# Natural Ventilation, Air Exchange and Conservational Aspects

W. Kippes

Schloss Schönbrunn Kultur und Betriebsges.m.b.H.
kippes@schoenbrunn.at

***Keywords**: air exchange, dust, RH fluctuations, textile artefacts*

## Abstract

In the „Rich Bedroom“ of Empress Maria Theresia conservational problems due to dust impact, changing humidity and regular cleaning needs are to be discussed. The exhibit is the oldest and most delicate textile room decoration (wall panels, bed of state, curtains, etc.) in Austria made of silk, velvet and rich embroidery of gilded silver threads.

Dust analysis showed organic compounds (visitors) and tiny silicate particles (less than PM10), which indicate the impact of outdoor air following the air exchange rate. Changing humidity, which also followed the ambient humidity fluctuations, proved as additional problem to the silver threads used for embroideries.

Principles of traditional natural ventilation measures versus modern conservational needs are to be discussed solving the problems via innovative exhibition techniques. The entire room was made to serve as a showcase, reducing ambient air impact via reduction of air exchange rates and isolating visitors from the exhibit leading them through a glass tunnel.

The indoor RH fluctuations were cut down to oscillate slowly between 40 % and 50 % according to outdoor air humidity without additional technical equipment. Dust impact was reduced to a minimum allowing cleaning cycles every third year to the glass tunnel and no cleaning needs on the exhibits since almost ten years by now.

## Reference

Kippes, W., (1999). Zum Raumklima im Reichen Zimmer der Kaiserin – bauphysikalische Rahmenbedingungen zur Lösung eines konservatorischen Problems. In: Neugebauer Hilde, *Zur Restaurierung des „Reichen Zimmers“,* Wissenschaftliche Reihe Schönbrunn, Band 5, Wien.

# Prediction of Damages Caused by Pollutants by Using Risk Assessment Approaches

J. Tétreault

Canadian Conservation Institute (CCI), 1030 Innes Rd, Ottawa, ON, K1A 0M5
jean_tetreault@pch.gc.ca www.cci-icc.gc.ca

***Keywords:*** *pollutants, risk assessment, museum*

## Abstract

To quantify the impact of pollutants to collections inside institutions, a lot of cumulated data were adapted in the form of doses (pollutant concentration x exposure time) at which the first adverse effect was observed on the material. This dose was defined as "Lowest Observable Adverse Effect Dose" (LOAED). This dose is based on the principle of reciprocity: Similarly to light fading, if it takes 1 year to see a small fade by ozone at 10 $\mu g/m^3$, it will take 10 years to observe the same amount of damage at 1 $\mu g/m^3$. Sets of LOAEDs can be found in a previous work [1]. To avoid assessing the extent of damages over time, results were reported as the numbers of years before to see the fist adverse effect on a material exposed to a specific pollutant.

CCI, ICCROM* and ICN** have formed a partnership to develop a model to assess the stage of preservation of collections over time. This model will predict what can be the state of the collection exposed to pollutants for the different time frames. For this reason, a new approach is needed to predict the state of materials beyond the first sign of damage observed. Notions of risk assessment previously used can be adapted for a new equation:

Equation 1: $D = 1 - e^{(-t * LOAE * C / LOAED)}$

where

D = actual Damage, a fraction of the maximum property change (no unit),

t = time (year),

LOAE= Lowest Observable Adverse Effect; critical fraction of maximum property change (no unit),

C = Concentration of the airborne pollutants ($\mu g m^{-3}$), and

LOAED = Lowest Observable Adverse Effect Dose ($\mu g m^{-3}$ yr).

The damage must be expressed in terms of a specific property change that is meaningful for the client such as fading, yellowing, loss of fold endurance, etc. Scales of the property change need to be defined. For example from none to full damage, like from intact to completely faded or completely fallen apart. The equation above can be adapted for different scenarios such as the effect of a pollutant on an already damaged material or the combined effect of multiple pollutants causing the same property change. The change in the property of the material could be eventually transposed into the lost or remained value of the material. Many criteria of loss of value (significance) may be used for this purpose.

