i.e. until 2100). Simple building simulation is coupled with high resolution climate predictions, to determine the future indoor environment. Results suggest increasing indoor temperatures in the future, as expected, with little change in annual average relative humidity (RH). However analysis of seasonal RH cycles highlights important shifts, such as drier summers and slightly damper winters indoors. The changing indoor environment will change the rate of damage to interiors. The work has explored various types of damage, including chemical ageing of paper, and silk, dimensional change to wood, salt damage to stone, the risk of mould growth and finally pest activity. Damage from mould growth and insects is likely to increase in the future, while humidity driven dimensional change to materials (e.g. wood) should decrease somewhat. Paper/silk may be damaged more rapidly and predicted change to salt damage is specific to each location, because of the dependence on critical humidities. The results allow collection managers to prepare for the impact of long-term climate change, putting strategic measures in place to prevent increased damage, and thus preserve our heritage for future generations.

Investigating relative humidity and its control in the National Trust Carriage Museum

I. Stewart

National Trust, UK

iain.stewart@nationaltrust.org.uk

Arlington Court is home to the National Trust Carriage Museum, which displays a representative collection of British horse-drawn carriages of the 19th century. The collection is housed in an original 1864 stable block and a museum purpose-built in 2005. The size and heat loss characteristics of these buildings make them unsuitable for conservation heating, the main method of relative humidity (RH) control used by the National Trust. Therefore, other methods of controlling RH have been sought. This paper will outline research into the environment of the buildings; discuss the decision-making process to arrive at the preferred RH band befitting this mixed-material collection; and describe the methods of testing used to find ways to control RH. The paper will present a comparison of the effectiveness of the two buildings in terms of environmental control and finally consider how to achieve the desired environmental results while delivering on the National Trust's commitment to drive down energy consumption. The methods employed during this research are of a practical nature and include for example trialling applications to seal gaps around windows and doors and in-between floorboards. The power consumption of dehumidifiers was taken using a plug-in energy calculator, before and after the gap sealant was applied. Using Hanwell instruments to measure the CO_2 decay rate, before and after measurements for ventilation rate have also been recorded. As a comparison, heating was trialled in both the old and new museum area as a measure of controlling RH, in order to show its effectiveness compared with dehumidification. The conclusion reached by the paper will show that a combination of the methods trialled have been successful to control the environment in the 1864 building. Presently, it has not been possible to achieve the recommended RH band in the 2005 building.

The influence of air exchange on the stability of the indoor climate in Skokloster Castle

A. Luciani[1]*, M. Wessberg[2], T. Broström[2]

[1] Doctoral program in Preservation of Architectural Heritage, Politecnico di Milano, Italy
[2] Centre for Energy Efficiency in Historic Buildings, Gotland University, Sweden

*Corresponding author: andrea.luciani@mail.polimi.it

Skokloster Castle is a historic masonry building located North of Stockholm without any active climate control and hosting an important and heterogeneous collection of artefacts. Despite being cited as a good passive preservation environment, conservators are now observing decay in the collections related to the indoor climate that may call for a re-evaluation of the climate control strategy.

Air exchange is generally considered one of the driving forces influencing unheated historic buildings. This study was developed to better understand and evaluate its influence on the indoor climate stability of the castle. The study has outlined an experimental procedure for the assessment of air exchange to be used (and tested) in other historic buildings.

Air exchange rate (AER) was measured in seven rooms on the first floor of the building using tracer gas passive sampling. The results were systematically compared with indoor climate parameters of temperature (T), relative humidity (RH) and mixing ratio (MR) in order to find correlations. The EN 15757:2010 standard was used to identify the most dangerous fluctuations for hygroscopic materials as well as a suitable target range based on a 30-days moving average. Problems connected with mould growth and high RH levels were also considered.

The data analysis shows quite clear correlations between AER and the variability of MR (even if differential seasonal behaviours were noticed) as well as between AER and RH fluctuations. Analysis of selected rooms' data was performed to evaluate the most efficient mitigation strategy, considering different possibilities (air tightness improvement, conservation heating, dehumidification). The pros and cons of the methodology applied in this study will be discussed as well as the potential to develop it to obtain a useful tool for assessing the influence of air exchange in historic indoor climates.

Monitoring environmental risks to historic tapestries – A holistic approach

C. Vlachou-Mogire*, I. Gibb, K. Frame

Historic Royal Palaces, UK

*Corresponding author: constantina.vlachou@hrp.org.uk

The spectacular Tudor tapestries that are located in the Great Hall and Great Watching Chamber at Hampton Court Palace are nearly five hundred years old and have been on display for over a century. In recent years, they have increasingly been exposed to environmental risks due to an upsurge in activities in these rooms to generate income and visitor access. We have launched a multi-phased research project to establish a scientifically based strategy to protect these irreplaceable tapestries from becoming damaged by the environmental conditions and enable continuous long term display. This paper will present the research methodology and the planning of the first phase of this project which will investigate the conservation conditions in each location that the tapestries are being displayed. Also, during this phase the impact of the environmental risks on the condition of each tapestry will be evaluated. The environmental parameters which will be monitored are temperature / relative humidity, light (visible / UV, ambient / direct) and dust deposition. The tapestries cover quite large areas (they might measure 5 m high to 8 m wide) thus, a number of sensors are being deployed in front of each one and bespoke support systems were designed to hold the monitoring equipment. The monitoring data will be processed using relevant standards (T: 19 – 21 °C, daily variations 1 °C RH: 50-60%, daily variations 5%, Light annual exposure: 150,000 luxh, 4.5 Whm^{-2}, Dust: 3% monthly deposition) to evaluate the risks that the tapestries are being exposed. Why these specific standards were used will be discussed extensively. The application of portable FTIR/NIR/ microscopic examination and colour measurement data will provide evidence if there are any chemical variations in areas that are exposed directly to an environmental risk. Other methods which will be used in this project are thermal imaging, video / image analysis and biodegradation survey. Also, information on the operational procedures, functions and visitor numbers will be collected to inform the findings.

Damage assessment of organic-based heritage materials in monitored locations

M. Odlyha[1]*, L. Bozec[2], D. Thickett[3], S. Hackney[4], M. P. Colombini[5], I. Bonaduce[5], F. Di Girolamo[5], R. Larsen[6], K. Mühlen Axelsson[6], D. Vestergaard Poulsen[6], M. Scharff[6], O. Marincas[7], P. Vandenabeele[8], A. Potthast[9], K. Ahn[9], T. Gronthoft[10], E. Dahlin[10]

[1] Department of Biological Sciences, Birkbeck, UK
[2] Eastman Dental Institute, UK
[3] English Heritage, UK
[4] Tate Conservation Department, UK
[5] Department of Chemistry and Industrial Chemistry, University of Pisa, Italy
[6] School of Conservation, Royal Danish Academy of the Arts, Denmark
[7] Conservation Department, University of Arts "George Enescu" Iasi, Romania
[8] Department of Archaeology, Ghent University, Belgium
[9] Department of Organic Chemistry, University of Natural Resources and Life Sciences, Austria
[10] Norwegian Institute for Air Research (NILU), Norway

*Corresponding author: m.odlyha@bbk.ac.uk

This paper will focus on the interaction of indoor environments and objects in locations where indoor air quality is monitored and consider the effect of mitigation strategies. Initially case studies will be presented of accelerated ageing performed in previous projects IDAP (Improved Damage Assessment of Parchment EVK4-CT-2001-00061) and PROPAINT (Improved protection of paintings during exhibition, storage and transit, FP6 SSPI no.044254). In IDAP accelerated ageing was performed using inorganic pollutants and damage was assessed at macro and nano levels [1]; in PROPAINT artists' varnishes were aged using inorganic and organic pollutants. In addition varnish coated dosimeters were displayed in monitored microclimates and analysed to obtain the relation between the pollutant dose received and resulting damage [2]. Within the current MEMORI project (Measurement, Effect Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets – Innovative Research for Market Transfer) the effects of volatile organic acids on parchment, leather, wool and silk textiles, paper, pigments, as well as varnishes are studied. Recent measurements have shown that parchment exposed to ethanoic acid vapour at levels close to those currently recommended for museum, gallery, library and archival collections cause damage measurable at the nanoscale level. However, this value is taken from what is known about the effect on metals, and still needs to be determined for organic-based objects. Collections in museums usually contain large numbers of organic-based cultural objects and it is not always possible to store them in modern showcases where emissions are low. Historic cases are frequently used where amendments are made to lower emissions from wooden parts [3]. Preliminary measurements will be presented of work performed in Tate store using various mitigation strategies and where air quality and damage assessment of exposed varnish dosimeters will be reported. The results obtained in this work seek to inform on recommended levels for these environments.

1. M. Odlyha, C. Theodorakopoulos, J. de Groot, L. Bozec, M. Horton, Fourier Transform Infra-red Spectroscopy (ATR/FTIR) and Scanning Probe Microscopy of Parchment, e-PS, 2009, 6, 138-144.
2. E. Dahlin Ed. PROPAINT Improved Protection of Paintings during Exhibition, Storage and Transit Final Activity Report, 2010 (http://propaint.nilu.no/Portals/23/PROPAINT-Final Report.pdf, accessed 05-01-12).
3. D. Thickett, B. Stanley, and K. Booth, Retrofitting old display cases J. Bridgland, Ed. in ICOM Committee for Conservation 15th Triennial Meeting, New Delhi, 2008, Preprints Vol II, 2008, 775-782.

Refinement in the use of AD strips for the measurement of organic acid vapours

S. Hackney

Research Department, EU MEMORI Project, Tate, UK

Stephen.hackney@tate.org.uk

AD strips are indicator papers devised by the Image Permanance Institute [1] to measure off-gassing associated with degrading cellulose acetate film stock. Working in the EU MEMORI project [2], a refinement in the use of AD strips has been developed employing a Minolta Chroma meter [3] to measure colour changes more precisely. The indicator, bromocresol green, changes from blue to yellow across the pH range 5.4 to 3.8. In L*a*b* colour space the b axis provides a convenient measure, which has been calibrated against the vapour over dilute acetic acid solutions (range 0.025 - 0.5% v/v). This provides an internally reliable scale that can be related to vapour concentration in ppm or mgm^{-3}. AD strips do not differentiate between individual acid gases but have been selected for sensitivity to acetic acid (pK 4.75). They respond quite quickly compared with diffusion tubes. They do not provide information on the presence of non-acidic materials such as aldehydes, which may be gradually oxidised to acids. They are affected by atmospheric carbon dioxide, which limits their usefulness at lower concentrations of pollution, and must be measured in less than a minute once removed from an enclosure. They must also be kept in the dark and in sealed envelopes when not in use. If exposed to light they fade (which affects the L* reading most). Organic acids are emitted by common construction materials, such as wood, plywoods, and hardboards, and by adhesives and coatings. Unfortunately these tend to be the most useful materials, i.e. strong, easily worked and inexpensive. In order to select the best materials for containing museum objects for extended periods of time, during storage and exhibition, detailed information is needed on the emission rates, concentrations and sorption rates of specific containers [4]. AD strips are conveniently small and can be placed in many locations to investigate internally generated acidic pollution in storage and enclosed spaces, which are isolated from external pollution sources. Differences in concentration within a container indicate the location of the worst sources of pollution and the efficiency of any barriers. AD strips are, of course, also useful in identifying emissions from a museum object.

1. https://www.imagepermanenceinstitute.org/imaging/ad-strips.
2. http://ec.europa.eu/research/environment/pdf/project_summaries/fp7/cultural_heritage/memori.pdf.
3. http://www.konicaminolta.com/instruments/.
4. http://propaint.nilu.no/Portals/23/PROPAINT-FinalReport.pdf.

Effect of environmental pollutants on the deterioration of the Daguerreotype image

R. E. Hodgkins[1]*, S. A. Centeno[1], A. G. Schrott[2]

[1] Department of Scientific Research, The Metropolitan Museum of Art, USA
[2] IBM Research, USA

*Corresponding author: robyn.hodgkins@metmuseum.org

Daguerreotypes are unique images created using the first commercially successful photographic process that was practiced for a very short period of time, starting in 1839 to the early 1860s [1]. These images, that consist of mercury-silver or mercury-silver-gold amalgam nanoparticles on silver-coated copper substrates, are very delicate and susceptible to damage by mechanical and chemical cleaning, light, and environmental pollutants, such as hydrogen sulfide and chlorine-containing compounds [1-4]. To better understand the formation of deterioration products frequently found on historic and artistic daguerreotypes, test samples prepared following 19 th century recipes were exposed to either chlorine or sodium sulfide environments, or both for one to three weeks. The exposed samples and original daguerreotypes were analyzed using Raman spectroscopy and scanning electron microscopy-energy dispersive X-ray spectrometry (SEM-EDS). Deterioration products, such as silver chloride, silver sulfide, silver oxide, and copper sulfide, were identified in the test samples and in the original daguerreotypes by their characteristic Raman bands complemented by SEM-EDS analysis and their occurrence was correlated to image properties such as density, particle size, and to the presence of a gilding layer. Additionally, the light sensitivity of these products was tested to aide in future planning of exhibition lighting conditions.

1. M. S. Barger, W. B. White, The Daguerreotype Nineteenth-Century Technology and Modern Science, The John Hopkins University Press, Baltimore, 1991.
2. M. S. Barger, S. V. Krishnaswamy, R. Messier, The Cleaning of Daguerreotypes: Comparison of Cleaning Methods, J. Am. Inst. Conserv., 1982, 22, 13-24.
3. S. A. Centeno, T. Meller, N. Kennedy, M. Wypyski, The daguerreotype surface as a SERS substrate: characterization of image deterioration in plates from the 19th century studio of Southworth & Hawes, J. Raman Spectrosc., 2008, 39, 914-921.
4. S. Centeno, F. Schulte, N. Kennedy, A. Schrott, The formation of chlorine-induced alterations in daguerreotype image particles: a high resolution SEM-EDS study, Appl. Phys. A, 2011, 105, 55-63.

Thermal microscopy and analysis for identifying environmentally sensitive parchment and leather documents and artefacts

E. Badea[1]*, L. Miu[2], K. M. Axelsson[3], R. Larsen[3], D. V. P. Sommer[3], G. Della Gatta[1]

[1] University of Turin, Italy
[2] National Research and Development Institute for Textile and Leather, Romania
[3] School of Conservation, Royal Danish Academy of Fine Arts, Denmark

*Corresponding author: elena.badea@unito.it

Conservation scientists focus their interest on non-invasive or micro-invasive characterisation of parchment/leather artefacts to understand previous degradation conditions and prevent further damage. The use of standardised procedures such as visual evaluation, microscopic fibre assessment and measurement of shrinkage activity are strongly promoted through training courses and workshops organised within the IDAP network [1-2]. These methods enable quantification of damage from the macroscopic to the microscopic level and classification of historical parchment/leather in four categories, i.e. not damaged, displaying minor, medium and major damage. However, the preservation strategy cannot only be based on this quantitative ranking, it is also indispensable to evaluate the stability of the object as well, i.e. its sensitivity to the environmental conditions and its capacity to withstand further degradation without the risk of irreversible damage. Within one collection there may be pieces with similar levels of damage but showing very different stability. Depending on damage and stability levels, a preservation strategy can be optimised: choosing the method and degree of cleaning, determining the optimum relative humidity for display, evaluating the need for more tightly controlled microclimates. Thermal microscopy, Micro Hot Table (MHT) method, and micro Differential Scanning Calorimetry (micro DSC), were used to profile heritage parchment and leather collections, identify environmentally sensitive objects and select the optimum environment for different objects depending on their "health" conditions [3-4]. Current environmental standards and the extent to which these standards should determine the practice are discussed in terms of their implications on collection longevity, available resources and climate change. This study is part of the work performed within the framework of the Italian project *Old Parchments: Evaluating, Restoration and Analysis* (OPERA, CIPE 04 D39, 2006-2009, www.opera-parchment.it). The authors are very grateful to the State Archives of Turin for providing the parchment samples and National Research and Development Institute for Textile and Leather of Bucharest for providing the leather samples.

1. R. Larsen, D. V. Poulsen, K. Minddal, N. Dahlstrøm, N. Fazlic, Damage of Parchment Fibres on the Microscopic Level Detected by the Micro Hot Table (MHT) Method, in: R. Larsen, Ed. Improved Damage Assessment of Parchment (IDAP) Collection and Sharing of Knowledge (Research Report No 18), EU-Directorate-General for Research, Luxembourg, 2007, 69-72.
2. K. Mühlen Axelsson, R. Larsen, D. V. P. Sommer, Dimensional Studies of Specific Microscopic Fibre Structures in Deteriorated Parchment before and during Shrinkage, J. Cult. Her., 2012, **13**, 128-136.
3. E. Badea, G. Della Gatta, P. Budrugeac, *Characterisation and Evaluation of the Environmental Impact on Historical Parchments by DSC*, J. Therm. Anal. Calorim., 2011, **104**, 495-506.
4. E. Badea, G. Della Gatta, T. Usacheva, *Effects of Temperature and Relative Humidity on Fibrillar Collagen within Parchment: A Micro Differential Scanning Calorimetry (micro DSC) Study*, Polym. Degrad. Stab., 2012, **97**, 346-353.

Evaluation of indoor air quality in Dolmabahçe Palace and risk assessment

F. Karaca[1]*, F. Ozdemir[2], Z. Kilic[2], S. Goren[2], A. Karaburun[3], B. Unal[4], F. Argonul[5]

[1] IVHM Centre, Cranfield University, UK
[2] Department of Environmental Engineering, Fatih University, 34500, Turkey
[3] Geography Department, Fatih University, Turkey
[4] BioNanoTechnology R & D Centre, Fatih University, Turkey
[5] Object Restoration and Conservation Division, Directorate of National Palaces, General Secretariat of Turkish Grand National Assembly, Turkey

*Corresponding author: f.karaca@cranfield.ac.uk

Dolmabahçe Palace was constructed between 1843 and 1855 as the last administrative building of the late Ottoman Empire. It is one of the most attractive palaces in the world. The palace has an area of 45,000 m^2, and contains 285 rooms, 46 halls, 6 baths (hamam) and 68 toilets. The site of Dolmabahçe is located on reclaimed seashore on the European coast of the Bosphorus. The southern part of its imperial garden goes along 600 metres of the Bosphorus. The northern side is bordered by 10 m high exterior walls to protect the structure from the outer environment. A main city road, characterised by heavy daytime traffic, follows these outer walls. Both city traffic and the sea are the main outdoor environmental dangers for the palace. During last two decades, several scientific works clearly proved that, air pollution has harmful effects on cultural heritage. Museums, galleries, libraries, historic buildings and archives are in danger from air pollution risk factors. Air pollution issues should be included in management plans, which are related to the protection and preservation of the cultural and historic fabric of any cultural heritage. In this study air pollutants (SO_2, NO_2, O_3, H_2S, HCOOH, HCHO, CH_3COOH and PM), were monitored in several indoor environments in Dolmabahçe Palace using passive and active samplers. This study is the first to evaluate the impact of indoor air quality on the historic and cultural objects stored in museums and historic buildings in Turkey. The results of the Dolmabahçe project will be given in three parts. In the first part, indoor pollutant concentrations and distribution characteristics will be presented. In the second part possible indoor and outdoor pollution sources will be identified and discussed. Finally, an air pollution risk assessment for Dolmabahçe place will be evaluated.

Is it time for a reactivity monitoring standard for museums?

G. Colman[1], P. Fish[1], C. Muller[2]*, D. Thickett[3]

[1] Prisma Services, Ltd., UK
[2] Purafil, Inc., USA
[3] English Heritage, UK

*Corresponding author: cmuller@purafil.com

Reactivity (corrosion) monitoring has been in continuous use in museums for more than 25 years to gauge the aggressiveness of the ambient environment towards materials and artefacts. It has become the de facto environmental monitoring technique for many institutions. The use of passive and real-time monitors has been written into specifications and a classification scheme relevant to conservation and preservation environments has been developed. Advances in real-time reactivity monitoring technology have provided for smaller, battery-operated devices with wireless communication capabilities and some now feel that it is time to formalize their use for exhibition and storage applications. This presentation will provide an overview of reactivity monitoring and a discussion of the types of devices that are currently available. Historical data from various institutions will be presented to illustrate where and how they have been and are still being used. The development of environmental severity levels for use with reactivity monitoring will be discussed including the work that led to the development and publication of a Dutch national standard [1] for air quality in archives. The activities of various standards organizations (e.g. BSI, CEN, ISO, NARA) pertaining to preservation environments will be discussed and recommendations on how and where a reactivity monitoring standard for museums could be published will be presented.