Concepts will be demonstrated as well as examples of damage with silver exposed to hydrogen sulfide and with soot deposition.

## Reference

[1] Tétreault, J., (2003). *Airborne Pollutants in Museums, Galleries and Archives: Risk Assessment, Control Strategies and Preservation Management*, Canadian Conservation Institute, Ottawa.

*…ICCROM: International Centre for the Study of the Preservation and Restoration of Cultural Property
**..ICN: Instituut Collectie Nederland

# Advances and Trends in Air Purification

C. Muller[1], R. Corel[2] and R. Van Dijke[2]

[1]Purafil, Inc., 2564 Weaver Way, Doraville, Georgia 30340 U.S.A.
cmuller@purafil.com www.purafil.com
[2]Purafil Europa BV, Kerkbuurt 27-29, 1511 BB Oostzaan, The Netherlands

***Keywords:*** *air purification, chemical contamination, chemical filtration, indoor air quality*

## 1 Introduction

The control of airborne chemical contaminants is becoming more specialized as many have realized that the "one size fits all" approach to prescribing air purification no longer works in many specialized applications such as preservation environments. This paper will describe some of the more important recent advances in chemical air filtration in general and, specifically, how these advances can be important to air purification strategies for museums and archives. Ongoing work as well as future trends will be presented.

## 2 Advances in Air Purification for Chemical Contaminants

Research has shown that an air purification system using a single gas-phase (or dry scrubbing) air filtration medium is not adequate for the control of the major chemical contaminants found in outdoor and indoor air. [1] Different types of media were tested against compounds found in motor vehicle exhaust (Figure 1) and these results illustrate why, at least for the control of this type of contamination, an air purification system needs to employ a minimum of two different media – granular activated carbon (GAC) and permanganate-impregnated alumina (PIA). For the gases tested, GAC performed better against chlorine, nitrogen dioxide, and toluene. The PIA was more effective against the formaldehyde, hydrogen sulfide, nitric oxide, and sulfur dioxide.

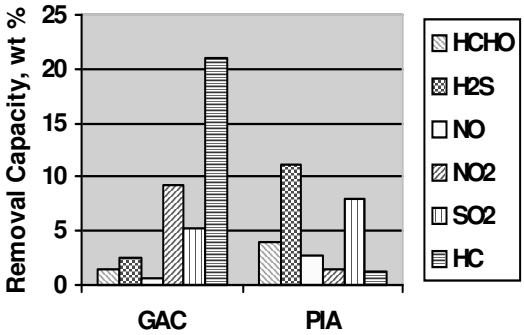



**Figure 1.** Removal capacity of GAC vs. PIA.

Because PIA showed an effectiveness for both NO and $NO_2$, research was initiated to determine if this type of dry-scrubbing media could be enhanced for the control of both contaminants. Advances in media manufacturing technology allowed for an increase in active oxidant content to a current level of 12 %, with a concurrent improvement in media performance. [2]

A promising new chemical filter technology applies both PIA and GAC to a bi-component non-woven fiber matrix. This product provides for flexible filter design with removal efficiencies and service lives comparable to many granular media systems.

## 3 Future Trends

With a new 12 % PIA media available that exhibits a much higher removal capacity for $NO_2$, adding this and GAC to a caustic-impregnated activated carbon-alumina medium, one can effectively control the primary gaseous contaminants of concern found in outdoor and indoor air. While the majority of these air purification systems are designed to treat the macro-environment using mechanical ventilation systems, many options are coming available to treat naturally ventilated spaces as well as for air purification in microclimates. Examples of new product research and specific application areas within preservation environments will be given.

## References

[1] Muller, C. and England, W., (1995). Achieving Your Indoor Air Quality Goals - Which Filtration System Works Best? *ASHRAE Journal*, 37:2, pp. 24-31.
[2] Muller, C. and England, W., (2006). A Comparison of Active Oxidant Impregnated Media. In: *Proceedings of AFS 2006 Annual Conference & Exposition*, American Filtration & Separations Society, Richfield, MN.

# Experimental and Computer Simulation Approach to Investigating the Environmental Performance of a Rare Books Archive

J. Chang[1] and B. Falk[2]

[1]University of Kansas School of Architecture and Urban Planning
1465 Jayhawk Boulevard, Lawrence, KS 66045 USA
jdchang@ku.edu http://www.saup.ku.edu
[2]Treanor Architects, 1715 SW Topeka Boulevard, Topeka, KS 66612 USA

***Keywords:*** *architecture, computer simulation, computational fluid dynamics*

## Abstract

Archive environments require strict environmental conditions for preservation of its collection. A key to successful archive spaces is the control of humidity, temperature, light, and pollutants at levels that differ from human comfort needs. This difference in environmental conditions presents a difficulty in designing and maintaining such spaces.

This paper presents the findings of a case study of a rare books archive that seeks to balance the environmental needs of both the collection and users of the library. With the aid of physical data collection and computer simulations using computational fluid dynamics (CFD) (see Figure 1), the indoor environmental performance of the archive was analyzed. Data was collected on the archive's air temperature, humidity, air speed, light level, volatile organic compounds (VOCs), particulates, mold, and formaldehyde. In addition, the mechanical system was investigated as was the design and construction of the archive and its maintenance and operation. Specific areas of investigation were ventilation effectiveness, temperature and air velocity distribution, pollutant concentration and distribution, and possible indoor and outdoor sources of pollutants specific to the environment under investigation.

Potential design solutions are presented that address some of the environmental shortcomings of this archive. Particular areas of focus deal with improving the overall local mean age of air, control of ultraviolet light levels that contribute to the rapid deterioration of books, and minimizing potential sources of pollutants as a result of maintenance and design. This study provides insight into how architects, preservationists, conservators, and environmental engineers can collaborate to design more environmentally sound archive spaces.

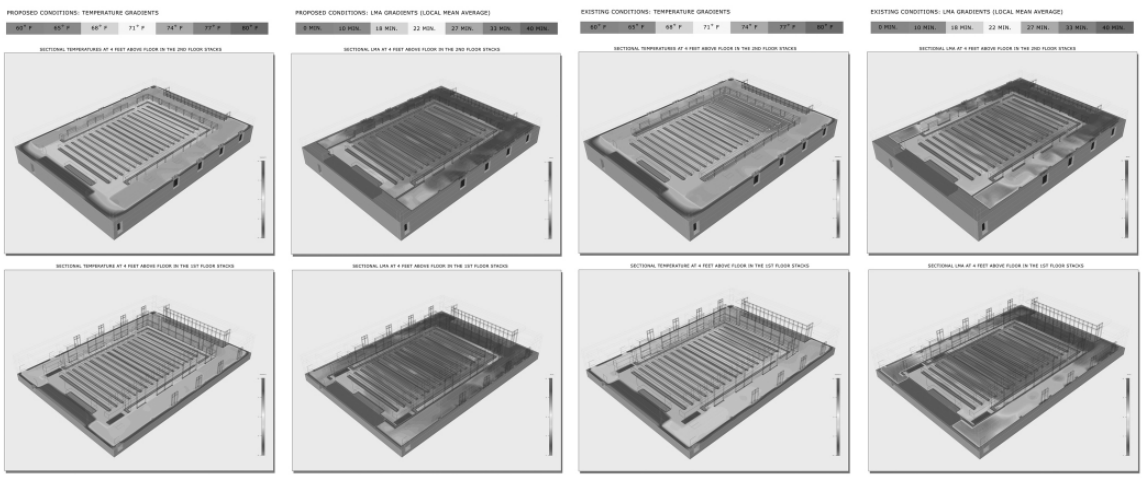



**Figure 1.** Computer simulation results of air temperature and local mean age of air.

# Monitoring Indoor Air Quality in the New Collections Centre of the Swiss National Museums

V. Hubert[1], K. Hunger[1] and L. Philippe[2]

[1]Swiss National Museums, Collections Centre, Lindenmoosstrasse 1, CH 8910 Affoltern am Albis, Switzerland
vera.hubert@slm.admin.ch www.landesmuseen.ch/e/sammlung/sammlungszentrum
[2]Laboratory of Mechanics of Materials and Nanostructures, Swiss Federal Laboratories for Materials Testing and Research (EMPA), Feuerwerkerstrasse 39, CH 3602 Thun, Switzerland