1. R. Vosteen, Advisory guide-line for air quality of archives, BCIN, 1994.

Application of automated corrosion sensors for corrosivity assessment of model indoor atmospheres contaminated with organic acids

T. Prosek[1]*, F. Dubois[1], M. Kouril[2], M. Dubus[3], M. Taube[4], V. Hubert[5], M. Jouannic[6], B. Scheffel[7], D. Thierry[1]

[1] French Corrosion Institute, France
[2] Dept. of Metals and Corrosion Engineering , Institute of Chemical Technology, Czech Republic
[3] Centre de Recherche et de Restauration des Musées de France, France
[4] The National Museum of Denmark, Denmark
[5] Swiss National Museum, Switzerland
[6] nke, France
[7] Fraunhofer Institute for Electron Beam and Plasma Technology, Germany

*Corresponding author: tomas.prosek@institut-corrosion.fr

Loggers for continuous measurement of the corrosion rate of metals under atmospheric conditions were developed [1]. The electronic unit measures and records changes in the electrical resistance of a thin metal track applied on an insulating substrate. If the metal corrodes, the electrical resistance increases [2]. Sensors made of silver, copper, iron/steel, zinc, bronze, brass and lead are available. Results of laboratory corrosion tests in different environments proving high sensitivity, short response times, good reproducibility and good accuracy of the corrosion depth measurement, will be presented. Due to the sensitivity of the measurement, as high as sub-0.1 nm in terms of corrosion depth, changes in air corrosivity were rapidly registered even in low-corrosive environments. Experiments in the presence of airborne formic and acetic acid at concentrations from 0–1590 and 0–870 ppb, respectively have been carried out using copper, lead and iron sensors. Gases in these concentrations were found in museums and other cultural heritage institutions and are reported to cause deterioration of objects made of different materials [3]. Threshold limits of the formic acid concentration in air at 60 and 80% RH and at 20 °C, causing changes in the classification of indoor air corrosivity according to ISO 11844-1, were established for copper.

1. Protection of cultural heritage by real-time corrosion monitoring (MUSECORR), Collaborative Project, 7th Framework Programme, Contract No. 226539, 06/2009–07/2012.
2. T. Prosek, M. Kouril, L. R. Hilbert, Y. Degres, V. Blazek, D. Thierry, M. Ø. Hansen, Real time corrosion monitoring in the atmosphere using automated battery-driven corrosion loggers, Corros. Eng. Sci. Technol. 2008, 43, 129–133.
3. L. T. Gibson, C. M. Watt, Acetic and formic acids emitted from wood samples and their effect on selected materials in museum environments, Corros. Sci. 2010, 52, 172–178.

Evaluation of pollutant impact on CH objects in enclosures. Measurement, modelling and guidelines

T. Grøntoft

NILU – Norwegian Institute for Air Research, Norway

teg@nilu.no

In the EU MEMORI project (EU FP7 – SCP: 265132) new methods for measurement, modelling and evaluation of environments inside protective enclosures for cultural heritage objects are developed, and extensive research is performed to better understand the effects of organic acids on mostly organic heritage materials. In the literature there exists some LOAELs (Lowest Observed Adverse Effects Levels) for the effects of organic acids on inorganic materials and also suggested NOAELs (No Observed Adverse Effects Levels) for museum objects in general [1]. Such levels give information about reactions with specific sensitive materials, and they can be used for a general (as opposed to object specific) assessment of the environmental quality, that compares and includes the damage risk due to a range of environmental factors (climate, pollutants, light etc) and allows comparison between locations on this basis. Assessment can be performed with modelling or with dosimeter measurements of the combined, often synergistic, effects.

Measurement results from the use of the NILU EWO (Early Warning Organic) dosimeter and the Fraunhofer GSD (Glass Dosimeter) [2] in the EU projects MASTER (EVK4-CT-2002-00093) and PROPAINT (SSPI-044254) are presented and compared with results from modelling of the potential impact of gaseous air pollutants on the objects inside the enclosures, with the expected impact on the objects without the protection from enclosures and with recommended levels. The use of modelling to evaluate the effect of mitigation measures to reduce the impact of gaseous pollutants in enclosures, such as the inclusion of pollutant absorbing materials, is demonstrated. The comparison of results from modelling and measurements with dosimeters show how a quite complex model is still a simplification which does not account for all the factors that affect real materials, but that the model gives useful complementary information for a preventive conservation assessment.

1. J. Tetreault, Airborne Pollutants in Museums, Galleries, and Archives: Risk Assessment, Control Strategies and Preservation Management, Canadian Conservation Institute, Ottawa, 2003.
2. E. Dahlin Ed., EU project POPAINT, Final report, Improved Protection of Paintings during Exhibition, Storage and Transit, NILU. OR 42/2010, http://propaint.nilu.no/, 2010.

Normalized environmental assessment of cultural heritage by electrical resistance (ER) measurements

M. Dubus[1]*, Y. Degres[2], T. Prosek[3], D. Robcis[1]

[1] Centre de recherche et de restauration des musées de France, France
[2] nke SA, France
[3] Institut de la Corrosion SAS (ICO), France

*Corresponding author: michel.dubus@culture.gouv.fr

Corrosion monitoring by resistivity measurement (RMS) [1] was used to assess conservation conditions for cultural heritage, in response to questions frequently asked by conservators and curators such as: "Are the conservation conditions correct in my museum, in that showcase, in that storage facility? Are improvements to those conditions urgently needed? What about transport and exhibitions abroad? "

We present here the results of over seventy studies performed in twenty museums, libraries and archives situated on the French territory, in permanent or temporary conditions. Most premises were heated (twenty-six showcases, eleven exhibition rooms, fifteen storage facilities, six crates), in sixteen environments the climate was not controlled, including two outdoor environments. Copper sensors were exposed for between fourteen and four hundred and eighty days. Data obtained with an exposure time of one year or more were interpreted with the ISO 11844 standard [2], which was specifically written to characterize environments with low corrosiveness. When the exposure time was less than one year, data were interpreted with the recommendations of Sacchi and Muller [3]. Sixty per cent of the environments have a *very low corrosiveness*, five per cent of the environments have a *high corrosiveness* The corrosiveness was found to be *low* for two-thirds of the heated rooms, *high* for three per cent of them. In half of the permanent premises, the corrosiveness was found to be *very low*; it is *low* or *medium* for the rest.

ER measurement is a very efficient tool to assess conservation conditions in archives, libraries and museums. This technique make it possible to compare conservation conditions in buildings, showcases, storage facilities; the ISO 11844-1 standard allows the classification of environments depending on their corrosiveness for an exposure time of one year, and the guidelines of Sacchi and Muller can be used for short term studies.

1. T. Prosek, M. Kouril, L. R. Hilbert, Y. Degres, V. Blazek ,D. Thierry, M. Ø .Hansen, Real time corrosion monitoring in the atmosphere using automated battery driven corrosion loggers, Corr. Eng. Sci. Tech., 2008, 43, 129–133.
2. ISO/DIS 11844-1: Corrosion of metals and alloys – classification of low corrosivity of indoor atmospheres – Part 1: determination and estimation of indoor corrosivity, ISO ,2006, 18.
3. E. Sacchi and C. Muller: Air quality monitoring at historic sites – redefining an environmental classification system for gaseous pollution, American Society of Heating, Refrigerating & Air-Conditioning Engineers, Inc. Atlanta GA, USA, 2005, 7.

Smart sensor platform for preservation of culture heritage

S. A. Bermudez Rodriguez [1], P. Dionisi Vici [2], H. F. Hamann [1], L. Kargere[3], L. Klein [1], M. Leona[2], V. Lopez [1], A. G. Schrott [1]*, M. Tsukada[2]

[1] IBM Research, USA
[2] Department of Scientific Research, The Metropolitan Museum of Art, USA
[3] Objects Conservation Department, The Metropolitan Museum of Art, USA

*Corresponding author: Schrott@us.ibm.com

Establishing the best environmental conditions for long term preservation of the art pieces in a museum is one the most important goals sought by the science of art conservation. In this presentation, we will describe the technical aspects related to the recent deployment of a vast numbers of sensors that have been strategically positioned in several adjacent rooms at “The Cloisters”, the medieval branch of The Metropolitan Museum of Art (MMA). Sensors include temperature, humidity, air flow, corrosion and door positions. They are part of a very low foot print platform of IBM design which includes radio chip, low power microcontroller and sensor boards designed to support multiple sensors with ultra low power consumption, thus leveraging time-synchronization.

All the data is fed into an enterprise-level software application where it is modelled to provide, for example, detailed real-time 3D temperature, humidity and dew point distribution visualization. This flexible and modular platform, that allows micro-environment sensing and precise and accurate modelling, was initially developed by IBM for energy usage optimization in buildings and data centres. All its properties make this platform a suitable technology for very powerful monitoring and modelling of a museum’s environmental conditions and to assess their implications. The strategy behind the implementation of this sensing approach by MMA will be explained in connection with achieving the goals of a broader sensing scheme integration, involving sensing in real time the response of actual art objects to the environment and providing predictive analytics for implementing the best conditions for their long term preservation.

Behaviour of particulate matter in the indoor environment of the National Library in Prague

J. Smolík[1]*, L. Ondráčková[1], L. Mašková[1, 2], J. Ondráček[1], N. Zíková[1, 3]

[1] Institute of Chemical Process Fundamentals ASCR, Czech Republic
[2] Institute of Environmental Studies, Faculty of Science, Charles University in Prague, Czech Republic
[3] Department of Meteorology and Environment Protection, Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic

*Corresponding author: smolik@icpf.cas.cz

In order to identify sources of particulate matter (PM) in the indoor environment of the National Library in Prague and describe transport of particles to the surface of deposited books, three extensive measuring campaigns were performed in the Baroque Library Hall over the period March-December 2009. The measurements included I/O (Indoor/Outdoor) particle number size distributions (Scanning Mobility Particle Sizer and Aerodynamic Particle Sizer, TSI, USA, size range 14 nm – 20 μm) and spatial variation of indoor PM (4 x DustTrak, TSI, USA). In addition, size resolved I/O PM was sampled using two cascade impactors (Hauke, Austria) for subsequent analysis. The results showed sufficiently well mixed indoor air with concentrations of nano- and fine particles at ~10^2-10^3 particles cm^{-3} and coarse particles at ~10^{-2}-10^{-1} particles cm^{-3}. The penetration of outdoor PM was found to be a main source of submicron particles and visitors were a main source of coarse PM. The highest I/O concentration ratio was found for accumulation mode particles with a maximum at about 300 nm (~0.6 in spring and summer, ~0.8 in winter). To test the gravitational and diffusional deposition of particles on book surfaces twelve bunches of Whatman cellulose filters fixed in open Petri dishes on a free shelf of the library were exposed for three, six, nine, and twelve months. The exposed filters were analysed after each period by Scanning Electron Microscopy (SEM) and Ion Chromatography (IC). The penetration and deposition of particles was also modelled as Brownian diffusion between two parallel discs. The results showed that penetration and deposition depend on particle size, with the depth of penetration limited by parallel diffusional deposition on filter surfaces.

This work was supported by the Ministry of Culture of the Czech Republic under grant DF11P01OVV020.

Measurement of nitric and nitrous acid inside archival indoors employing a "multipollutant" diffusive sampler

F. Vichi*, F. De Santis, A. Imperiali

Institute of Atmospheric Pollution Research, National Research Council of Italy, Italy

*Corresponding author: vichi@iia.cnr.it

Indoor air quality assessment is important to appraise the safety of environments where cultural heritage items are stored or exhibited. Appropriately filtered and up-to-date HVAC systems can contribute to keep under control both the composition and the physical parameters (T, RH) of the ambient air. However, in many cases, HVAC systems are installed in historic buildings with strict regulations and constraints as to what extent their fabric can be altered. It is therefore not surprising that contradictory results have been reported in the literature about the effectiveness of these systems in preventing infiltrations of outdoor pollutants [1-3]. In some museums in the UK and the Republic of Ireland [4-6] the efficiency of air filtration systems was also tested in different operative conditions. In the case of archives containing paper artefacts susceptible to degradation by atmospheric pollutants [7, 8], a preventive conservation approach requires the control of acidic species such as nitric and nitrous acid, which are products of heterogeneous reactions of nitrogen dioxide on moisture containing surfaces. In this paper, we report on investigations carried out in two archives in Switzerland. Measurements of nitrous and nitric acid were performed during summer 2011 and winter 2011-2012 making use of a newly designed diffusive sampler able to simultaneously collect the two species separately on specific absorbing filters. The two winter campaigns were planned to compare the indoor pollution levels without the filtration system and then just after the installation of new filters on the HVAC facility, whereas during the summer the HVAC was working in usual conditions. The results of these studies are reported and discussed. The assessment of the performance of the filtration system in different operating conditions can be useful for the cost/benefit analysis of the HVAC operation and maintenance.

1. M. Cassar, N. Blades, T. Oreszczyn, Air Pollution levels in air-conditioned and naturally ventilated museums: a pilot study, in ICOM Committee for Conservation, 12th Triennal Meeting, Lyon, 29 August-3 September 1999, J. Bridgeland Ed., James & James, London, 1999, 31-37.
2. L. G. Salmon, G. R. Cass, K. Bruckman J. Haber, Ozone exposure inside museums in the historic central district of Krakow, Poland, Atmos. Environ., 2000, 34, 3823-3832.
3. M. Rhyl Svendsen, Indoor air pollution in museums: prediction models and control strategies, Rev. Conserv., 2006, 7, 27-41.
4. S. Hackney, The distribution of gaseous air pollution within museums, Stud. Conserv., 1984, 29, 105-116.
5. D. Saunders, The environment and lighting in the Sainsbury Wing of the National Gallery, in Committee for Conservation, 10th Triennal Meeting, Washington, D.C. 22-27 August 1993, Ed. J. Bridgeland, ICOM-CC, Paris, 1993, 630-635.
6. M. McParland, Environmental conditions in the National Gallery of Ireland, The Conservator, 1992, 16, 55-64.
7. J. B. G. A. Havermans, Environmental Influences on the Deterioration of Paper, Barjesteh, Meeuwers & Co, Rotterdam, 1995.
8. M. Strlič, J. Kolar Eds., Ageing and Stabilisation of paper, Ljubljana, National and University Library, 2006.

Carbon and oxygen isotopes: A tool to diagnose environmental degradation of historic mortars

E. Dotsika[1], D. Kyropoulou[1]*, E. Iliadis[1], S. Dadaki[2], S. Doukata-Demertzi[2], I. Iliadis[2]

[1] Institute of Material Science, Stable Isotope Unit, National Centre for Scientific Research, Greece
[2] 12th Ephoreia of Byzantine Antiquities, Greece

*Corresponding author: author: dkyropoulou@ims.demokritos.gr

Samples of mortars were collected from Byzantine architectural constructions. The stable C and O isotope composition of the mortar samples were analysed to examine the environmental conditions during calcite formation, the carbonate origin and to determine the potential degradation mechanisms. Composition and morphological analyses were undertaken using energy dispersive X-ray analysis in the scanning electron microscope, while the mineralogical phases were detected using X-ray diffraction. The results show that most of the mortar samples are composed of hydraulic lime and ceramic or quartz aggregates. The backscattered electron photomicrographs demonstrated the morphology of the aggregates and the matrix in the mortar and provide signs of recrystallisation and calcite dissolution in the mortar matrix. Mineralogical and elemental analysis also indicated signs of sulphation and salt crystallisation. Stable isotope analysis provided information on the origin of CO_2 and water during calcite formation and degradation mechanisms. Isotopic change of the initial $\delta^{13}C$ and $\delta^{18}O$ in the carbonate matrix was attributed to the primary source of CO_2 and H_2O in mortar over time. Recrystallisation of calcite with pore water, evaporated or re-condensed water, and CO_2 from various atmospheric and biogenic sources affect the isotopic signatures of lime mortars. Exogenic processes related to biological growth are responsible for further alterations of $\delta^{18}O$ and $\delta^{13}C$ in lime mortar.

Museum pollutants and preventive conservation: Review and future perspectives

M. J. Alcayde[1], B. de Tapol[2], S. Borros[1]*

[1] GEMAT, Institut Químic de Sarrià, Universitat Ramón LLull, Spain
[2] MNAC, Museu Nacional d'Art de Catalunya, Spain

*Corresponding author: mariaalcaydep@iqs.url.edu

This paper attempts to outline the state of the art in the analysis of pollutants in museums and heritage buildings for the purpose of preventive conservation. 95 publications have been reviewed, most of them (65%) from the last decade. Although the effects of contaminants on museum collections have been known since the 18th Century, they have been considered as a main contributor to the quality of the museum environment only in the last 25 years. The aim of this paper is to assess the recent research and reflect on the what, why and how. Based on the classification of pollutants and their sources, both external and internal, the study focuses on the evolution of techniques for the identification and quantification of pollutants. The methods reflect their effects on the constituent materials of artefacts, also considering additional parameters such as T, RH, light, air-circulation. The importance of identification of environmental contaminants in museums using rapid tests is discussed, including the effectiveness and sensitivity of the tests. Most importantly, the impact of pollutants on works of art by methods of accelerated degradation of the materials is also discussed. In order to choose a suitable conservation strategy, draft guidelines to assess the risk to heritage collections have been put forward. From this point of view, discussions about the suitability of enclosures to protect objects are necessary. The latest research on how environmental pollutants affect polymers, both as coatings and constituents of the works of art is discussed.

Standards and guidelines – Understanding consequences and implementation

H. Roemich[1]*, S. Weintraub[2]

[1] Conservation Center of the Institute of Fine Arts, New York University, USA
[2] Art Preservation Services, USA

*Corresponding author: hr34@nyu.edu

The re-examination of IAQ standards and guidelines for the preservation of cultural property provides an opportunity for improving general practice by taking into account current research, new technologies, and a need for more energy sustainable solutions. Although more accurate information about how materials respond to environmental conditions is essential, there is a risk that complex chemical reactions and physical processes will once again be simplified and reduced to rigidly enforced prescriptive environmental recommendations. There needs to be a greater emphasis on flexible implementation strategies that are cost-effective, practical, and sustainable. This presents a challenge to the conservation community because of the wider range of knowledge and skills required to pursue performance-based rather than prescriptive-based solutions. This presentation will focus on the evolving curriculum developed for teaching preventive conservation at the Conservation Center of the Institute of Fine Arts (IFA-CC), New York University. The program prepares students to face the challenges of a performance-based world in which the goal is to ensure that objects are cared for properly, rather than to make sure that rigid environmental requirements are followed. The curriculum focuses on the knowledge required by a preventive conservation specialist so that they can successfully interact with non-conservation technical staff and consultants such as exhibit designers and facilities engineers. It also focuses on areas where the conservator has the primary or exclusive responsibility for implementing preventive strategies. The purpose of the presentation is to encourage a discussion of the critical areas of knowledge and expertise that are best learned in a conservation training program to prepare conservators so they can implement IAQ standards and guidelines that make sense in daily practice.

Natural history collections affecting the indoor environment

J. Havermans

Team Conservation Technology, TNO Technical Sciences, The Netherlands

john.havermans@tno.nl

Museums of natural history form not only a source of knowledge of vegetation, animals, plants and minerals, but also a source of pollutants. In our work we investigated storage rooms belonging to the Netherlands collections of natural history: two herbariums, two storage rooms with collections put in ethanol, one ethnological collection and one mammal collection. Based on our work we conclude that herbarium collections may emit mercury at high levels of up to 9.4 μgm^{-3}. The emissions from filled herbarium boxes may even rise to above the TLV of Hg. Ethnological collections emit not only naphthalene at high levels, but also formaldehyde, causing levels higher than 150 μgm^{-3} [1-3].