***Keywords:*** *Collections Centre, Swiss National Museums, air monitoring, chemical interactions*

The Collections Centre of the Swiss National Museums, constructed in 2007 in the township of Affoltern-am-Albis, is a state-of-the-art facility which contains both the newly designed conservation treatment laboratories, the laboratory for conservation research as well as the museum's storage facility. Housed are the nearly one million objects that comprise the museum's entire collections. Having formerly been dispersed amongst various storage locations throughout the city of Zurich, these objects are now to be found under a single roof. The outfitting of the new storage space was determined by a number of considerations and challenges, important among them were that the objects themselves are of a wide variety of materials (wood, textiles, leather, metals, glass, stone, ceramics and plastics among them), as well as the large size of the three-storied building (3 x 2970 $m^2$) designated for the storage space.

Priority is given to maintaining the condition – and thus integrity – of the objects by long-term, specific environmental controls within the storage space. Strict use of archival quality packing materials and the engagement of equipment with state-of-the-art facilities are engaged. Temperature and RH are controlled at a constant rate and environmental data are monitored and logged by computer. Fresh, incoming air is filtered and the air in the storage space is exchanged with a fixed rate.

As most of the pollutants within the storage area derive, in fact, from the objects themselves (due to prior conservation treatments, fumigants, etc.) there is the need for monitoring these pollutants which could affect other valuable museum objects. In order to find a suitable method to monitor the indoor air quality in the storage facilities, different projects have been started.

The Collections Centre was testing a new type of automated corrosion loggers as a partner in a research project entitled, 'Automated Corrosion Sensors as On-Line Real Time Process Control Tools' CORRLOG. This research project was performed under the support of the European Commission within the Sixth Framework Program [1]. The Collections Centre acted as an end-user in the final testing phase.

Moreover, the Collections Centre started a research project „Chemical interactions between selected cultural metallic artefacts and indoor environment in the new Collection Centre of the Musée Suisse Group" in spring 2008. This project is supported by the COST Action D42 (Chemical Interactions between Cultural Artefacts and Indoor Environment (ENVIART) [2]). In this project, a study of the main pollutants in the new Collection Centre playing a role in the modification and alteration of the corrosion layers of metallic cultural objects is carried out.

To investigate the air flow of the automated ventilation system, trace gas measurements have been carried out. In this way areas of higher and lower air flow could be identified. The results of this investigation are used for the placement of artificial metal samples (Ag, Cu, Pb) as monitors for possible corrosion processes.

The project consists of three phases: A field study which aims to give a complete overview of the storage conditions of the new Collections Centre by placing different sensors in selected places of the storage and studying their alteration. A study of artificial patinas on metal dummies (Ag, Cu, Pb) is carried out in order to understand the effect of the storage conditions on metal cultural objects in EMPA that owns all equipments required, such as a gas chamber, to study those effects. Finally, once the main pollutants are identified and evaluated in terms of their detrimental action on the metallic objects, prevention routes in the conservation conditions would be implemented.

## References

[1] Hubert, V., Prosek, T., Doubravova, K. (2007). Real Time Corrosion Monitoring with Automated Corrosion Loggers – End-user Testing in the New Collections Centre of the Swiss National Museums. In: Padfield, T., Borchersen, K. (eds.), *Museum Microclimates, Abstracts of Posters,* Museum Microclimates Conference Nov. 2007, Copenhagen, Denmark.
[2] http://www.echn.net/enviart.