Until the mid-1980s, materials for natural history collections were treated with organic and inorganic chemicals to reduce pest and mould in the collections. $HgCl_2$ was used for plant collections, naphthalene and formaldehyde for ethnological collections. There were also very large collections put in ethanol. In order not to close these collections and museums, assessment studies need to be carried out worldwide to identify and understand this problem in more detail and to solve it. Nowadays there is increased knowledge on the effect of these pesticides on humans and therefore on the negative impact of treated collections on occupational health and on visitors Based on our work, the understanding of historical natural collections has improved. However, more work will be needed in order to gain improved insight into the relationship between an historical treatment and the emissions of inorganic and organic compounds.

1. J. B. G. A. Havermans, H. J. M. Cornelissen, J. A. D. v. Renesse van Duivenbode, Binnenluchtkwaliteit in het alcoholdepot van Naturalis aan de Darwinweg 2 te Leiden. Delft, TNO Bouw en Ondergrond, Rapport no. TNO-034-DTM-2010-03585, 2010.
2. J. B. G. A. Havermans, H. J. M. Cornelissen, J. A. D. v. Renesse van Duivenbode, A. Hacquebord, Binnenluchtkwaliteit in de depotruimten van het Nationaal Herbarium Nederland - vestiging Universiteit Leiden in het Van Steenisgebouw. Delft, TNO Bouw en Ondergrond, Rapport no. TNO-034-DTM-2010-03614, 2010.
3. J. B. G. A. Havermans, J. A. D. v. Renesse van Duivenbode. Luchtkwaliteit in depotruimtes en arseen in geprepareerde objecten van de Zoologisch Museum van de Universiteit van Amsterdam aan de Mauritskade 61. Delft, TNO Bouw en Ondergrond, Rapport no. TNO-034-DTM-2010-03584, 2010.

Changes in indoor climate and pollution in Brodsworth Hall (Doncaster, UK) during the 21st century

P. Brimblecombe[1], C. M. Grossi [1]*, P. Lankester [2]

[1] School of Environmental Sciences, University of East Anglia, UK
[2] English Heritage, UK

*Corresponding author: c.grossi-sampedro@uea.ac.uk

Air pollution and climate indoors at Brodsworth Hall has been estimated by linking outdoor historic climate data at the site and a more limited record of pollution data in the area. Climate has been projected through to the end of the 21st century using the UKCP09 weather generator output at a 5 km spatial resolution. The transfer of climate indoors was estimated by adopting the method of Lankester using transfer functions that calibrate outdoor and indoor daily temperature and humidity observations. The use of conservation heating at Brodsworth Hall meant that transfer functions had also to be re-calibrated to allow for this modification to natural climate. The pollution concentrations of ozone, nitrogen dioxide and sulphur dioxide were estimated, focussing on the library at the property, where some data existed, allowing indoor/outdoor ratios to be estimated. These have been combined with limited outdoor measurements from Scunthorpe, Barnsley and the Yorkshire Moors (Defra UK-air data archive). Indoor SO_2 from coal used in the library fire place was also adjusted. Future pollutants were estimated from GAINS/EMEP models. Formic/acetic acid concentrations have been estimated theoretically from degassing rates as a function of temperature and acid emission rates from wood, combined with the measured dimensions of the rooms. This has enabled us to predict the emission rates and concentrations in the future with variation of temperature and to assess the potential threat to materials indoors including the leather bindings.

Indoor air quality in the future

P. Brimblecombe

School of Environmental Sciences, University of East Anglia, UK

p.brimblecombe@uea.ac.uk

The overall quality of air improved in cities of the developed world by the end of the 20th century and this lowered the concentrations of external air pollutants that leaked indoors. This improved urban environment arose from a reduction in the major primary pollutants, notably sulfur dioxide and soot from coal (decreased urban in use), lowered automotive emissions (improved engine design, catalytic converters and less fuel evaporation), NO_x and particles from industrial boilers (adoption of electrostatic precipitators and low NO_x burners) and VOCs from architectural coatings (more water-based solvents). Regulations seem unlikely to permit substantial increases in urban emissions in the coming century. However, changing climate, novel fuels and a rising vehicle fleet can serve to limit potential improvement. Higher temperatures mean greater evaporation of fuels and biogenic volatiles (difficult to control) that can act as precursors to photochemical smog in days with longer sunlight hours. Enhanced ozone concentrations, particularly over rural continental Europe seem possible in the present century, although some earlier predictions may have exaggerated these and over emphasized the threat materials such as pigments and dyes. Lower air exchange rates have been introduced to save energy, but effectively reduce the transfer of pollutants indoors. However, they allow those generated indoors to rise to higher concentrations. A wide range of consumer products and architectural materials release volatile substances more rapidly at higher temperatures. Although a widening range of materials are used indoors they are increasingly the subject of EU regulation which limits their impact on indoor air quality. In museum cases careful pre-testing of display materials much reduced the risk of air pollutants in this micro-environment. The future is hopeful, but nevertheless there remain risks worth managing, so this presentation will examine the magnitude of likely change and the balance of threats posed air pollutants in the heritage environment.

Round Table

Standards and guidelines: Help or hindrance?

M. Cassar

UCL Centre for Sustainable Heritage, University College London, UK

m.cassar@ucl.ac.uk

The aim of this panel discussion is to examine the role of standards and guidelines for researchers and practitioners. The group of distinguished panellists – David Grattan, Nancy Bell, Vasco Fassina, Frances Halahan and Jerry Podany – will use their individual and collective experience to reflect on the impact of standards and guidelines has on heritage science and conservation. Do standards and guidelines help? Who do they help, and how? Do standards and guidelines create obstacles, and if so what type and how can they be overcome? Standards and guidelines are intended not only to regulate or to provide frameworks for research and practice, but they can also address policy-makers. They may signal that a profession is coming of age, or they can be exclusive rather than inclusive and risk stifling innovation. The drafting of standards and guidelines, the organisations under whose auspices the standards and guidelines are published, and how they are implemented, may influence their wide acceptance or rejection.

Indoor air quality in heritage and historic environments: Standards and guidelines

David Grattan

formerly of Canadian Conservation Institute, Canada

dwgrattan@gmail.com

The underlying question posed by this conference is how do the contributions support the development of environmental standards for museums, libraries or archives? Standards could specify relative humidity variation and level, temperature or the maximum allowable concentration of pollutant gases or particulates. If they are to be meaningful, they should, however, also be supported by measurement protocols and techniques, which are also described by a standard. This latter type of standard, probably the most commonly written, is vital if our developing environmental standards are to be workable, yet as far as I am aware they have not been seriously discussed. It is not useful to specify a particular relative humidity or a maximum value for a pollutant unless you also specify exactly how, where, when and how often data are to be measured.

Measurement and monitoring: The papers and posters that deal with monitoring, analytical development and computer simulation provide some of the basis for a measurement/monitoring procedure. Techniques on which standards can be based must be simple, reliable and readily available to all who might wish to apply a standard. Twelve papers deal with what may be termed “analytical development” and there are another twelve on monitoring of the environment or objects.

Several contributors investigated multi-pollutant samplers of various kinds (Vichi, Hackney, Dahlin, Agbota, and Alcayde). Wireless sensor monitoring allows monitoring in several internal locations and is obviously useful in historic buildings where it is difficult to run wires. (Roberts and Martinez Garrido). There are three initiatives for the development of measurement protocols one is by Smolik for libraries and archives and another by Schieweck for development of a standardised emission test and Keable’s paper is directed towards a standardised measurement protocol for the Oddy Test. The Oddy test is a perfect example of the type of test which could form the basis of a standard as it is already widely used and relatively simple to apply. Young’s paper which surveys different methods of monitoring atmospheric pollutants could also be very helpful as we move toward standards development.

Those papers which document conditions within individual buildings (Anaf, Gomez-Heras, Grossi, Grossmannova, Holl, Karaca, Luciani, Schrott, Short-Traxler, Stewart, Taube, Vavrova, Vlachou Mogire and Xu) are also fundamentally important, because they describe the actual environment in which a standard might be applied and they also provide a practical basis for development of measurement standards. It is essential to have knowledge of actual pollutant levels and actual RH variation etc, and it is especially useful to compare those levels to exterior conditions. Some countries monitor pollutant levels very closely in urban centres and one can sometimes obtain good data on NO_x and SO_2 (Cavicchioli’s paper is noteworthy in this context).

Environmental Standards/Guidelines or not? New environmental standards or guidelines are beginning to emerge as the climate as well as the economic climate alters and more scientific information becomes accessible. The ASHRAE guidelines have been available for some years now and a number of organisations such as CCI have done much to popularise them. Bell's paper on the new UK standard is therefore of particular interest. It should be noted however, that there are diverse views about standards and for this reason the paper of Weintraub et al. is of particular relevance, and I quote from their abstract "There needs to be a greater emphasis on flexible implementation strategies that are cost-effective, practical, and sustainable". The term "flexible strategies" does not sound much like a standard although it might encompass a guideline. The work of Bøgvad Kejser et al. is relevant here as it discusses the application of the ASHRAE guidelines for a specific building. Dillon's paper is also of particular note in that it deals with rational decision making and discounting factors in seeking to balance things such as initial cost versus long term preservation. Perhaps it should be emphasised that an environmental standard is an agreement made by people – often with different perspectives and agendas - and rational decision making can be (should be?) a vital component of the process.

Display cases: Another possible approach to environmental control is to avoid the issue of controlling the building by using display cases in which the local environment can be more closely controlled. Standards can also be developed for these (Jeberien et al.) and this is certainly a very well established approach for sensitive, special or travelling exhibits. The problem is of course that smaller containment can accumulate harmful volatile emissions in the vicinity of objects. Bailey's, Koskinen's, Havermans', Curran's, Mitchell's, Trafela's and Tetreault's papers on VOCs are all relevant here). Curran and Mitchell's posters are especially useful in this context, because they both use VOCs as indicators of plastic decomposition Grontoft et al.'s work in the Memori project on new methods for measurement, modelling and evaluation of environments inside protective enclosures and the effects of organic acids on organic heritage materials is also relevant.

Materials: The more specific papers which describe the influence of environmental factors on individual materials are of course the bedrock of environmental studies as they are key to defining what standards should attempt to accomplish in terms of control. In this conference there are several such works and include the study of rubber in a showcase (Koskinen), the study of the impact of pollutants on daguerreotypes (Hodgkins) the impact of acetic acid on paper degradation (Di Pietro) the humidity sensitivity of inkjet prints (Fricker), the effect of indoor pollution on historic paper (Menart) and finally the impact of pollutants on mortars (Kyropoulou) is particularly intriguing. The determination of which objects are most environmentally sensitive (Badea's paper on thermal microscopy) is a key aspect of materials research.

Dust: Historically, dust or particulate pollution has avoided significant serious study so it is gratifying to see a number of papers address this issue. These include the work on dust cementation (Kyropoulou) and four other papers on dust or particulates, including mould spores (Xu, Maskova, Dmitrieva and Kyropoulou).

Concluding remarks: This conference illustrates the wide diversity of information required for an environmental standard to be developed. Every paper in the conference has relevance. It is not enough to argue about RH levels or their variation for example – one must also consider what is

measurable, how it can be measured reliably. Does the fact that something is measurable increase its significance? There is also the underlying question whether having any standard is a useful proposition, although personally I think that for many reasons it is extremely important to have something agreed on written down and widely accepted. Any Standard of international value should recognise that extreme climatic conditions in many parts of the world make any environmental control challenging. There are sub questions which should perhaps be considered such as or whether in addition to monitoring the building interior you also monitor the artifacts (and there are a number of papers particularly on corrosion which deal with this issue – Dubus, Hubert).

Buildings: We must also consider the behaviour of buildings and what kind of control is possible. We now know of the dangers of humidification of buildings not constructed to sustain higher levels of moisture (Building codes which define materials and vapour barriers etc. are of relevance).

The bottom line – dollars: There are also two factors which are not discussed directly which are profoundly relevant - what is the effect of implementing standards on public access to collections and on budgets – both capital and operational. Museums are generally under-resourced and as we know cuts to conservation can result from expansive spending on dramatic buildings and the resulting belief that the building is of greater interest than the collection it houses.

Standards: Hindrance or help?

N. Bell

The National Archives, UK

nancy.bell@nationalarchives.gov.uk

For the purposes of this paper, 'standard' means something against which actions and outcomes can be measured, and which usually includes an element of compliance, i.e. some statutory requirements. And, in that single-sentence attempt to define what I mean, I see that I have already used 'standard' in the sense of both an objective metric and an encouraging stick – or carrot. But I am attempting to avoid the common meaning of generic guidelines and benchmarking, the 'best practice' sense of 'standard', as commonly found in conservation, and to recognise that the different languages of, for example, conservators, collection managers, estate managers and heritage scientists can impede fruitful interdisciplinary discussion.

Standards are extremely useful – so that answers the Roundtable question! They are based upon the synthesis of expert experience and scientific evidence, and have credibility and authority. As such they can make the lives of professionals much easier, avoiding a need to 'reinvent the wheel' every time, for example, a loan agreement is required or a new museum building constructed. And they can provide a common starting point for discussions in multi-stakeholder activities, such as collection management.

In recent years there has been an increased number of standards published internationally, and there has also been a shift in their style. These changes represent an effort to avoid the imposition of ever greater regulation in many professions and industries, but also to overcome some of the impediments to their use. For example, despite the value standards can add to the decision making process, many collection management standards may be viewed as too onerous; because they are felt not to recognise local contexts, more work is required to satisfy them. And, for conservators with a focus on single objects, standards applied to collections are often considered irrelevant.

Two environmental standards have been published in the UK in the last twelve months: British Standards sponsored Publically Available Specification: 198 *Environmental Standards for Cultural Heritage Collections*; and PD 5454: 2012 *Guide for the storage and exhibition of archival materials.* While distinctly different in scope, they have both been informed by collection environment research that has grown significantly over the last ten years

PAS: 198 is a significant departure from previous work. It recognises the need to be less prescriptive and places the materials found in collection at the core. It recognises that the key elements for setting appropriate standards must take into account the context of use, the previous history of the materials, the composition of the materials, and the expected useful purpose of the collection, because materials behave differently in different contexts.

Importantly, PAS: 198 also makes explicit the key research underpinning the standard, as well as the significant research gaps. This provides an opportunity to critically assess collection

environment research and contributions made to the development of environmental standards for cultural heritage collections.

The multi-disciplinary approach of heritage science has benefited the development of standards and has the potential to be the most significant factor in contributing to the future development of environmental standards. The more comprehensive and credible the evidence we use to underpin standards, the more authoritative and therefore useful the standard. And credibility comes with critical assessment. The question should not be whether standards are a help or hindrance, as if set in stone, but whether they can continue to develop so as to better serve the developing needs of conservation professionals.

CEN TC 346 - Conservation of cultural heritage

V. Fassina

European Committee for Standardisation, *TC 346, Chairman*

Vasco.fassina@gmail.com

The Need for EU Standards

A specific European standardisation activity in the field of conservation of cultural heritage is essential to acquire a common unified scientific approach to the problems relevant to the preservation and conservation of cultural property. The scientific approach to the conservation of cultural heritage is essential as a preliminary basis ensuring effective planning of ordinary and extraordinary maintenance, as well to assure its efficacy and durability.

Objectives of CEN TC 346

The scope of CEN TC 346 is to establish standards in the field of the processes, practices, methodologies and documentation of conservation of tangible cultural heritage to support its preservation, protection and maintenance and to enhance its significance. This includes standardisation of characterisation of the deterioration processes and environmental conditions, and the products and technologies used for the planning and execution of conservation, restoration, repair and maintenance.

Users of CEN TC 346 Standards

This standards address all parties concerned with the subjects covered by the documents. These include owners, stakeholders and users of cultural heritage (monuments, museums, archives, libraries and collections) as well as peer groups such as architects, custodians, archaeologists, engineers, planners, conservators-restorers, craftsmen, heritage and conservation scientists, energy advisers, national authorities, and transport and insurance companies.

Expected Benefits

Standardisation in the field of conservation of cultural property will:

- Facilitate the exchange between European stakeholders through the use of a common vocabulary;
- Improve the efficiency and relevance of diagnostic work, and subsequently better management of funds for conservation/restoration thus increasing the number of conservation projects and spin-off economic benefits/opportunities for new investment, and consequent job creation;
- Give appropriate and accurate indication on the type of diagnostic studies to be performed, thus promoting conservation of an increasing number of artefacts;
- Increase longevity and reduce costs of conservation and maintenance, therefore reducing costs in the long-term because conservation operations will be needed less frequently;
- Facilitate professional mobility and international trade and increase the employment opportunities especially for young conservators, restorers, technicians;

- Improve methodology, protocols, guidelines to allow implementation of better practices or define equipment for preservation and conservation.

Update on the CEN TC 346 Activity

The activity was initially developed according to a "matrix-based" method, a theoretical approach perfectly suited to the establishment of the most urgent standards.
Until now, twelve EN standards have been published according to the matrix-based method in which three main topics have been developed.
The first topic deals with *general guidelines and methodology*. The following four drafts were published:

- EN 15898-Main general terms and definitions
- EN 16095-Condition recording of movable heritage
- EN 16096-Condition survey and report of built cultural heritage
- EN 16085-Methodology for sampling from materials of cultural property-general rules

The second topic focuses on *Evaluation of methods and products for conservation works*. The work was focused on the general draft "Surface protection for porous inorganic materials-laboratory test methods for the evaluation of the performance of water repellent products". The evaluation is based on measurements of different parameters to assess the performance of the product using standardised and reproducible methods.
Among the six parameters selected in the draft, four have been already standardised:

- EN 15801:2010 - Determination of water absorption by capillarity
- EN 15802:2010 - Determination of static contact angle
- EN 15803:2010 - Determination of water vapour permeability (δp)
- EN 15886:2010 - Colour measurement of surfaces

The following two are in the final stage of approval:

- prEN 16302-Determination of water absorption under low hydrostatic pressure
- prEN 16322-Determination of drying properties.

The third topic is concerned with *Indoor/outdoor climate-Specifications and measurement.* The purpose of the work was to develop standards and recommendations relating specifically to the climate and its influence on the preservation of heritage. The standards developed will assist professionals involved in environmental diagnostics and in the investigation and control of the climate for preventive conservation and maintenance. The assistance includes the choice of methodologies and instruments and the interpretation of results. The following three drafts have been already published:

- EN 15757-Specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic materials
- EN 15758-Procedures and instruments for measuring temperatures of the air and the surfaces of objects
- EN 15759-1-Indoor climate – Part 1: Guidelines for heating churches, chapels and other places of worship

Two more drafts are under discussion:

- prEN 16242-Procedures and instruments for measuring humidity in the air and moisture exchanges between air and cultural property

- WI 00346034-Conservation of cultural property – Procedures and instruments for measuring moisture content in objects and building material

Crucial points influencing the current and future development

One of the main problems with the development of new drafts is the lack of specific funds to allow participants to be involved in the standardisation process.

According to the matrix-based method the most urgent standards can be established, but if no interested volunteers with the required experience are found the matrix will fail; on the other hand, it was successful whenever it helped optimise the existing technical and human resources.

The market-based method should work if the market is in charge of the work and travel costs. However, if the "market" gains from standardisation but does not pay for it, it is deprived of any link with the standardisation activity. If experts work in the absence of any financial support they have no reason to follow the market.

Some European countries might have resources to support standardisation and in such cases their National Standardization Bodies can impose priorities. In the case experts are neither paid for their activity nor reimbursed for their travel expenses, finding the volunteers who are experts in the selected topics, becomes crucial.

The third possibility is based on "feasibility", i.e. a compromise between requests (i.e. matrix) and potentials or "exploitation and optimisation of the existing capabilities" in terms of technical and human resources, i.e. the number and type of experts.

In conclusion, having analysed the different situations in different European countries, we find that only a few allocate financial resources to support standardisation. We are therefore obliged to optimise the existing human resources, establishing a compromise between the available experts and the desired priorities time and time again.

Informed choices

J. Podany

International Institute for Conservation of Historic and Artistic Works, UK

JPodany@getty.edu

I must admit that I often find discussions about the exact meaning of words fruitless. It's not that I don't see value in exacting communication; it's just that words simply don't always behave or agree to be contained, to the degree we may wish. Words carry a myriad of meanings and insinuations that shift according to the context in which they are used and the intonation by which they are delivered. Their meanings are often filtered according to what the listener wants, or is willing, to hear. Once the multitude of possible pitfalls in translation from one language to another are added into the mix, a great deal of time and effort can be expended on the simplest word or phrase; a word or phrase that everyone thought they understood, and perhaps in fact did understand, before the debate ensued.

Nonetheless, there are times when exploring generalized definitions can encourage the discussion of core issues, hidden perhaps by the more pedantic debates regarding word-smithing or opinion.

Take for example these two words: "standards" and "guidelines". And consider them in the light of the recent concerns about which word should be used when referring to advancing our efforts to provide suitable preservation environments for collections. A standard is typically understood to be a collection of system-specific or procedural-specific requirements that must be met by everyone. They must be followed and adhered to exactly.

Until recently "standards" was the preferred term within heritage conservation for temperature and humidity levels thought best for collections. And why not. The term sounds confident, confirmed, full of consensus, wisdom and scientific rigor. It gave us peace of mind to know that if we followed a simple set of numbers, even at great cost, we would fulfil our obligation to save all that is deemed worth saving for all time. 50% +/- 3% RH, or the 55/70 rule, or any of the other options within a relatively small range of variation, all provided what appeared to be an easy answer. Looking back perhaps we should have been more sceptical of anything easy given the enormous complexity and combinations of materials, states of preservation, vagaries of history and external environments we must face. Perhaps our existing standards were defined to narrowly and then applied too broadly. These mid-range numbers, made ever more narrow by plentiful energy and our expanding ability to precisely measure them (though not always to achieve them) at least gave us something to strive for, some consensus of best practice. One must now ask however if consensus ever really occurred. Advice was given, that can be agreed upon, but it has only been relatively recently that we have come to ask if this advice was universally substantiated or at least scrutinized sufficiently to deserve such lasting prominence. And it is substantiation, even more than sustainability, which the conservation profession should be focused on at this moment.

The observation that from 1941 to 1945 a number of paintings experienced less flaking or warping in the underground tunnels of the Manod quarry than they had previously experienced in the National Gallery of London has become a thing of legend, a moment of revelation. To some it was the birth of preventive conservation. All true, but when today one institution requires more stringent climate control for a period of a three month loan than it has provided for the last 50 years or more in its own galleries, the question of whether the intention of the "standards" has not been corrupted must be raised. One wonders if specificity and restriction have not only formed a shield to protect the work of art (and the conservator), but also forged a sword meant to intimidate.

We have a long way to go before we can fully substantiate any imposed set of accurate and useful" standards". While significant research has occurred, it is cautious scepticism and belief that still win the day when so much is at stake. If conservators and collections care professionals risk error they are inclined to err on the conservative, safe side when the range of unknowns is large. It has been suggested that wood can be perfectly safe in ranges of 30% to 60 % RH or even greater; perhaps, but with exceptions. Because of that last word, “exceptions”, is so common in these discussions a conservator will always be inclined to ask: "But what about THIS piece of wood, the wood with the priceless painting from the 12th century on it. The wood I cannot directly test the response of. The wood I have no condition or treatment history for? What if IT is the exception?" It is in this series of questions where our dilemma lies. We simply do not know enough about the unique objects under our care. We have not developed the non-invasive tools to characterize these objects to the extent of knowing what is ultimately best for them. And there are so many of these objects and they are all quite unique.

With those needs in mind one has to ask if we have taken a good look at what is right in front of us...the collections. There has been a call, for quite some time, to keep records of the environmental histories of each collection and object. A call to gather the empirical knowledge that often drives or substantiates the more scientific analysis and research. It has been my experience however that this is not always gathered in a meaningful way. When records are kept, and there is certainly a lack of consistency across the world in this activity itself, hygrometric chart after hygrometric chart, some of questionable accuracy, fill file drawers but rarely get incorporated into the history of the object. When damage occurs, the culprit named is often humidity or temperature, even though these two conditions may have had little to do with the event. Horror stories abound, "It cracked right in front of my eyes... within minutes". It is not my intention to question such reports but it must be said that it would be beneficial to all if many of these stories could be substantiated, recorded, shared and examined; very few are. Could it be that we exaggerate in the name of protection, much the way most conservators will ask for +/. 3% in order to achieve +/-6%? Is it possible that over time these well intended exaggerations have become dogma that we believe or are reluctant to question? If even some of this is true, then we are not in a position to set "'standards" and the need for well-founded guidelines is even greater than we have previously thought.

Guidelines are typically collections of system-specific or procedural-specific "suggestions" for best practice. They are not requirements to be met, they have, as they say, no "teeth", but are strongly recommended, usually by consensus or by some informed body that represents best practice. We are in great need of concentrated research, accurate documentation and the development of tools enabling us to establish responsible guidelines and then eventual standards. While there are many good reasons for this effort, the inevitable interest of legal or governmental agencies to frame regulations must be recognized as increasingly influential, particularly when energy restraints become fully codified in the architectural field (as is increasingly the case) or when cross border agreements will require "standards" within heritage conservation. The originating bodies will look to the experts to define these standards. Should we not be ahead of the curve?

I have not delivered any revelations here. The narrowing "standards" have been questioned for some time and the widening of those same standards promoted for some time. While we have recently achieved some consensus regarding how few institutions actually achieve the RH and temperature range long insisted upon, we seem to be struggling with formally redefining the acceptable range. I will not suggest that what exists is wrong, except that it seems to be masquerading as a standard rather than as guidelines. Replacing 50 +/- 5 with 50 +/-10 or changing it to 45% +/- 15% is just replacing one set of magic numbers with another without providing a more in-depth understanding of the material that supposedly drives this effort.

What this moment offers is an opportunity to understand how objects respond to a wide range of conditions, both static and dynamic, over a protracted period of time and with a variety of influences affecting the objects over their history. To take greatest advantage of this opportunity every person involved in heritage preservation needs to engage in this issue. Conservation scientists need to incorporate this purpose into their daily work, and to develop better methods of evaluating material properties without the invasive processes so well known to material engineers. Conservators need to change the way, and the degree to which, they document. Documentation must be seen as a continuum, not a momentary point in time. Directors need to take preventive care as part of their mission. This is a clarion call to all who use the term preventive conservation. There are many definitive statements to be had in these debates but indeed few would stand the scrutiny of careful consideration.

Let's catalogue what we don't really know, and work toward a better understanding of it. The task, of course, will not be an easy. Conditions vary, needs vary, and experience varies (not to mention memory). In the process we must recognize that some comparisons are not as useful as others. For example many archives might well have quite different needs, might have environments that respond differently, and might present quite different challenges when compared to many recently built museums. The comparison of galleries in new museums to historic house museums is another pairing that might not be justified. The historic house museums often incorporate into their very fabric a significant amount of buffering material (wood, carpets, wall hangings, plaster, upholstered furniture, books, etc) while the obsession of modern architects with hard "clean" surfaces has resulted in containers that respond rapidly and unforgivingly to even minor changes in the environment. Each situation can benefit from the thorough characterization of the others, but essential differences must be taken into account. Such variation is what makes a universally applicable standard so difficult to arrive at.

Perhaps standards, if we desire or eventually require them, should dictate the degree to which the material is allowed to respond and the guidelines should serve to define environmental conditions that limit that response to no more than what is deemed safe and necessary.

Either way, whatever terms are arrived at, conservators will now be accepting greater responsibility in coping with unknowns. Every decision will be unique, like the objects and the collections. Each decision, like the guidelines and the eventual standards, must be evidence-based. And our shared familiarity with what we are preserving will serve the ever more crucial role in making defensible, sustainable and informed choices.

Standards and guidelines for cultural collections

F. Halahan, J. Dinsmore

Halahan Associates, UK

frances.halahan@halahan.co.uk

Our experience of standards comes from working with clients to improve the overall conditions in which their collections are kept and used, assessing collections against a standard for funders and working with architects, project managers and engineers on planning new buildings and improved facilities. We have also been involved with developing guidelines, rather than standards.

Standards and Guidelines

We view guidelines as suggestions and indications of standards, usually with explanations of why when and how they should be achieved. I view standards as less flexible with briefer explanations. However, my perception is not correct as standards often include guidelines: for example the Museums and Galleries Commission series of Standards in Museum Care published in the 1990s, or, more recently PAS 198:2012 Specification for Managing Environmental Conditions for Cultural Collections include extensive guidelines and explanations. The BSI (British Standards Institution) describes the published standards as containing '*a technical specification or other precise criteria designed to be used consistently as a rule, guideline, or definition*.' They also add that standards '*help to make life simpler*'.

Institutions such as major museums, often have their own standards which are usually intended to reduce risks to the collection, facilitate decision making and provide some uniformity within the institution; as a result they can be rigid with little room for interpretation. An example are loan conditions where a lender may demand very high and inflexible standards of the borrower with little opportunity to negotiate or consideration of the circumstances. Such standards for loans mean a non-specialist can deal with the loan and time does not need to be spent evaluating the environment. This situation should be changed as it conflicts with the pressure for increased access to collections and, in some cases, with energy efficiency policies.

Advantages and Disadvantages of Standards and Guidelines

The level of collection care and understanding the environment has improved over the last 20 year's partly because standards have been available and funding has been connected to collection care and managements standards.

Standards and guidelines provide conditions and practices to aim for, particularly for people managing collections who are neither conservators nor scientists. Therefore standards can:

- be successful in enabling a guardian of a collection to advance the care, protection and condition of their collection
- be a lever for funding
- be a guide to priorities and actions and a measure of improvements and developments.

- help small institutions make changes, or feel confident with their current circumstances or can indicate poor performance in larger institutions that may have become complacent.

The Government Indemnity Scheme, although not a standard (and is not as demanding as commonly thought) forces an awareness of environmental issues which otherwise might be ignored. Guidelines on the air exchange rates for display cases have helped develop successful microenvironments and reduced the desire or need for tightly controlled relative humidity in a gallery. Recommendations for dust assessment have aided collection housekeeping and care. However, they can also be a millstone round the collection manager's neck unless he or she is well enough informed to interpret the standards.
The disadvantage of standards include:

- The user may not take into account the complexity of a collection or an object and stick to conditions that may be unsuitable, unnecessary or unduly expensive. For example the common standard for light levels for displaying of work on paper is 50 lux which does not consider the sensitivity of the materials, the long-term exposure to light, the type of light, the expected lifespan of the object and other criteria which should go into making such decisions.
  We still encounter museums with recently installed but unused air conditioning systems that were fitted in an attempt to provide close relative humidity and temperature control, which is in fact unnecessary for the collection concerned.
- The reliance on standards may result in the condition of the objects not being checked or considered. Unnecessarily expensive conditions may be provided; alternatively objects may deteriorate within the standard conditions.
- Even when standards may indicate that the conditions can be flexible depending on the collection, they can be interpreted very rigidly.
- Non-specialist staff maintains standards without comprehending the best overall solutions for the collection; this is a particularly true when the standards include minimal guidance for how they should be interpreted and implemented.
- Inappropriate use in tenders and planning. Local authorities, project managers and architects work with standards in many areas of their work and therefore expect and desire performance standards for museums, archives and libraries. BS5454:2000, designed specifically for library and archive material is applied, inappropriately, to mixed collections. Often general tight RH and temperature control are sited without evaluation of the condition or nature of the collection.
- Numerical standards are easier to demonstrate than non-numerical ones and are therefore emphasised. For example, relative humidity, temperature and light levels are easier to assess than pollution measurement which needs specialist input, or pest management which involves setting up an operational system. Resources may be directed towards unnecessary humidity control but are not available for changes to a building to help protect against pests.

The Heritage Science Contribution

Improving collection care and the environmental conditions for cultural collections would be very difficult without guidelines and standards and without the input of information from heritage science. Most people working with collections, whether conservators or not, depend on the research of scientists for information on materials. They /we are therefore dependant on the work carried out by scientists to provide the evidence base for standards. Ongoing research into

what actually happens to materials and objects in certain conditions and the effect and mitigation of the environment can help us make judgements about our work and prioritise need. Resources can be used as efficiently as possible and risks of deterioration reduced. Arguments for advocating a particular action can be strengthened by having an understanding of the issues involved including research results.

For us, clear standards and guidelines, written with an understanding of collections and their use and care provide a framework in which we can work and help collection managers both protect and make the most use of their collections. Inappropriate standards can be damaging and costly.

Posters

A new multi-pollutant sensor for remote indoor and outdoor heritage environment monitoring

H. Agbota[1]*, J. Mitchell[1], A. Nathan[2], C. Young[3], M. Odlyha[4], M. Strlič[1]

[1] UCL Centre for Sustainable Heritage, University College London, UK
[2] London Centre for Nanotechnology, UK
[3] English Heritage, UK
[4] Department of Biological Sciences, Birbeck College London, UK

*Corresponding author: h.agbota@ucl.ac.uk

The logistics and cost of environment monitoring can prove a tough challenge for heritage managers, partly because of the sheer number of parameters to consider. There is a need for a monitoring system which can measure multiple environmental parameters remotely while remaining relatively easy to use and affordable [1]. This poster presentation is an update on our research in developing such a tool. The monitoring system is designed flexibly which allows seamless integration of any number of small electronic environmental sensors. Since low-cost sensors for individual pollutants are not commercially available, a dosimeter array is used. The array consists of piezoelectric quartz crystal microbalances coated with different metals, each differently sensitive to pollutants. One of the aims of the research is to investigate whether the different metal corrosion signals measured over a long period of time (a year or more) can be calibrated against environmental parameters such as inorganic pollutants sulphur dioxide, nitrogen oxide and ozone. Additional features will ensure easy access to the data. Thus, thanks to embedded radio and cellular chips the collected data will be directly accessible via text messaging or from the project website [2]. It is expected that the system described above will be of great use to heritage managers. It can be easily set up, including at relatively remote sites. Among the current case study sites are historical houses in UK and Benin (West Africa).

The authors acknowledge the support of the AHRC / EPSRC Science and Heritage Programme.

1. T. Prosek et al., Survey on air quality control in cultural heritage institutions and development of automated corrosion sensors for real time monitoring, 9th Indoor Air Quality Meeting, 21-23 April 2010, Chalon-sur-Saône, France.
2. http://www.ucl.ac.uk/accessible-heritage

Measurement of environmental pollutants using diffusive cartridges. A practical case in Picasso Museum, Barcelona

M. J. Alcayde[1]*, R. Jimenez[2], A. Vélez[2], S. Borros[1]

[1] GEMAT, Institut Químic de Sarrià, Universitat Ramón LLull, Spain
[2] Conservation and Restoration Department, Museu Picasso, Spain

*Corresponding author: mariaalcaydep@iqs.url.edu

As part of a study of the deterioration of a Picasso drawing on paper "Arlequin's head" (Barcelona, 1917), some analyses of the pollutants in the drawing environment have been done. The drawing shows blackening of the carnations and shadow areas of the face painted in white, due to the possible oxidation of lead white ($Pb_3(CO_3)_2 \cdot (OH)_2$), and there is foxing occurring all over the paper. The paper support has been deacidified during a previous conservation intervention. The aim of this study is to assess the environment of the drawing in order to advise on the optimal strategy for its conservation. For the sampling of pollutants, diffusive cartridges with TEA (triethanolamine) as the adsorbent have been used. Low-molecular weight VOCs, NO_x and SO_x can be sampled using this chemical. Formic and acetic acid were identified and quantified using HPLC, while NO_x and SO_x were analysed using ion chromatography [1]. The choice of Radiello® diffusive cartridges was made taking into account the easiness of application, shape, size and length of sampling time [2]. The method was first tried on another Picasso drawing (El Loco, Barcelona, 1904). This painting is exhibited in a climatised showcase, with absorbents for pollutants, and control of T and RH. Pollutants in the gallery were also analysed. The method is easy to use for monitoring of pollutants, and it can be recommended for assessment of the museum environment.

1. M. Stranger, S. Potgieter-Vermaak, P. Sacco, *Analysis of indoor gaseous formic and acetic acid, using radial diffusive samplers*. Environ. Monit. Assess., 2009, **149**, 411-417.
2. J. Tétreault, *Airborne Pollutants in Museums, Galleries and Archives: Risk Assessment, Control Strategies and Preservation Management*, Canadian Conservation Institute, Ottawa, 2003.

Characterization of airborne particles and gaseous pollutants in the Museo Nacional do Azulejo, Lisbon

W. Anaf[1]*, T. I. Madeira[2], M. L. Carvalho[2], R. Van Grieken[1], K. De Wael[1]

[1] Department of Chemistry, University of Antwerp, Belgium
[2] Centro de Física Atómica, University of Lisbon, Portugal

*Corresponding author: willemien.anaf@ua.ac.be

The Museu Nacional do Azulejo (National Tile Museum), Lisbon, is one of the most important Portuguese museums mainly due to its unique collection of tiles. It is well known that external stressors such as air pollution can have deleterious effects on cultural heritage [1]. To interpret preventive conservation requirements, an in-depth air quality study was performed by mapping the pollutants during a winter and a summer campaign. We focused on the characterization of gaseous and particulate pollutants. Gaseous pollutants were sampled by means of Radiello® diffusion tubes. Bulk particulate matter (PM_{10} and $PM_{2.5}$) was sampled by impacting on a pre-weighed Teflon filter (Harvard impactors). Size-segregated PM samples were collected with a 9 stage Berner cascade impactor for single particle analysis. To study the extent of PM-deposition, sticky samplers and filters were mounted to the wall for a total collection period of three months.

In the museum building, high concentrations of NO_2 and O_3 were observed, respectively up to 24±4 μgm^{-3} and 20.7±1.4 μgm^{-3} during the summer campaign. SO_2 was below the detection limit. A fraction of the NO_2 can, in combination with a high relative humidity, be further oxidized to HNO_3, a potentially harmful agent for the glaze. Indoor PM concentrations reached 5 day average values up to 24.0 μgm^{-3} (PM_{10}, summer) and 12.5 μgm^{-3} ($PM_{2.5}$, winter). Indoor PM_{10} deposition velocities on vertical surfaces were estimated in the order of 0.3×10^{-3} ms^{-1}. Deposited PM will mainly cause visual damage by soiling of dark-coloured particles such as black carbon (soot) [2-3]. However, hygroscopic particles such as sea salts could also catalyse chemical degradation.

1. P. Brimblecombe, Effects of the cultural environment, in: R. Van Grieken, K. Janssens, Eds., Cultural Heritage Conservation and Environmental Impact Assessment by Non-destructive Testing and Micro-analysis, Balkema, Leiden, 2005, 8-11.
2. L.M. Bellan, L.G. Salmon, G.R. Cass, A study on the human ability to detect soot deposition onto works of art, Envir. Sci. & Tech., 2000, **34**, 1946-1952.
3. W.W. Nazaroff, L.G. Salmon, G.R. Cass, Concentration and Fate of Airborne Particles in Museums, Envir. Sci. & Tech., 1990, **24**, 66-77.

How collagen-based materials respond to temperature and relative humidity: A combined DSC, SEM and FTIR study

E. Badea[1]*, A. Kurysheva[2], W. Vetter[3], I. Petroviciu[4], C. Carsote[4], L. Miu[5], M. Schreiner[3], G. Della Gatta[1]

[1] University of Turin, Italy; Permanent address: University of Craiova, Romania
[2] Ivanovo State Chemistry & Technology University, Russia
[3] Institute of Science and Technology in Arts, Academy of Fine Arts, Austria;
[4] Centre of Research and Scientific Investigation National Museum of Romanian History, Romania
[5] National Research and Development Institute for Textile and Leather, Romania

*Corresponding author: elena.badea@unito.it

Micro-differential scanning calorimetry (DSC), scanning electron microscopy (SEM) and Fourier-Transform Infrared (FTIR) spectroscopy measurements were used to investigate the synergistic effects of temperature and relative humidity on deterioration of parchment/leather from micro- to molecular level. Macroscopic surface mechanical and dimensional properties were also measured. Samples were obtained by exposing new parchments to atmospheres of various temperature and relative humidity, for increasing time periods in test chambers with environmental control. Ageing experiments were carried out in the EC Project "Improved Damage Assessment of Parchments" and Romanian – Austrian Bilateral Project "The Influence of Environmental Factors on the Conservation of Collagen-based Museum Objects".

The impact of this accelerated ageing was assessed by measuring the thermodynamic parameters associated with the thermal denaturation of fibrillar collagen: denaturation temperature, DSC peak half-width, denaturation enthalpy and DSC peak maximum height. Deconvolution of DSC denaturation peaks provided a valuable illustration of both the dynamics and the pattern of the deterioration of bulk samples [1].

The spectroscopic techniques refer to the deterioration at the molecular level. Denaturation is indicated by the shift of amide II band (AII) relative to amide I (AI) ($\Delta A = AI - AII$), whereas the ratio AI/AII measured the hydrolysis level [2]. The morphology of the surface of samples, the shape of the fibre bundles and the structure of individual fibres/fibrils was revealed by the high-resolution images provided by SEM. Two morphological markers were used to evaluate the impact of environmental factors on parchment during accelerated ageing experiments: (i) persistence of the fibre network and fibre features such as clean contours, swollen, rounded, twisted, shrunk or split; (ii) the presence of glossy and/or granular surface and its extent, presence of cracks and/or detached layers [3].

The impact of temperature and relative humidity on parchment/leather integrity and stability is discussed in terms of their implications for conservation science.

1. G. Della Gatta, E. Badea, A. Masic, R. Ceccarelli, Structural and thermal stability of collagen within parchment: a mesoscopic and molecular approach, in: R. Larsen Ed., Improved Damage Assessment of Parchment (IDAP) Collection and Sharing of Knowledge, Research Report No. 18, Office for Official Publications of the European Communities, Luxembourg, 2007, 89-98.
2. E. Badea, L. Miu, P. Budrugeac, M. Giurginca, A. Mašić, N. Badea, G. Della Gatta, Study of deterioration of historical parchments by various thermal analysis techniques, complemented by SEM, FTIR, UV-Vis-NIR and unilateral NMR investigations, J. Therm. Anal. Calorim. 2008, **91**, 17-27.
3. G. Della Gatta, E. Badea, M. Saczuk, M. Odlyha, R. Larsen, Sustainable preservation of historical parchments, Chimica e Industria (International Journal of the Italian Society of Chemistry), 2010, **4**, 106-111.

Corrosive atmospheres inside showcases

G. T. Bailey[1]*, J. Brian[1], C. E. Champion[1], D. Mastello[2]

[1] Australian War Memorial, Australia
[2] Newcastle Maritime Museum, UK

*Corresponding author: george.bailey@awm.gov.au

It is generally the conservator's wont to have objects exhibited in airtight showcases to protect against pests and airborne pollutants. However, in some situations an adverse microclimate can form over a period of years, resulting in a build up of harmful organic acids that can cause the objects to corrode. The pollutants can come from the showcase materials or from the objects themselves. The corrosion products found on a World War One machine gun, and three ship models were analysed and found to be lead formats and carbonates. In each example the object was kept inside a reasonably well sealed showcase or storage case that had not been opened for at least twenty years. In the case of the machine gun, the pollutants came from the gradual degradation of the material used in the showcase construction. With the three ship models, the pollutants probably came from both the showcases and the timber used in the construction of the models themselves. The concentration of pollutants gradually builds up until a critical concentration is reached and rapid corrosion is initiated. Periodic opening and airing of the showcases would have prevented the pollutant levels reaching the critical concentration.

Study of PCM technology for application to cultural heritage objects

F. Becherini[1]*, A. Bernardi[1], M. D. Romero Sánchez[2], A. Vivarelli[1], L. Pockelè[3], S. De Grandi[3]

[1] Istituto di Scienze dell'Atmosfera e del Clima CNR-ISAC, Consiglio Nazionale delle Ricerche, Italy
[2] AIDICO, Instituto Tecnológico de la Construcción, Spain
[3] R.E.D. s.r.l., Italy

*Corresponding author: f.becherini@isac.cnr.it

The European project MESSIB (Multi-source Energy Storage System Integrated in Buildings) [1] is aimed at introducing new energy storage capacity in buildings, integrated with conventional installation and building architecture, in order to reduce energy consumption and improve energy management in terms of quality, security and indoor environment. The Phase Change Materials (PCMs) technology is well known in the civil engineering field where it is applied for short-term storage of thermal energy [2-4]. When applied to historic buildings with a conservation and/or display function, PCM technology needs to be adapted to specific requirements. Besides the important objectives of economy and people comfort, microclimate conditions have to be suitable for the conservation of works of art and of the historical building itself [5]. The application of the PCM technology to cultural heritage has been evaluated through a study and testing of methodologies of incorporation of PCMs in different materials. In particular, the thermal behaviour of gypsum panels and silicon coatings containing PCMs was characterized in the laboratory. Gypsum panels containing PCMs were also tested in the S. Croce Museum in Florence, where microclimatic monitoring showed that thermal conditions were dangerous for works of art. Laboratory tests were also carried out to evaluate VOC (Volatile Organic Compounds) emissions by PCMs, before installing them in the field [6].

1. www.messib.eu (accessed 09/05/2012).
2. A. M. Khudhair, M.M. Farid, *A review on energy conservation in buildings applications with thermal energy storage latent heat using phase change materials*, Energy Conv. Manag., 2004, **45**, 263-275.
3. A. Felix Regin, S. C. Solanski, J.S. Saini, *Heat transfer characteristics of thermal energy storage system using PCM capsules: A review*, Renew. Sust. Energy Rev., 2008, **12**, 2438-2458.
4. F. Kuznik, J. Virgone, J. Noel, *Optimization of a phase change material wallboard for building use*, Appl. Therm. Eng., 2008, **28**, 1291-1298.
5. A. Bernardi, *Microclimate inside Cultural Heritage buildings*, Il Prato, Padova, 2009.
6. J. Tétreault, *Airborne Pollutants in Museums, Galleries and Archives: Risk Assessment, Control Strategies, and Preservation Management*, Canadian Conservation Institute, Ottawa, 2003.

A study of volatile organic compound (VOC) emissions during the degradation of early 20th century plastics

K. Curran[1]*, M. Underhill[1], L. T. Gibson[2], M. Strlič[1]

[1] UCL Centre for Sustainable Heritage, University College London, UK
[2] WestCHEM, University of Strathclyde, UK

*Corresponding author: k.curran@ucl.ac.uk

As part of the Heritage Smells project, a study of modern materials is ongoing in order to characterise the volatile organic compound (VOC) signatures (the "smell") of historic plastic objects and to gain a deeper understanding of the relationships between these VOC signatures and the condition, stability or potential hazards of historical plastics. This work will enable heritage practitioners to make well-informed decisions regarding the conservation and storage of these valuable items in order to extend the length of time for which they are accessible to the public and to reduce the effects of harmful VOC emissions on the health and safety of museum staff and visitors, and on other heritage objects in the vicinity.

A method is being developed for the analysis of a series of historical plastic objects dating from 1910 onwards from the Historic Plastics Reference Collection at the Centre for Sustainable Heritage via gas chromatography/mass spectrometry (GC/MS). The objects collected are composed of a variety of materials, including cellulose acetate, cellulose nitrate, polyurethane and poly(vinyl chloride), the four plastic types known to deteriorate most rapidly in museum collections [1]. Some of the samples have been degraded at 80 ^{o}C and 65% relative humidity for 2, 4, 6, 8 or 10 weeks. The VOC signatures of these samples will be characterised via GC/MS using headspace analysis and solid phase micro-extraction (SPME) fibres. Multivariate data analysis will then be used to study the relationship between VOC signatures, polymer identity and the different periods of degradation.

The authors acknowledge the support of the AHRC / EPSRC Science and Heritage Programme.

1. Y. Shashoua, *Conservation of Plastics,* Elsevier, Oxford, 2009, 177.

The MEMORI dosimeter for indoor environment

E. Dahlin[1]*, T. Grøntoft[1], S. Lopez-Aparicio[1], P. Bellendorf [2], A. Schieweck[2], K. Drda-Kühn[3], M. Perla Colombini[4], I. Bonaduce[4], P. Vandenabeele[5], R. Larsen[6], D. Vestergaard Poulsen Sommer[6], A. Potthast[7], O. Marincas[8], D. Thickett[9], G. Andrade[10], A. Tabuenca[10], M. Odlyha[11], S. Hackney[12], P. Laurenson[12], C. McDonagh[13], J. Ackermann[14]

[1] Norwegian Institute for Air Research, Norway
[2] Fraunhofer Institute, Germany
[3] Association “Culture & Work”, Germany
[4] Department of Chemistry and Industrial Chemistry, University of Pisa, Italy
[5] University of Ghent, Belgium
[6] School of Conservation, The Royal Academy of Fine Arts, Denmark
[7] University of Natural Resources and Applied Life Sciences, Austria
[8] University of Arts "George Enescu" Iaşi, Romania
[9] English Heritage, UK
[10] SIT Transportes Internacionales S.A., Spain
[11] Birckbeck, School of Biological Sciences, University of London, UK
[12] Tate, UK
[13] Optical Sensors Laboratory, National Centre for Sensor Research, Dublin City University, Ireland
[14] NILU Innovation AS., Norway

*Corresponding author: emd@nilu.no

The ongoing EU FP 7 MEMORI project **(**Measurement, Effect Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets. Innovative Research for Market Transfer) which is coordinated by NILU-Norwegian Institute for Air Research has 14 partners from 10 European countries, and eight assigned end-user institutions. Through the MEMORI project a new early warning dosimeter for the evaluation of the quality of indoor environments for cultural heritage objects will be developed. The MEMORI dosimeter will combine the advantages of the Early Warning dosimeter for Organic materials (EWO) developed by NILU within the EU-MASTER project, and the Glass Slide Dosimeter (GSD) developed by Fraunhofer ISC within the EU-AMECP project. The new MEMORI dosimeter will be sensitive to the main degrading components of indoor environments in a synergistic manner that can be compared with the degradation of cultural heritage objects. The dosimeter will be sensitive to indoor climate and light, and to the photo-oxidising and acidic air pollutants. By detection of the common major damaging factors, the MEMORI dosimeter will be a useful early warning system. A handheld reader for in situ measurements and results evaluation will be developed. This will improve the functionality of the dosimeter, reduce the time needed for the evaluation of results and make the system flexible. MEMORI will do research to better understand the degradation effects of organic acids on moveable heritage objects and to improve measures for mitigation of degradation caused by air pollution inside enclosures. This will require novel sensor systems, such as the MEMORI dosimeter. The mitigation studies will also focus on volatile emission rates for construction materials and the use of absorbents and anoxic enclosures. MEMORI aims to contribute to preventive conservation in terms of safe use of low-energy demanding and effective protection of moveable cultural assets by the use of enclosures of various types, from large showcases to small storage boxes.

Comparison of two methods of assessment of airborne bio-contaminants. Questions without answers

M. Dmitrieva*, M. Linnik

Biological Survey Department, The Russian State Archive of Scientific Documents (RGANTD), Russia

*Corresponding author: biorest.maria@gmail.com

We often use different methods to assess the dust and mould contaminants in Libraries, Archives and Museums. In Russia it is still very popular to implement the sedimentation method for determination of air bio-contaminants. In this method spores and mycelium fragments from air are deposited on a nutrient medium in a Petri dish during a 1 h exposure. The quantity of bio-contaminants per volume is measured by assessing the number of grown colonies. Another well-known way of taking air samples is by pumping of a predetermined volume of air through a Petri dish. In this method, microbe cells stick to the nutrient medium or to bar-shaped traps. The most commonly used are PBU-1 (Russia) or ActiveCount (USA). Probes of different manufacturers may lead to significantly different results.

In this report, we attempted to assess the correlation between passive sedimentation and active impact methods. At the same time, we tried to reveal its relation to particulate pollutants. The investigation was performed at the Russian State Archive of Scientific Documents (RGANTD) where indoor air conditions are suitable for the storage of documents. We used the ActiveCount-90 for the assessment of air bio-contamination and a piezobalance Dust Counter Kanomax to determine the amount of dust. Despite the relatively good storage conditions (space available, temperature, humidity, ventilation) we found many different species of microscopic fungi from genus *Aspergillus*, *Penicillium*, *Fusarium*, *Trichoderma, Alternaria*, *Botrytis*, *Cladosporium* and others.

We discovered a significant diversity of results obtained using different methods of sampling. We show that the sedimentation method did not give an objective evaluation of air contamination. Furthermore, in our work we discuss some questions that still remain open: (i) How did the big amount of different microscopic fungi survive in the well ventilated and filtered air; (ii) Why did we not get a good correlation between the amount of microscopic fungi and dust particles; (iii) Which method or combination of methods is suitable for a reliable assessment of air contamination; (iv) What amount of airborne fungi is safe for both people and archival documents?

Heritage environmental protection from low energy air filters

P. Dyment

Camfil Ltd. CIBSE, HVCA, BSRIA, BIFM, FETA, Eurovent, UK

peter.dyment@camfil.co.uk

Large public buildings like museums and art galleries hold our nations' heritage in the form of priceless works of art. Unique paintings, manuscripts and books are all vulnerable and easily damaged by airborne pollution. People who are charged with the responsibility of protecting these artefacts need to know that the building ventilation and air conditioning systems are effectively cleaning the air and removing these problem contaminants.

The majority of these cultural buildings are sited in urban centres with high concentrations of population and airborne pollution. This pollution can come from outside the building in the form of fine combustion particles and gases, principally from traffic, that can cause harm to the health of people in these buildings as well as to the works of art. Consideration must be given to ensure that the people in these buildings have air filtered and cleaned to the required level, whereby they can inhale it without risk to health.

Unfortunately people themselves are a source of indoor air pollution and so provision must be made to ensure air inside the building is filtered clean and re-circulated where possible to increase energy efficiency. A popular exhibition means increased numbers of people, meaning more cleaned and conditioned air is required. We must look at the latest standards concerning classification and testing of air filters and the recommendations for the required Indoor Air Quality. There have been many improvements in the performance of products available allowing both gas and particle pollution to be removed from air to a high level of efficiency but using the minimum amount of energy.

Air filter Life Cycle Costing is a valuable tool in ensuring that once the working filtration efficiency is determined, the solution selected gives best value for money. This paper will examine some applications of Low Energy Air Filters in order to move towards an optimum solution for Heritage Environments using the latest standards and guidelines and the benefits.

1. http://www.modbs.co.uk/news/fullstory.php/aid/8908/Filtering_out_energy_costs.html.
2. http://www.keepthecityout.co.uk/.
3. http://www.camfilfarr.co.uk/filter-technology/.
4. Environmental Audit Committee, House of Commons , *Air Quality: A Follow Up Report,* London, UK, 2011. http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenvaud/1024/1024.pdf
5. http://www.keepthecityout.co.uk/tag/peter-dyment/.

Humidity sensitivity of inkjet prints

A. Fricker[1]*, A. Hodgson[2]

[1]University of the Arts London, UK
[2]3M UK PLC, UK

*Corresponding author: fricker@gmail.com

One of the potential degradation routes of digitally printed images results from their sensitivity to ambient airborne moisture. The influence of humidity on image bleed, and the sensitivity of inkjet prints in particular, have been well documented [1-4]. These studies have used various methods to characterise the humidity sensitivity of inkjet prints and this substantial experimental evidence has aided in the development of an ISO standard test method, published as ISO 18946 [5]. The authors have also published an appraisal of the test method [6]. This paper will detail some practical experience of the use of this standard to test humidity sensitivity. A number of ink and media combinations have been studied, predominantly resulting from inkjet printing. The paper will compare and contrast the results from different humidity test conditions described in ISO 18946; variations in the humidity sensitivity of different areas of the proposed test target will also be examined. The work gives further information on the sensitivity of different ink/media combinations to ambient humidity.

1. D.E. Bugner, B.L. Lindstrom, A closer look at the effects of temperature and humidity on inkjet photographic prints, Proc. IS&T's NIP21, 2005, 348-352.
2. R. Hofmann, J. Reber, Humidity Diffusion of Dye based IJ Prints, Proc. IS&T's NIP 25, 2009, 126-129.
3. H. Kaimoto, Y. Shibahara, Test Methods of Humidity Fastness of Inkjet Printing Materials, Proc. IS&T's NIP 23, 2007, 728-731.
4. M. McCormick-Goodhart, H. Wilhelm, The Correlation of Line Quality Degradation With Color Changes in Inkjet Prints Exposed to High Relative Humidity, Proc. IS&T's NIP19, 2003, 420-425.
5. ISO 18946, Imaging materials - Reflection colour photographic prints - Method for testing humidity fastness.
6. A.L. Fricker, A. Hodgson, P. Green, An Evaluation of the Humidity Test Method ISO 18946, Proc. IS&T's NIP27, 2011, 267-270.

Compressive catalytic air purification for preservation of collections of artistic and historic works in museums, libraries and archival collections

J. Garvey[1]*, J. A. Lordi[2], R. J. Martin[2], C. E. Rogge[3], P. Ravines[3]

[1] Chemistry Department , State University of New York at Buffalo, USA
[2] Buffalo BioBlower Technologies LLC, USA
[3] Art Conservation Department, State University of New York College at Buffalo, USA

*Corresponding author: ubgarvey@fastmail.fm

An estimated 4.8 billion cultural heritage objects held in public trust in American institutions are facing a preservation crisis, and it is only through preventive conservation efforts that our cultural legacy can and will be preserved. Currently, most institutions utilize costly, low efficiency, high maintenance filtration systems to preserve their valuable artistic and historic objects. Successful development of an innovative hybrid compressive catalytic air purification (CCAP) process is capable of completely sterilizing airflow as well as simultaneously fully oxidizing a wide range of chemical compounds and organic particulate matter into harmless by-products. This is accomplished by combining simple compressive heating, provided via an electrically operated air compressor, with a low temperature heterogeneous catalyst. Experiments combining a Roots compressor with an off-the-shelf diesel catalyst operating at 160 ^{o}C showed complete oxidation of volatile organic hydrocarbons, including hexane, acetone, ethanol and toluene to water and carbon dioxide as determined by triple quadrupole mass spectrometry. Nitrogen containing species such as ammonia were oxidized to water and nitrogen. In addition to removal of organic pollutants this system is also capable of effective biological sterilization. Spores of *Bacillus globi* (*Bg*), a hardy organism capable of surviving several hours exposure to boiling water and often used as an anthrax model, were passed through a Roots compressor operating at 240 ^{o}C. After a single pass a kill effectiveness of >99.9999% or a 6.5 log was observed. This high efficiency kill is due to the homogeneous heating provided by the Roots compressor. Testing against vegetative bacteria and a virus showed the same high level of kill. The CCAP system appears to be fully capable of completely removing biological and organic contaminants from the existing air in a mechanical air handling system and not merely temporarily sequestering them as many current systems do. Therefore, the CCAP system is a potentially viable system and tool in cultural heritage preservation.

Microclimate in a church with a forced-air central heating system (San Juan Bautista, Talamanca de Jarama, Madrid, Spain)

M. Gomez-Heras [1, 2]*, M. J. Varas-Muriel[1, 2], M. I. Martínez-Garrido[2], R. Fort[2], P. López-Arce[2], A. Zornoza-Indart[2]

[1] Departamento Petrología y Geoquímica, Facultad de Geología, UCM, Spain
[2] Instituto de Geociencias (CSIC-UCM), Spain

*Corresponding author: mgh@geo.ucm.es

Microclimate in cultural properties in use is complex and it is influenced by many factors [1, 2]. In the case of San Juan Bautista church (12th – 18th century), its indoor microclimate depends on the external climatic conditions (Continental climate with cold winters with common nocturnal freezing episodes), the building structure (rectangular plan (36.5 x 12.5 x 10.5 m) with a nave and two aisles with a single apse and a tower), geological setting (built on the floodplain of the Jarama River) and the building materials employed (combination of ashlars and blocks of dolostone and bricks with mortar and wood panelling). Average relative humidity within the building is relatively high (50-70%) and temperature moderate to low (9-20 °C) throughout the year, which leads to building managers opening the church gates for 10 hours per day to promote air circulation and to try to bring internal microclimate conditions in line with those outside. In addition, there are punctual changes (RH lowers and T rises) when people gather for a service within the church and the heating system is turned on. In 1972, the management installed a forced-air central heating system, which is only used in the "winter" period (November to April) for approximately half an hour during a daily religious service. European standards nowadays discourage the use of this sort of forced-air system, as they create intense fluctuations in indoor microclimates that adversely affect the conservation of cultural heritage within the church [3- 5]. Therefore, the aim of this work is to check the microclimatic fluctuations in this church due to the use of this heating system and how it affects the conservation of its interior. This paper presents results of the variation of indoor microclimate when turning on the heating system on a temperate winter morning (indoor T 10-11 °C). The microclimate monitoring is carried out with non-invasive techniques, such as a network of sensors monitoring T and RH continuously and punctual measurements with infrared thermography and of wind speed and air flow when the heating system is turned on. There is only one set of air vents, which are located at a height of 3 m on the side wall of the northwest aisle by the apse. On a winter's day, temperature and RH at heights below 2 m in front of the vents change very little (from 12 to 14 °C and 60%), while the most intense changes are found above that 2 m threshold, where T increases quickly to 18-20 °C and RH drops to 35-40% near the air vents promoting a thermal stratification in the interior of the church.

This study was funded by CGL2010-19554 and CGL2011-27902 projects. The authors would also like to thank the UCM Research Group ''Alteracion y Conservacion de los Materiales Petreos del Patrimonio'' (ref. 921349).

1. D. Camuffo, *Microclimate for Cultural Heritage*, Developments in Atmospheric Science 23, Elsevier, Amsterdam, 1998.
2. A. Bernardi. Microclimate Inside Cultural Heritage Buildings. il Prato, Padova, 2008.

3. HL. Schelle, Heating Monumental Churchs-Indoor Climate and Preservation of Cultural Heritage. PhD thesis, Technical University of Eindhoven, The Netherlands, 2002.
4. D. Camuffo, E. Pagan, HL. Schellen, D. Limpens-Neilen, R. Kozlowski, L. Bratasz, S. Rissanen, R. Van Grieken, Z. Spolnik, L. Bencs, J. Zajaczkowska-Kloda, P. Kloda, M. Church heating and preservation of the cultural heritage: a practical guide to the pros and cons of various heating systems Electa Mondadori, Milano, 2007.
5. prEN 15759-1: 2011. Conservation of Cultural Property - Indoor climate - Part. I: Guidelines for heating churches, chapels and other places of worship. CEN/TC 346.

Modelling particulate matter as a threat to cultural heritage indoors

J. Grau-Bové*, M. Strlič

UCL Centre for Sustainable Heritage, University College London, UK

*Corresponding author: josep.grau-bove.11@ucl.ac.uk

Studies of the effects of particulate matter (PM) on cultural heritage have been largely focused on the outdoors environment. Soiling of building façades is a well-known effect and several experimental studies have determined its temporal evolution [1, 2], and even identified some of its chemical consequences [3]. Soiling is, first and foremost, an aesthetic problem, since the human eye can detect soiling at very low area coverage [4]. Indoor PM received much less attention, although some authors have raised concern about possible penetration mechanisms, the importance of removal strategies [5] and have determined particle deposition rates [6]. Despite the generally lacking literature, there is now good evidence of material degradation promoted by particular matter indoors. PM emissions will remain a significant threat for the next decades, although their emissions are predicted to decrease slowly. Diesel particulate matter (DPM) represents around 30-50% of PM in the UK, a larger proportion of it in urban areas [7]. Due to its particular aerodynamic properties, PM can easily penetrate and accumulate inside semi-enclosed spaces. Particles in the range 0.1 to 1 µm, typical of DPM and known as the 'accumulation mode', are generally too small to be affected by gravity and too large to be governed by Brownian motion, and therefore can travel in suspension in the air for weeks, can leak through cracks and cannot be efficiently removed by filtered ventilation. Coarser particles (1-10 µm) deposit faster and predominantly on horizontal surfaces, and are most commonly produced by indoors sources or carried by visitors [8]. Particle inlets and outlets, indoor air movement and other effects such as coagulation, ultimately define the soiling rates and surfaces of indoors objects. To assess this risk, Computational Fluid Dynamics (CFD) modelling is suggested as the most suitable tool.

1. C. A. Pio, M. M. Ramos, A. C. Duarte, *Atmospheric aerosol and soiling of external surfaces in an urban environment*, Atmos. Environ., 1998, **32**, 1979-1989.
2. C. Rodriguez-Navarro, E. Sebastian, *Role of particulate matter from vehicle exhaust on porous building stones (limestone) sulfation*, Sci. Total Environ., 1996, **187**, 79-91.
3. J. Watt, D. Jarrett, R. Hamilton, *Dose-response functions for the soiling of heritage materials due to air pollution exposure*, Sci. Total Environ., 2008, **400**, 415-424.
4. L. M. Bellan, L. G. Salmon, G. R. Cass, *A Study on the Human Ability To Detect Soot Deposition onto Works of Art*, Environ. Sci. Technol., 2000, **34**, 1946-1952.
5. W. Nazaroff, G. Cass, *Protecting museum collections from soiling due to the deposition of airborne particles*, Atmos. Environ., 1991, **25**, 841-852.
6. W. W. Nazaroff, G. R. Cass, *Mathematical modeling of indoor aerosol dynamics*, Environ. Sci. Technol., 1989, **23**, 157-166.
7. AQEG, *Particulate Matter in the UK*, DEFRA, London, 2005.
8. Y. Yoon, *Clothing as a source of fibres within museums*, J. of Cult. Her., 2000, **1**, 445-454.

Pollutant concentrations in the Technical Museum (Brno) – Monitoring, evaluation, strategy

H. Grossmannová

Technical Museum in Brno – Methodical Conservation Centre, Czech Republic

grossmannova@technicalmuseum.cz

The internal project at the Technical Museum in Brno - Methodical Conservation Centre involved research, monitoring and evaluation of the current pollution levels and the design of a mitigation strategy. As the mission of Methodical Conservation Centre is to provide consulting, information and education service, our considerations and motivation for the research were various. Firstly, complex evaluation of air quality in our institution was performed to protect the existing technical collections, and secondly, practical method guidelines (a cost-effective and simplified method for pollution control) and educational courses. Many measurement campaigns were carried out simultaneously, in spring time, at specific locations. The measurement sites were selected on the basis of a careful survey of the museum according to specific parameters (expected pollutants, environmental stress, object degradation, climate). It was decided to perform measurements in new display cases (where presence of active corrosion on metal objects was detected), near the outdoor exhibition of a military aircraft, in a small, air-conditioned room with a historic stereovision exhibit, display of steam engines (main hall), a newly constructed exhibition area, a storage area and a room of mechanical music. Various dangerous pollutants were measured as NO_2, O_3, SO_2, HNO_3, HCOOH, CH_3COOH, NH_3, HCl, aldehydes, VOC, heavy metals and PM10. The monitoring techniques were both of the passive and active type: Radiello and IVL dosimeters, Gradko tubes, photometry, chemiluminescence, gas chromatography, high-performance liquid chromatography, gravimetry and inductively coupled plasma mass spectrometry[1,2]. Evaluation of the experimental results gave us the data for the museum control strategy and some interesting ideas for enhancement of methodical guidelines and practical educational courses in preventive conservation.

1. C. M. Grzywacz, *Monitoring for gaseous pollutants in museum environments*, Getty Publications, Los Angeles, 2006.
2. P. B. Hatchfield, *Pollutants in the Museum Environment: Practical Strategies for Problem Solving in Design, Exhibition and Storage*, Archetype Publications, London, 2002.

Emission of VOCs after gamma- and ethylene oxide disinfection of cellulose materials

J. Havermans

Team Conservation Technology, TNO Technical Sciences, The Netherlands

john.havermans@tno.nl

Bound books, containing cotton-cellulose, have been subjected to gamma disinfection (8 kGy) and ethylene oxide disinfection (650 $mgml^{-1}$; 45 °C; 600 mbar). By means of a 0.1 m^3 emission room the specific emission rates of the materials have been investigated. Non-disinfected materials were taken as a reference. Air was sampled using active samplers (Tenax GR, DNPH and HBr coated carbon) and subsequently analysed. It was concluded that no emission of ethylene oxide could be detected from samples that had been disinfected with ethylene oxide as carried out by ISOTRON VENLO, the Netherlands. For most volatile organic carbons the specific emission rate (SER) decreased after disinfection by ethylene oxide or gamma radiation. However the SER value of acetone increased. The SER value of volatile aldehydes increased for both the ethylene oxide treatment and gamma radiation treatment. The SER value of aldehydes following gamma radiation treatment was higher than that for the ethylene oxide treatment. Finally, due to the increase in the emission of lower aldehydes such as formaldehyde and acetaldehyde, we conclude that these are occurring due to oxidative deterioration. This was more severe for the gamma radiation treatment than for the ethylene oxide treatment.

The historic furnishing of Linderhof Palace - in-situ investigation of the state of preservation with regard to the indoor climate

K. Holl[1]*, S. Raffler[2]

[1] Fraunhofer Institute for Building Physics, Germany
[2] Bavarian State Castles, Germany

*Corresponding author: Kristina.holl@mytum.de

Linderhof Palace, built by King Ludwig II of Bavaria is one of the most visited sites in Germany. The rooms on the upper floor are richly decorated with painted ceilings, gilded stucco in the cavetto, gilded wooden ornaments, and textiles such as curtains, tapestries, carpets. Linderhof has no air-conditioning system, so the indoor climate follows the outside climate, buffered to some extent by the building. In the summer, due to the high volume of visitors, the air inside is very sultry and humid. The only way to get rid of it is by opening the windows. This causes high climatic fluctuations and risks insect attacks. Both damage the historic furnishings. But what is the condition of the historic furnishings in Linderhof? For six months the rooms in Linderhof Palace have been investigated by two conservators. The aim was to find out if the state of preservation has changed in the last 20 years due to climatic fluctuations. 20 years ago, room data sheets for every room in the palace were established. Certain types of damage were described and examples were photographed. Those pictures helped to compare the state of preservation back then with the condition today. Several kinds of damage can be related to other factors such as visitors, cleaning works or roof leakages. Renovation works, like painting of the background, were documented in the archive. This helped to distinguish changes caused by climate from those due to other factors. In Linderhof Palace, gilded wooden decoration is especially affected by climatic fluctuations. Notably the folding shutters, decorated with gilded sand-textured surfaces and wood carved ornaments, show heavy losses and loosening. Mould growth could be found in places, where the air exchange is very low, like in the folded shutters and the state bed. Separated from the visitors by a balustrade, the wooden gilded bed, furnished with a coating made of glue is an ideal medium for fungi.

Musecorr: Internal testing of real-time corrosion monitoring at the Swiss National Museum

V. Hubert*, M. Woerle, K. Hunger, E. Hildbrand

Collection Centre, Swiss National Museum, Switzerland

*Corresponding author: vera.hubert@snm.admin.ch

In the EU research project “Musecorr” data loggers for real-time corrosion monitoring were developed and refined for the use in the cultural heritage domain [1]. One of the project tasks was to test these data loggers in real cultural heritage applications. The Swiss National Museum is one of the partners in this project. Here, two types of data loggers were tested in indoor conditions, in the museum itself as well as in the depot building of the Collection Centre. The permanent exhibition at the Swiss National Museum presents Swiss cultural history from its beginnings to the present. In 2009, a new permanent exhibition was built where in some of the showcases silver objects started to tarnish although nearly any material was tested on its suitability in advance. Two AirCorr I Plus loggers were placed at the same location near to the air conditioning behind the wall panelling. The main objective was to compare the data of both loggers in means of sensor sensitivity. The Collection Centre of the Swiss National Museum is a state-of-the-art facility which contains the laboratories for conservation and conservation research and the museum’s storage facility. Storage equipment, building and packing materials were chosen carefully and tested in advance as far as possible. Temperature and relative humidity are automatically controlled and the incoming air is filtered. However, it must be considered that many pollutants within the storage area could derive from the objects themselves. In the case of silver objects, tarnishing was noticed after one year. An AirCorr I logger was placed here in order to determine the corrosion class in this area. A detectable difference between running the HVAC system without or with active charcoal filters should be evident.

The project was made possible by financial support of the EU FP7 Framework Programme.

1. www.musecorr.eu (accessed 01/05/2012).

Are hypoxic conditions beneficial for parchment documents?

I. Kralj-Cigić[1]*, M. Strlič[2], A. Možir[1], V. Deselnicu[3], I. Rabin[4]

[1] Faculty of Chemistry and Chemical Technology, University of Ljubljana, Slovenia
[2] UCL Centre for Sustainable Heritage, University College London, UK
[3] INCDTP- Branch Leather-Footwear Research Institute, Romania
[4] Federal Institute for Materials Research and Testing, Germany

*Corresponding author: Irena.Kralj-Cigic@fkkt.uni-lj.si

Many historically important texts are written on parchment and therefore conditions for their storage and display are important to archives, libraries, and museums. As parchment object are often exhibited or stored in enclosures with specific microenvironment, the influence of volatile organic compounds (VOCs) on parchment degradation was examined. Shrinkage temperature was chosen as an indicator of the level of deterioration of collagen fibres. The influence of VOCs on parchment degradation at 80 °C (in darkness) was examined in static experiments (closed vessels) with a contemporary and two historic parchments. Removal of VOCs with carbon cloth reduced the extent of degradation of historic parchments compared to accelerated degradation in air. Nevertheless, reduction is less intensive comparing to degradation in nitrogen atmosphere (anoxia), where oxygen was removed using oxygen scavengers. In the case of modern parchment the decrease of shrinkage temperature was independent of the degradation conditions, indicating the existence of an initial degradation process independent of oxygen. Therefore, the effect of atmosphere on accelerated degradation at 90 °C in dynamic mode (continuous stream of gas) was examined. In all cases, oxygen promoted the degradation as measured by changes in shrinkage temperature. In air and nitrogen atmosphere, the degradation rate is higher for modern parchment comparing to historic parchments. On the basis of the preliminary experiments, it can be concluded that oxygen and volatile organic compounds play a role in the degradation process and that hypoxic conditions could be recommended for storage of important parchment documents.

Reference samples for XRF investigation of museum objects

S. Krug, O. Hahn

BAM Federal Institute for Materials Research and Testing, Germany

*Corresponding author: sonja.krug@bam.de

From a conservator's point of view the aim of scientific analysis of cultural heritage is to get guidelines for its practical handling. There is always an opening question which should be answered by measurements: How to decide the further steps? How to intervene, how to transport, what are the risks for objects and persons, and how to handle such valuable and complex objects that our cultural assets are? To get answers to these questions we need guidelines and to create guidelines we need reference samples as standards. In our project in collaboration with the textile collection of the German Historical Museum in Berlin the aim is to determine pesticides on textile objects. The first step was to determine marker elements such as arsenic, mercury, lead and chlorine with X-Ray Fluorescence spectrometry (XRF). The measurements were carried out using a handheld XRF-spectrometer (TRACER III-SD/ Bruker AXS Nano). We investigated 147 objects in-situ, in the museum. The quantification of elements in light (organic) and inhomogenous matrices is complex [1]. Depending on the matrix, the penetration depth of the beam can vary between 10^{-6} and 10^{-1} cm [2]. Depending on the elements (light or heavy) the information depths can vary. To obtain useful reference samples we took into account the diverse matrices (fabrics, weave constructions, density and thread sizes) and the corresponding elements. The different matrices were immersed in four different concentrations of chlorine, lead, arsenic and mercury single-element standard solutions. These samples were analysed with XRF in different layer thicknesses and validated by atomic absorption spectrometry (AAS) or ion chromatography (IC). By measuring the element concentrations and different layer thicknesses it was possible to perform calibration. The quantification provides the basis for evaluation and further decisions concerning the textile collection.

1. Ö.G. Üstün, The limitations of hand-held XRF analyzers as a quantitative tool for measuring heavy metal pesticides on art objects, ICOM-CC Ethnogr Conserv Newsl, 2009, **30**, 5-8.
2. P. Hahn-Weinheimer, A . Hirner, K. Weber-Diefenbach, Röntgenfluoreszenzanalytische Methoden, Vieweg Verlag Braunschweig, Germany, 1995.

Stable isotope (^{13}C and ^{18}O) analysis for investigation of dust cementation in historic libraries

D. Kyropoulou*, E. Dotsika

Institute of Material Science, National Centre for Scientific Research Demokritos, Greece

*Corresponding author: dkyropoulou@ims.demokritos.gr

Micro-samples of loose dust were obtained from the Hellenic Literary and Historical Archive in Greece, a historic library with significant levels of particle pollution, as part of a Cost D42 short-term scientific mission [1]. The samples were analysed using scanning electron microscopy with Energy Dispersive X-ray Analysis (SEM-EDXA). Qualitative EDXA was used to identify the characteristics and origins of individual particles, while bulk analysis was achieved by rastering the electron beam over whole samples. The mineral phases were characterised using X-ray diffraction, while stable isotope analysis ($\delta^{13}C$ and $\delta^{18}O$) was conducted in order to evaluate the setting environments and secondary processes and to determine the dissolution/recrystallisation mechanisms in calcite-based dust particles. Mineralogical and chemical analysis showed that the principal component in dust samples is calcite that occurs as a deterioration product of the building fabric. The isotopic values of the calcite-based dust particles comprise a wide range of $\delta^{13}C$ and $\delta^{18}O$ values, from -12 to -3.79‰ and from -7.65 to -3.2‰ (Vienna Pee Dee Belemnite, VPDB), respectively. The calcite-based dust is associated with limestone produced in Greece [2]. The isotopic values for $\delta^{18}O$ and $\delta^{13}C$ appear slightly more negative than these for the original limestone. This difference is attributed to the dissolution/recrystallisation processes that take place on the surface layers of the material. The recrystallisation of calcite-based dust particles took place with water and CO_2 from various sources. From these isotopic values, it can be seen that calcite-based dust particles were recrystallised and then cemented on the surface of books.

1. D. Kyropoulou, A technical investigation on the cementation processes of calcite based particles in loose dust samples – Preliminary results. Cost D42 Action Reference: COST-STSM-D42-05902 (2010).
2. E. Dotsika, D. Psomiadis, D. Poutoukis, B. Raco, P. Gamaletsos, Isotopic analysis for degradation diagnosis of calcite matrix in mortar and plaster, Anal. Bioanal. Chem., 2009, **395**, 2227–2234.

Wireless sensor networks for monitoring microclimatic conditions in architectural heritage

M. I. Martínez-Garrido[1, 2]*, S. Aparicio[3], R. Fort[1, 2], M. A. G. Izquierdo[1, 4], J. J. Anaya[3]

[1] CEI Campus Moncloa, UCM-UPM y CSIC, Spain
[2] Instituto de Geociencias, IGEO, (CSIC-UCM), Spain
[3] Centro de Acústica y Evaluación No Destructiva, CAEND, (UPM-CSIC), Spain
[4] E.T.S.I. Telecomunicación (UPM), Spain

*Corresponding author: mi.martinez.garrido@csic.es

The current outlook is oriented to preventive conservation of architectural heritage, reducing the risk of damage before it has occurred. Controlling the environment to create suitable conditions is often a very complex problem and it is necessary to monitor a great number of variables [1] to get a whole study of the factors contributing to decay of materials, reducing costs in the long term. To tackle this problem it is very important to facilitate data acquisition and monitoring parameters to detect indoor changes or the presence of harmful compounds and problems like damp, or salts. All these goals are possible thanks to the use of wireless sensor networks, a non-invasive or minimally invasive technique.

The current project presents different wireless sensors networks (WSN) and the main sensors used to monitor deterioration, for proper data acquisition and analysis in view of the current typologies and technology. The project is being developing in a Renaissance church of the 16 th century in the north of Madrid (Spain).

The results analyze the temporal and spatial distribution of the different parameters over different studied periods. This allows us to relate them with activity inside the church; parishioners' presence or feasts, ventilation conditions or the heating system working. The temperature (T) and relative humidity (RH) network studies noticeable differences between these parameters depending on the height, sensor situation and its location along the church. Sensors can be positioned inside the wall's construction material (stone, brick, etc) or on the surface of it. We have compared this wireless technique with button sensors distributed in the church recording surface T/RH conditions, and established the most suitable system and convenience of each one.

A second wireless sensor network includes pollutant sensors for example for CO, CO_2 or O_3, this network is very important to detect activity inside the building, and complements the first network. This work helps us to understand and monitor decay agents, such as salt crystallization and microclimate changes, which can be modelled later. Outdoor conditions are also monitored and related with inside conditions to understand the relationship between the variations thus developing the wireless into a full monitoring system.

1. A. Bernardi, Microclimate Inside Cultural Heritage Buildings, il Prato, Padova, 2008.
2. M. Gómez-Heras, R. Fort, Patterns of halite (NaCl) crystallisation in building stone conditioned by laboratory heating regimes, Environmental Geology, 2007, **52**, 239-247.
3. M. Gómez-Heras, Procesos y formas de deterioro térmico en piedra natural del patrimonio arquitectónico, Editorial Complutense, Madrid, 2006.
4. D. Camuffo, Microclimate for Cultural Heritage, Developments in Atmospheric Science, 23 Elsevier, Amsterdam, 1998.

Aerosol particles in the National Museum of the Czech Republic

L. Mašková[1, 2]*, J. Smolík[1], M. Ohlídalová[3]

[1] Institute for Environmental Studies, Faculty of Science, Charles University in Prague, Czech Republic
[2] Department of Aerosol and Laser Studies, Institute of Chemical Process Fundamentals AS CR, Czech Republic
[3] National Museum, Czech Republic

*Corresponding author: maskova@icpf.cas.cz

Particulate matter (PM) can be harmful for works of art by causing soiling and chemical damage, depending on particle size and chemical composition [1, 2]. The aim of this study was to investigate concentrations and sources of airborne PM in two types of indoor environment of the National Museum (NM): (i) in an exhibition hall in the centre of Prague, and (ii) in a depository in a small town Terezín. The measurements have been done during two intensive campaigns and included particle number concentrations and size distributions. In the NM Prague the results showed visitors as the source of coarse particles and traffic in the outdoor environment as the most probable source of fine particles. In the NM Terezín the results indicated smoking in an adjacent office as an important source of fine particles. The average value for the indoor/outdoor ratio of the submicron particle number concentration had a maximum between particle diameters of 0.1 – 1 µm for both museums, which indicates a maximum penetration factor and low indoor deposition velocity of these particles. During a day windows in Prague were mostly opened, higher penetration was observed than in Terezín. During the visiting hours in Prague the average indoor concentration of coarse particles was even higher than outdoors, which confirmed visitors as the source of these particles (Figure 1).

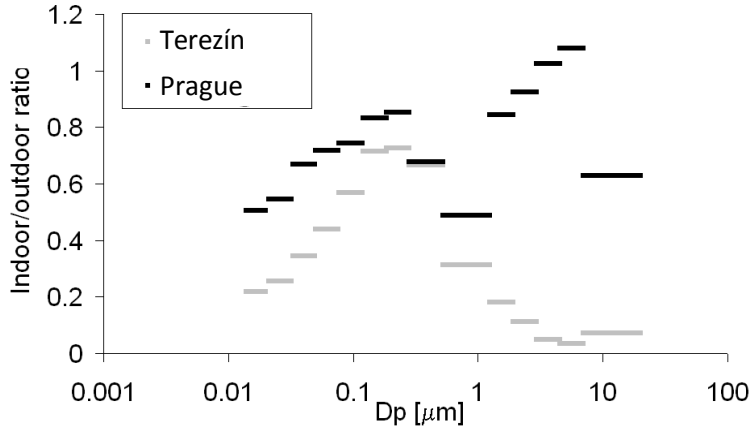

Figure 1. Indoor/outdoor ratios of particle number concentration versus particle size in the NM Prague and Terezín.

This work was supported by the Grant Agency of the Charles University under grant 307111.

1. P. B. Hatchfield, *Pollutants in the Museum Environment*, Archetype, 2005.
2. N. S. Baer, P. N. Banks, *Indoor air pollution: Effects on cultural and historical materials*, in: *Care of collections*, Routledge, London, 1994, 150-163.

Can emissions from polymeric materials be used to evaluate their condition?

G. Mitchell[1]*, M. Strlič[2], L. T. Gibson[1]

[1] WestCHEM, University of Strathclyde, UK
[2] UCL Centre for Sustainable Heritage, University College London, UK

*Corresponding author: gemma.mitchell@strath.ac.uk

This poster will present the results of accelerated aging experiments that were set up to examine emissions from a range of polymeric materials under thermo-oxidative conditions. An in-house, dynamic chamber, was built to allow the materials to be kept at elevated temperature (80 °C) using dynamic flow so that air can be constantly supplied to the material (thus ensuring that deterioration was not retarded due to oxygen depletion). The chamber outlets flowed through Tenax TA sampling tubes so that volatile products emitted from the heated objects were pre-concentrated and trapped. Analysis by Thermal Desorption-Gas Chromatography-Mass Spectrometry (TD-GC-MS) allowed the identification of the analytes produced. In addition to examination of the vapour phase surrounding polymer materials, the objects were examined by optical spectroscopy (FTIR and Raman) and also Direct Analysis in Real-Time (DART) mass spectrometry to examine correlations between emitted volatiles and any alteration in material characteristics. Additionally, a range of plastic materials, degraded at 80 °C for 2, 4, 6, 8, 10 weeks were examined using headspace (HS)-GC-MS. The materials were placed inside a sampling vial and the vapour phase equilibrated at optimum temperature, providing equilibrium conditions, to determine the volatiles given off. Volatiles from plasticizer and additives were expected from new samples and degraded samples and the data was be examined to see if there were relationships between the analytes driven off when degraded for different periods of time.

Development of a dose-response function for parchment

A. Možir[1]*, I. Kralj-Cigić[1], G. de Bruin[2], R. Larsen[3], F. France[4], K. Ntanos[5], P. Garside[6], M. Strlič[7]

[1] Faculty of Chemistry and Chemical Technology, University of Ljubljana, Slovenia
[2] Nationaal Archief, The Netherlands
[3] School of Conservation, Schools of Architecture, Design and Conservation, The Royal Danish Academy of Fine Arts, Denmark
[4] Preservation Research and Testing Division, Library of Congress, USA
[5] The National Archives, UK
[6] The British Library, UK
[7] UCL Centre for Sustainable Heritage, University College of London, UK

*Corresponding author: alenka.mozir@fkkt.uni-lj.si

Parchment is a natural material manufactured from animal skin [1]. Historical parchment was commonly used as a writing support or for bookbinding. Most research into its stability has focused on thermal and structural methods of analysis [1,2], although studies of historic materials are difficult due to unknown storage history, production methods and inhomogeneous composition and structure. Parchment consists mainly of collagen type I, with some lipids, water and inorganic matter. The helix structure of parchment plays an important role in its mechanical properties, however, numerous denaturation processes, biological and non-biological, lead to degradation of this ordered structure, converting it into unfolded and disordered gelatine. This leads to fragility and brittleness of the parchment object, and is reflected in the fact that in parchment research shrinkage temperature is often used as an indicator of the hydrothermal stability and the degree of deterioration of this material. The higher the shrinkage temperature, the more energy is needed for bonds to break between collagen molecules, thus indicating better condition of the parchment object, although shrinkage temperature should not be considered as the sole indicator of condition [3,4]. The poster will present preliminary results of an extensive accelerated degradation experiment aimed at development of a dose-response function for parchment, based on determination of shrinkage temperature changes during degradation. A goat parchment from 2005 and eleven selected historic parchments produced between 1650 and 1887 were used in the experiment. This significant variety increased the reliability of the obtained results, and represents the most comprehensive study of historic parchment degradation to date. Rates of decrease of shrinkage temperature were determined at different combinations of temperature (50, 65 and 75 °C) and relative humidity (30, 50 and 70 %), which allows for extrapolation of the results to room temperature using Arrhenius equation. Finally, the dose-response function allows us to evaluate the relative importance of temperature and relative humidity control during long-term storage of parchment.

1. R. Larsen, *Microanalysis of Parchment*, Archetype Publications, London, 2002.
2. A. Možir, M. Strlič, T. Trafela, I. Kralj Cigić, J. Kolar, V. Deselnicu, G. de Bruin, *On Oxidative Degradation of Parchment and Its Non-destructive Characterisation and Dating,* Appl. Phys. A, 2010, DOI 10.1007/s00339-010-6108-z.
3. R. Larsen, M. Vest, K. J. Nielsen, Determination of Hydrothermal Stability (Shrinkage Temperature) of Historical Leather by the Micro Hot Table Technique, J. Soc. Leath. Technol. Chem., 1993, **77**, 151-156.
4. K. Mühlen Axelsson, R. Larsen, D.V.P. Sommer, Dimensional studies of specific microscopic fibre structures in deteriorated parchment before and during shrinkage, Journal of Cultural Heritage 2011, DOI 10.1016/j.culher.2011.08.001.

Computational modelling of the role of volatile organic compounds in the degradation of 3D paper objects

A. Nimmo*, L. Mazzei

Department of Chemical Engineering, University College London, UK

*Corresponding author: alexander.nimmo.09@ucl.ac.uk

Paper is an important carrier of information and is made of natural polymers: cellulose and lignin. As with all materials, it degrades over time and the resulting products, in particular Volatile Organic Compounds (VOCs) are known to increase the rate of its degradation. It is known that acidity of paper in the centre of books can be higher than in the margins, from where the degradation products can escape into the environment. While much of the current research into paper degradation focuses on the degradation of single sheets, the challenge of understanding the degradation of 3D objects is not only in detailed studies of chemical reactions and kinetics, but also in the understanding of the migration of VOCs through the fibrous absorptive material. For this reason, a mathematical model will be developed to describe the degradation process by accounting for all the important phenomena involved: diffusion, adsorption and chemical reactions of VOCs. With this in mind, the degradation can be viewed as a problem of mass transfer with chemical reaction. The model can therefore be based on the classical theories of transport phenomena and chemical reaction engineering, which will be applied to the degradation of paper for the first time. The poster shows what role the phenomena have in the degradation of paper and how these are then accounted for in the mathematical model. Once the model is developed, computational fluid dynamic modelling will be used in order to solve it.

Applications of wireless IAQ monitoring systems

L. Roberts

PPM Technology Ltd, UK

laura@ppm-technology.com

Measurement and monitoring of hazardous gases is a critical issue, conventionally this has been concerned with acute levels of airborne pollutants. Today there is also mounting concern about the effect of long-term exposure to low levels of pollutants. Typical indoor air quality investigation and examination consists of taking single point measurements of pollutant levels. This monitoring method is unreliable, as the pollutant levels are subject to hourly, daily and indeed seasonal fluctuations. Building service professionals and designers alike have regarded these IAQ examination methods as being inadequate considering today's environmental challenges. However advances in technology have made it possible for a wireless system to continuously monitor the indoor environment. This allows a scientific approach to the systematic monitoring and management of IAQ. A wireless monitoring system can integrate with the building automation systems. Continuous monitoring of IAQ enables a profile of the indoor air environment to be created. Analysis of the recorded data through dedicated software allows for more efficient management of resources and energy.

TiO_2 with different dopants for self-cleaning natural stone

M. D. Romero-Sánchez*, M. Fuensanta, V. J. Forrat, C. Guillem-López, A. M. López-Buendía

AIDICO, Technological Institute of Construction, Spain

*Corresponding author: md.romero@aidico.es

The concentration of pollutants indoors is continuously increasing due to the increase in traffic, technology development (air conditioning/heating systems, computers, electronic devices) and the increased number of additives included in cleaning and household products (floors, concrete, plastics, paints, detergents, etc). These products and compounds can be considered pollutants even at low concentrations because of their odour intensity, they can be irritating or they can even react with other species to form new and more active species. The use of TiO_2 as a photocatalytic agent is proposed in the literature [1-3] for the safe removal of organic contaminants and for the removal of NO_x and other pollutants from the indoor air and in the atmosphere. Photo-catalysis in the presence of titania is also highly effective in generating and maintaining biochemical decontamination of a wide spectrum of bacteria, fungi, algae and viruses [4]. In this study, differently doped TiO_2 materials have been prepared as photocatalytic agents under visible light and characterised using different experimental techniques (XRD, UV-Vis diffuse reflectance spectroscopy, IR spectroscopy, surface area, XPS, etc). The effects of the different dopants on the band gap and photocatalytic activity have been analysed. The capacity for organic matter decomposition on natural stone coated with doped-TiO_2 under visible light has been demonstrated. Results have also shown that the photocatalytic activity depends not only on the band gap values of the semiconductor, but also on the type of dopant, size and surface area of synthesised particles.

1. M. V. Diamanti, M. Ormellese, M.P. Pedeferri, Characterization of photocatalytic and superhydrophilic properties of mortars containing titanium dioxide. Cement and Concrete Res., 2008, **38**, 1349-1353.
2. S. Liu, X. Liu, Y. Chen, R. Jiang, A novel preparation of highly active iron-doped titania photocatalysts with a p-n junction semiconductor structure, J. Alloy. Compd., 2010, **506**, 877-882.
3. O. Carp, C. L. Huisman, A. Reller A. Photoinduced reactivity of titanium dioxide, Prog. Solid State Chem., 2004, **32**, 33-177.
4. S. Banerjee, J. Gopal, P. Muraleedharan, A. K. Tyagi, R. Baldev. Physics and chemistry of photocatalytic titanium dioxide: visualization of bactericidal activity using atomic force microscopy. Res. Comm. Curr. Sci., 2006, **90**.

Vapour-phase detection of biocides in cultural heritage environments

I. Rushworth*, M. Smith, L. T. Gibson

WestCHEM, University of Strathclyde, UK

*Corresponding author: iain.rushworth@strath.ac.uk

Pesticide use around the world has been extensive with the application of many different chemicals across a wide range of well known industries such as agriculture and food. A lesser well known application is aimed towards determination of pesticide residues on objects of cultural significance held in museums, libraries or archives. Ethnographic and natural history collections have been comprehensively treated in the past with a wide range of chemicals which now present difficulties when objects are to be accessed by scholars, conservation scientists or the public. In the heritage science sector solutions are often sought which involve non-invasive or non-contact sampling, and as such this research seeks to develop novel methods of determination for pesticides (and other selected chemical hazards) by sampling the atmosphere surrounding potentially treated objects. Thermal desorption – gas chromatography – mass spectrometry (TD-GC-MS) methods have been developed to allow analysis of selected chemicals present in the headspace around heritage objects. Direct volatilisation has been explored though the use of headspace GC-MS and passive adsorption onto Tenax TA before analysis by TD-GC-MS. Additionally objects have been spiked with specific chemicals and artificially aged before headspace analyses (using Tenax and direct HS methods of trapping) of the atmosphere around the contained object. The results obtained were compared to analyses methods using liquid chromatography. This poster will discuss the results of the new vapour phase methods of analyses; the advantages and limitations for the determination of pesticides in heritage environments

The application of standards in the design of the Weston Library

K. Short-Traxler[1]*, T. Kirtley[1], B. Antieul[2]

[1] Bodleian Libraries, University Of Oxford, UK
[2] Building Services Division, Hurley Palmer Flatt, UK

*Corresponding author: kristie.short-traxler@bodleian.ox.ac.uk

The Bodleian Libraries have begun construction on the £80.6 million restoration and renovation of the New Bodleian Library, to be reopened as the Weston Library in 2014/2015. The new library, has three aims: to create high quality storage for the Libraries' valuable special collections, which include the rare and unique collections that the Bodleian preserves for the international world of scholarship; to develop the Libraries' space for the support of advanced research; and to expand public access to its treasures through new exhibition galleries and other facilities. The New Bodleian Library has been in urgent need of upgrading to meet modern standards appropriate for one of the largest and most important repositories of historical and legal deposit materials in the world. This includes significant modifications to create necessary environmentally sound storage conditions and fire protection. Conservation have been working closely with other professionals involved in the project to ensure the best home for the Library's unique Special Collections. Only through constant and open dialogue with each other have we been able to wade through the vast amount of information available to us in order to make decisions that balance all of the project's objectives. This has been a useful collaborative process for the authors and especially for the main author; it continues to underline the fact that standards cannot substitute experience and professional knowledge. After examination and debate of several guidelines and standards and taking part in consultations with The National Archives, English Heritage and the City of Oxford we have greater confidence that we have developed a plan that respects the best aspects of Giles Gilbert Scott's classic 1930s building whilst opening it up to readers and visitors in a sympathetic fashion and maintaining preservation of our collections.

Methodology of evaluation of the effect of air quality on library and archival collections

J. Smolík[1]*, L. Mašková[1, 2]

[1] Institute of Chemical Process Fundamentals ASCR , Czech Republic
[2] Institute of Environmental Studies, Faculty of Science, Charles University in Prague, Czech Republic

*Corresponding author: smolik@icpf.cas.cz

The aim of the project, supported in 2011-15 by Ministry of Culture of the Czech Republic, is to develop evaluation methods for indoor air quality in libraries and archives, targeted at reduction of damage to library and archival collections caused by adverse effects of the environment. The project includes indoor/outdoor monitoring of gaseous pollutants and particulate matter at 4 different locations: depository of National Library at Zlatá Koruna Monastery, State Regional Archives at Třeboň, Library at Cloister Osek, and National Archives in Prague, representing different outdoor environments: rural, small city with seasonal tourism, industrial area, and large city with traffic. Beside detailed characterisation of indoor air the possible adverse effects of the deteriorated environment will be studied by comparison of identical copies of the same books from these locations using a SurveNIR instrument. Parallel to field studies the possible deterioration of paper caused by deposited particulate matter will be studied in laboratory conditions. The air exchange rate at different ventilation conditions and transport of pollutants in the indoor environment will also be also investigated at all locations, which will enable us to mitigate the adverse effects of outdoor air pollution.

This work is supported by the Ministry of Culture of the Czech Republic under grant DF11P01OVV020.

Real-time monitoring of air quality at the National Museum of Denmark

M. Taube*, M. Ryhl-Svendsen

National Museum of Denmark, Denmark

*Corresponding author: michelle.taube@natmus.dk

Newly-developed thin, responsive sensors and AirCorr loggers were tested at the National Museum of Denmark as part of the Seventh Framework European Project MUSECORR [1]. The loggers were tested in two indoor locations where corrosion has previously been found on metal objects. Metal coupons, passive samplers, and temperature and relative humidity loggers were also included in each location.

The first location tested was within an exhibition case inside the museum in Copenhagen. Many of the lead objects in the showcase exhibit thin layers of white, powdery corrosion. An AirCorr I Plus logger equipped with two lead sensors of different thicknesses was placed in the case. An increase in corrosion depth was measured on both sensors with the thin sensor responding almost immediately to organic acids in the environment.

The loggers were also placed in one of the conservation workshops in the Museum conservation department. Iron objects corrode more in this room than in other rooms in the building. As part of an ongoing investigation as to the cause of the corrosion problem, two AirCorr I loggers with iron sensors of different thicknesses were placed in the workshop. Rust was found on the iron sensors and coupons in the suspect room within three months. While the thick sensor was too thick to register corrosivity in the room, the corrosion depth on the thin sensor indicated a low to medium corrosivity. Although the iron sensors and coupons responded in the same way as iron objects in the room, passive samplers did not help to determine the specific cause for the corrosivity. The investigation is continuing through examination of the particulate matter in the room.

1. http://www.musecorr.eu (accessed 02/05/2012).

Evaluation of the effect of relative humidity and temperature on the corrosion rate of gilded bronzes by means of galvanic sensors

S. Goidanich[1], L. Brambilla[1], S. Porcinai[2], L. Toniolo[1]*

[1] Department CMIC, Politecnico di Milano, Italy
[2] Opificio delle Pietre Dure – MiBAC, Italy

*Corresponding author: lucia.toniolo@polimi.it

Relative humidity and temperature play an important role in the conservation of any artefact and each material requires specific values of temperature and relative humidity for its optimal preservation. Gilded bronzes need great attention due to the fact that the patina of corrosion products, usually located between bronze and gold, is often made of unstable compounds. In addition, the situation is worsened by the galvanic coupling between gold and bronze, which accelerates the corrosion processes. In general, corrosion rate decreases by decreasing relative humidity. Unfortunately, in the presence of hygroscopic salts such as chlorides, the relative humidity values required to block the degradation processes may be very low. On the other hand, a too low relative humidity may lead to the dehydration of the corrosion layers making them brittle and more sensitive to subsequent accidental increases of RH. It is therefore important to evaluate the optimal thermo-hygrometric conditions for these precious artefacts, depending on the composition of the corrosion layers that have formed over centuries. Normally, it is not advisable to test the effect of environmental parameters directly on artefacts; it is therefore necessary to make replicas with similar composition and stratigraphy to simulate the real cases. The presence of the galvanic couple gold/bronze allows the use of macrocouple current to monitor the degradation rate of gilded bronzes. Unfortunately, this cannot be done on the original artefacts due to the frequent short-circuits occurring between the two metals. Therefore, galvanic sensors were developed, for simulations of real gilded bronzes, for in-situ monitoring of degradation processes under different microclimatic conditions. The sensors were used for the evaluation of the effect of relative humidity and temperature on the corrosion rate of gilded bronzes. The stability of the patina of corrosion products was also investigated. The sensors can also be used for studying degradation mechanisms and for testing new conservation procedures or treatments.

Evaluation of protective glazing for medieval stained glass windows

M. Torge*, M. Bücker, I. Feldmann

BAM Federal Institute for Materials Research and Testing, Germany

*Corresponding author: manfred.torge@bam.de

For a long time, protective glazing for medieval stained glass windows has been one of the most widely accepted conservation interventions. While protective glazing can be implemented in several ways, inside air circulation has become a popular intervention [1, 2]. Glazing is applied in the attempt to prevent corrosion of stained glass windows. The long term effects of such interventions was investigated by measuring temperature, humidity and air velocity in combination with light microscopy and electron microscopy analysis of original glass fragments. Environmental parameters, as well as analysis of dust deposition and original materials, were investigated to assess the condition of stained glass windows in five cathedrals where protective glazing was installed between 10 and 25 years ago. The Federal Institute for Materials Research and Testing was involved in many conservation projects of stained glass windows since 1990. The levels of corrosion of original glass samples were documented during these projects. This documentation can now be used to compare the present condition by investigating the environmental parameters many years after the installation of the protective glazing. Conclusions can be drawn by analysis and interpretation of environmental parameters collected during one year. Important factors for the state of preservation are temperature and relative humidity fluctuations. The reaction between dust and stained glass window under specific climatic conditions could be analyzed by measuring dust deposition in the gap between the original glass and the protective glazing and by ex-situ experimentation using climatic chambers [3].

1. B. Konrad, Schutzverglasung in E. Drachenberg, Ed. Historische Glasmalerei Schutzverglasung, Bestandsicherung, Weiterbildung, Edition Leipzig, 1999, 17-37.
2. S. Oidtmann, Die Schutzverglasung eine wirksame Schutzmaßnahme gegen die Korrosion an wertvollen Glasmalereien Verlag M. Brimberg, Aachen, 1994, 28-47.
3. M. Torge, M. Bücker, I. Feldmann, Modellhafte Evaluierung von Restaurierungs- und Konservierungsmaßnahmen an historischen Glasmalereien mit starken Schäden durch anthropogene Einflüsse, Fraunhofer IRB Verlag, Stuttgart 2011.

Determination of wood protective agents in a world heritage site church

M. Torge*, D. Brödner, I. Feldmann, S. Krug, H. Mathies, B. Mull

BAM Federal Institute for Materials Research and Testing, Germany

*Corresponding author: manfred.torge@bam.de

In the last decades, pentachlorophenol and lindane have been used for preventive wood protection indoors. The use of these substances has been forbidden in Germany since 1989 [1]. The emissions of pentachlorophenol and lindane can affect the indoor air quality also years after the application; this can be a risk to human health. In the World Heritage Site church in *świdnica* in Poland, completely made of wood, protection substances (Xylamon/Xyladur) were used in the last century. In combination with restoration projects, measurements were done by the Federal Institute for Materials Research and Testing to evaluate the presence of wood protection agents and volatile organic compounds as a consequence of these treatments. First on-site measurements on wood were done by X-ray fluorescence analysis (XRF). In this study we used the handheld XRF spectrometer TRACER III-SD (Bruker Nano GmbH) with a 1-cm measurement spot. All measurements were conducted with a 1-W low-power rhodium tube, excitation parameters were 15 KV and 55 µA for the determination of chlorine. In a second step wood samples (10-100 mg) were investigated in a micro chamber at different temperatures and analysed by GC-MS-MS to detect substances contained in the wood. In the next step, VOC sampling was carried out using Tenax TA tubes with followed by thermal desorption and GC-MS analysis. The sampling volume was 20-25 l with an air flow of 200 ml/min. Quantification was carried out using internal standards. Finally, dust samples were investigated as a possible carrier of substances from the treated wood into the indoor air. After extraction with acetone the samples were analysed by GC-MS. The dust was also investigated by EDX-analysis to identify the PCP containing particles. In all samples pentachlorophenol and lindane could be detected either quantitatively or qualitatively.

1. R. Bessing, R. Derra, Holzschutzmittelbelasungen durch Pentachlorphenol und Lindan in Wohn- und Aufenthaltsräumen, Staub – Reinhaltung der Luft, 1992, **52,** 265-27.

Systematic investigation of interferences in the use of SPME fibres in studies of degradation of organic materials

T. Trafela[1]*, I. Kralj-Cigić[1], M. Strlič[2]

[1] Faculty of Chemistry and Chemical Technology, University of Ljubljana, Slovenia
[2] UCL Centre for Sustainable Heritage, University College London, UK

*Corresponding author: tanja.trafela@fkkt.uni-lj.si

Volatile compounds, emitted by paper during degradation, have been shown to be both numerous and information-rich [1]. Most frequently, volatile compounds are determined using gas chromatography coupled with different detectors and several sampling methods are in use, SPME (solid-phase micro-extraction) being among the most popular ones. In this research, SPME fibres with a divinylbenzene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS, thickness 50/30 µm) stationary phase, which is very commonly used in material degradation studies, were considered. It has been reported, namely, that methoxy-phenyl-oxime (MPO) with a base peak m/z 133 and molecular ion of m/z 151 is believed to originate from the glue that is used to attach the fibre to the syringe plunger [2]. Therefore we have tested the influence of fibre storage in air for 1 day, 3 days and 3 weeks, on MPO peak areas. The peak areas of MPO increased with the period of storage. After conditioning the fibre at least two times, the peak area of MPO decreases considerably. Numerous studies have been published where MPO is reported as an analyte, whereas in fact it interferes with analyses. Based on this, we studied the degradation of lignin in ground-wood containing paper from the SurveNIR historic paper collection [3], in which the lignin-containing papers were mostly acidic and particularly unstable [4]. A 10-mg paper sample was pre-heated in a closed vial and extraction of headspace volatiles was performed using a SPME fibre. Following desorption, separation and detection of volatiles was performed using GC/MS. The most often discussed volatile degradation product of lignin is vanillin, which also has a characteristic aroma. However, in this research vanillin could not be detected, but its degradation products benzaldehyde and alkyl aldehydes such as pentanal, hexanal were found.

1. A. Donetzhuber, B. Johansson, K. Johansson, M. Lövgren, E. Sarin, *Analytical characterization of the gas phases in paper and board products*, Nord. Pulp Pap. Res. J., **14**, 1999, 48-60.
2. C. C. Grimm, E. T. Champagne, K. Ohtsubo, *Analysis of volatile compounds in the headspace of rice using SPME/GC/MS*, in: R. Marsili, *Flavor, Fragrance and Odor Analysis*, CRC Press, 2001, 229-248.
3. http://www.science4heritage.org/survenir/collection (accessed 26/12/2011).
4. M. Strlič, J. Thomas, T. Trafela, L. Csefalvayova, I. Kralj-Cigić, J. Kolar, M. Cassar, *Material degradomics: On the smell of old books*, Anal. Chem. 2009, **81**, 8617-9622.

Digital Image Correlation (DIC) as a novel tool for monitoring response of canvas paintings to variations in environmental conditions

L. Tymińska-Widmer[1]*, K. Malowany[2], M. Malesa[2], B. J. Rouba[1], M. Kujawińska[2], P. Targowski[3]

[1] Institute for the Study, Restoration and Conservation of Cultural Heritage, Nicolaus Copernicus University, Poland
[2] Institute of Micromechanics and Photonics, Warsaw University of Technology, Poland
[3] Institute of Physics, Nicolaus Copernicus University, Poland

*Corresponding author: lutym@umk.pl

Whether the range of acceptable fluctuations of relative humidity and temperature is based either on assumed or actual risks is still a matter of debate within the environmental standard frameworks. We will show how Digital Image Correlation (DIC) [1-4] may be used to asses quantitatively the response of painting on canvas to changes of relative humidity in a non-contact and non-invasive way. Contrarily to the wood , canvas paintings reacts immediately to changes in the environment [5,6]. This can lead to cracking or cleavage but also to significant distortions of the whole picture plane. When compared to coherent techniques, DIC is able to register large distortions in three dimensions simultaneously. In addition, this technique is significantly less sensitive to mechanical unsteadiness of the experimental set-up and thus is well suited to be used on-site, e.g. in museum environment. DIC is an easily implemented method. 3D tracing only requires two good-quality digital cameras. Using 21 MPx (Cannon EOS 5D) cameras, sensitivity over a 100 cm x 60 cm area is up to 4 µm and 7 µm for in plane and out-of-plane displacements respectively. It is essential that this sensitivity scales with the object dimensions and thus the same set-up may be used for broad range of objects. The measurement is based on recording a sequence of images of the object subjected to varying conditions. The algorithm of DIC relies on correlating small regions (subsets) of a reference image against the corresponding subsets in following images from the sequence. By estimating displacements of all the subsets within the image, deformation and strain maps for the whole field of view are calculated. It will be shown how this method may be applied to both original paintings on canvas and model specimens made especially for this project.

1. M Sutton, J-J Orteu, H Schreier, Image correlation for shape, motion and deformation measurements, Springer, 2009.
2. D. Khennouf, J. M. Dulieu-Barton, A. R. Chambers, F. J. Lennard, and D. Eastop., Assessing the Feasibility of Monitoring Strain in Historical Tapestries Using Digital Image Correlation, Strain, 2010, **46,** 19-32.
3. M. Malesa, K. Malowany, L. Tymińska-Widmer, E. Kwiatkowska, M. Kujawinska, B. Rouba, P. Targowski, Application of digital image correlation (DIC) for tracing of canvas painting deformations, Proc. SPIE, 2011, **8084**, 80840L-1-8.
4. M. Kujawinska, M. Malesa, K. Malowany, A. Piekarczuk,L. Tymińska-Widmer, P.Targowski, Digital image correlation method: a versatile tool for engineering and art structures investigations, Proc. SPIE, 2011, **8011**, 80119R-1-8.
5. L. Tymińska-Widmer, P. Targowski, M. Góra, M. Iwanicka, T. Łękawa-Wysłouch, B. Rouba, Optical Coherence Tomography – a Novel Tool for the Examination of Oil Paintings, in: J. H. Townsend, L. Toniolo, F. Cappitelli, Eds. Conservation Science 2007. Papers from the Conference held in Milan, Italy 10-11 May 2007, Archetype Publications, London, 2008, 175-182.
6. P. Targowski, M. Góra, T. Bajraszewski, M. Szkulmowski, B. Rouba, T. Łękawa-Wysłouch, L. Tymińska-Widmer, Optical Coherence Tomography for Tracking Canvas Deformation, Laser Chem., 2006, doi:10.1155/2006/93658.

Monitoring of the indoor environment in The National Library of Czech Republic and other Czech libraries

P. Vávrová[1]*, M. Součková[1], S. Lopez-Aparicio[2], J. Smolík[3], L. Mašková[3]

[1] National Library of the Czech Republic, Czech Republic
[2] Norwegian Institute for Air Research, Norway
[3] Institute of Chemical Processes Fundamentals AS CR, Czech Republic

*Corresponding author: Petra.Vavrova@nkp.cz

Thanks to the support of the Czech Ministry of Culture and Norway Grants, it was possible to monitor the indoor environment and air quality in Czech libraries. The project is focused on monitoring and analysis of the composition of particulate matter. Particulate matter may represent different degrees of risk to materials within historical buildings such as libraries or archives. Particles are not only soiling, but are abrasive, provide sites for surface reactions and have the potential to damage books due to their hygroscopic nature. Particles can be generated indoors by various processes such as heating, material deterioration, or produced by visitors and during cleaning, or penetrate from the outdoor environment. Air quality was measured for a year using active detectors or passive diffusion samplers in two buildings of the National Library of the Czech Republic: the Baroque Library Hall and the new Central repository. VOCs levels in the Baroque library were compared with a condition survey of manuscripts or prints (incunabula) within the repositories (SurveNIR). At present, four libraries and archival depositories in Czech Republic with different quality of outdoor air are being monitored for air pollutions. The outcomes of this research will be used to inform interventions with the aim to improve air quality within libraries and archives.

These presented results are obtained in the research project no. DF11P01OVV020 supported by the Ministry of Culture of the Czech Republic.

Monitoring and controlling of the conservation microenvironment at the EXPO 2010 Shanghai, China

L.-M. Wu[1]*, F.-Y. Xu[1], H. Huang[1], L.-K. Cai[2], H. Deng[3]

[1]Shanghai Museum, China
[2]School of Resources & Environmental Engineering, East China University of Science & Technology, China
[3]Microwise System Technology Co. Ltd, China

*Corresponding author: wu_laiming@163.com

"Preventive Conservation" is through effective quality management, monitoring, evaluation and control, inhibition of various environmental factors that may have harmful effects on cultural heritage. Preventive conservation aims at creating a stable, clean, living environment for artefacts at preventing or delaying physical and chemical changes and at achieving long-term conservation. In EXPO 2010 Shanghai China, more than 300 objects from many countries were exhibited in the Pavilion of Footprint and World Exposition Museum. During the exhibition, a variety of environmental monitoring and control techniques were used to ensure a suitable environment for the objects, which have been on display for more than 12 hours a day for 200 days. This monitoring and control provided a smooth progress of the exhibition. A specific design was introduced to enhance showcase tightness; all materials used in the showcase were screened and assessed; all cabinets in the showcase were covered with aluminium-plastic film to prevent the spreading of pollutants in cabinets. Before the exhibition was opened, the quality of the showcase was evaluated comprehensively. Passive samplers were used to detect polluting gases within the showcase. Nearly 2000 kg of humidity-controlling materials and adsorbents, as well as 10 small electronic humidistats, were used to clean and smooth the microenvironment in the showcase. The lighting in the exhibition was tested and adjusted one by one to meet conservation criteria. During the exhibition, a set of monitoring sensors (network system) was set up in Pavilion of Footprint and World Exposition Museum. More than 50 wireless sensors were used to monitor temperature, relative humidity, carbon dioxide and illumination 24 hour real-time. The monitoring data was analysed timely to make risk assessments and to give advice to adjust the control parameters of the air-conditioning system. The passive control materials were replaced periodically to smooth and control the relative humidity in the showcase in the attempt to meet the requirements for the conservation of the objects.

Characterization of airborne particles at Shanghai Museum, China

F.-Y. Xu[1]*, L.-M. Wu[1], G.-L. Xiu[2]

[1] Shanghai Museum, China
[2] Institute of Energy Economics and Environment Management, East China University of Science & Technology, China

*Corresponding author: xfyxbq@hotmail.com

Behaviour and characteristics of particles have become influential factors within the museum environment. There is an increasing interest in monitoring the particles and reducing their impacts on museum objects. The Shanghai Museum is an ancient Chinese art museum. It holds a collection of 120,000 works of art and is located in the People's Square, right in the heart of the city. In this paper, the concentration of airborne particles with different diameters was monitored in twelve galleries and in the main hall of the Shanghai Museum. While this monitoring campaign was on-going, samples under various conditions, including seasons, working days and holidays, were collected to analyse their mass and ion composition. The results of the investigations showed that the concentration of particles smaller than 0.5 µm in diameter PM_{10} is over 90%. The concentration of particles around 1 µm increased with visitor numbers. The materials used for the decoration of the galleries and ventilation conditions can also impact the concentration. The concentration of particulate matter in carpeted galleries is higher than in those without a carpet. The concentration in galleries with one passageway is higher than in galleries with two passageways. The proportion of ultrafine particles (<0.1 µm) in PM_{10} in summer was higher than that in winter. The mass concentration spectral distribution of ultrafine particles presented seasonal variation, but the regularity was not very obvious. Most of the mass concentration of water-soluble inorganic ions spectral distribution changed little with the seasons, and modal characteristics were similar. Na^+, Ca^{2+} was in Coarse mode, while SO_4^{2-}, NO_3^-, NH_4^+ was under Accumulation mode. Particle concentration during the holiday period was higher than usual, and some ions in the ultrafine particles increased significantly: CH_3COO^- concentration increased 7.87 times, Ca^{2+} increased 5.91 times and Na^+ increased 4.68 times. The change in concentration is related to visitor number during this period. According to this study, fine particles play an important role.

Instrument development for the measurement of atmospheric species: Adapting to a cultural heritage environment

I. Young

Department of Conservation and Scientific Research, The British Museum, UK

iyoung@thebritishmuseum.ac.uk

The formulation of standards and guidelines for indoor air quality in the cultural heritage environment requires a thorough understanding of the atmospheric species harmful to materials in museum and heritage collections. The identification and quantification of atmospheric species and investigation of their reactivity and interaction with materials, both in microenvironments and on a larger scale, provides information relevant for collection care. Characterisation of atmospheric species can also provide diagnostic information about degradation processes and thus the composition and condition of objects. Analysis and monitoring techniques therefore need to be developed to determine the concentration of relevant pollutants and to explore their reactions and interactions. As atmospheric samples are inherently low in concentration and usually consist of complex mixtures measurement techniques require a range of sampling, separation and detection methods that provide sensitive, real-time, in-situ analysis. Current research in atmospheric chemistry relies heavily on target-specific instrument development to overcome difficult analytical problems in a challenging environment. Spectroscopic, mass spectrometric, chromatographic and chemical methods have been developed, based on the physical and chemical properties of the target gas phase or particulate species. For optimum results simultaneous deployment of complementary instruments could allow more comprehensive understanding of the multi-component systems under question in the heritage environment. An overview of methods currently used for the detection of trace chemical species in the atmosphere will be presented, highlighting recent advances in instrument development for field measurements and how these might be applied to heritage science and the indoor environment. Factors considered during instrument development such as sensitivity, range of target species, temporal and spatial resolution of data required, together with practicalities such as cost, power consumption, size of instrument and in-situ detection versus sample collection will be discussed in the context of optical and spectroscopic instrumentation.

Microbiological control of the indoor air in the National Library of Poland

B. F. Zerek

The National Library of Poland, Poland

b.zerek@bn.org.pl ; bfilipzerek@gmail.com

There are over 9 million items in the collections of the National Library of Poland (including books, manuscripts, graphic prints, drawings, photographs, maps, microfilms, audiovisual material etc.). They are stored in over 60 storage rooms in three buildings and accessed in several reading rooms. The parameters of the environment (including conservation ateliers) are regularly controlled: air temperature and relative humidity, presence of chemical compounds and microbiological colonies forming units. In October 2011 the first 7 months cycle of the new pattern of microbiological control of the air in storage, reading and conservation rooms was accomplished.

The paper presents the results obtained in this research cycle as well as following aspects of the control: organisation and sampling methods (two microbiologists taking over 150 impact samples per month including background (atmospheric air outside the buildings) and identifying mould colonies as far as genus); interpretation of the results (comparing to the previous results from the same room, background values and available guidelines as well); identification of threats (fungi genera dangerous to humans or library material); counteractions (introducing filters, changing the climate parameters); significance of microbiological air control (e.g. in case of air temperature and humidity changes – a typical situation during hot and rainy summer). The most important reference source for this paper and the final discussion are materials of Netherlands Institute for Cultural Heritage (the question of threshold levels) and publications of Professor Bronisław Zyska (the question of identification of fungi as far as species).