# Air Quality in Museum Storage Buildings

M. Ryhl-Svendsen

National Museum of Denmark, Dept. of Conservation, IC Modewegs Vej, DK-2800 Kgs. Lyngby
morten.ryhl-svendsen@natmus.dk http://www.natmus.dk

***Keywords:*** *indoor air quality, ventilation, passive sorption, re-circulation*

## Abstract

An intervention study was carried out in archives and storage rooms at three Danish cultural heritage institutions, examining the effect of three different air quality control strategies on the indoor air pollution level [1]. The rationale was that such storage rooms are often insufficiently controlled with regard to indoor air pollution, despite the fact that they usually contain the major part of a museum's collection. Instead the main focus has traditionally been on climate control, and the buildings in this project therefore initially had a low ventilation exchange rate, and some were passively climatized. The effectiveness of (1) mechanical ventilation, (2) recirculation/filtration and (3) passive sorption toward pollution control was studied when applied to such low ventilated and unoccupied buildings. For one site mechanical ventilation and recirculation/filtration was initiated by the use of an existing built-in system, where at other sites a mobile stand-alone recirculation/filtration unit and a new ventilation system were introduced. Passive sorption was initiated by hanging sheets of sorptive materials on walls and interior surfaces.

The control strategies were evaluated with regard to their ability to lower the concentration of indoor generated pollutants, and the indoor-to-outdoor concentration ratio of outdoor pollutants, and the overall environmental impact during each intervention was evaluated by material damage dosimeters.

It was found that passive sorption produced more pronounced benefits in smaller rooms, compared to a large room. Mechanical ventilation and filtration with activated charcoal provided a high degree of protection for ozone, but less for nitrogen dioxide. Increased ventilation rates were expected to dilute internally generated pollutants but ambiguous results imply that the indoor emission rate of organic acids also varied so the outcome was difficult to predict. Recirculation/filtration was generally the most efficient intervention, which may partly be due to the fact that the recirculation rates were higher than the ventilation rate that was used, due to climate control issues. A cautious conclusion is that a combination of a low air exchange rate and internal recirculation with filtration will be most beneficial to the indoor air quality, for the type of low-activity storage buildings investigated in this study.

## References

[1] Ryhl-Svendsen, M., (2007). *Air Quality in Museum Storage Buildings. The effect of ventilation, filtration and passive sorption on indoor air pollution in archives and storage rooms.* (PhD-Thesis) School of Conservation, Royal Danish Academy of Fine Art, Copenhagen.

# The Evaluation of the Indoor Air Quality of Four Storage Rooms of the Royal (National) Library of the Netherlands

J. Havermans[1], H. Abud Aziz[1] and H. Porck[2]

[1]TNO Built Environment and Geosciences. PO Box 49. 2600 AA Delft, The Netherlands
john.havermans@tno.nl
[2]Royal Library, the Hague, The Netherlands

***Keywords:*** *air quality, indoor pollution*

## 1 Introduction

The Royal Library (Koninlijke Bibliotheek) aims to preserve all Dutrch literature and other publications. They have a scientific collection (history and Dutch culture), digital collections, and a rare collection including medieval handwritings.

The indoor environment contributes to the long term accessibility of the collection. As the repositories do not have air purification, there is a serious risk of entrance of the outdoor pollutants as $SO_2$, $NO_x$ and $O_3$. These pollutants have been proven to accelerate the natural ageing of paper collections.

Due to preservation actions and due to natural ageing of the collection, off gassing of the materials may have an effect on the indoor air quality as well. Known problems at the repository workers are e.g. headache and loss of concentration.

Four repositories were chosen for investigating the air technical and air chemical conditions.

## 2 Experimental

In and outlet air flow, ventilation rate including tracer gas analyses, air velocity rate, temperature and relative humidity. *Continuously during 4 weeks*

- $SO_2$ (API 100 Fluorescent $SO_2$ Analyser)
- $NO_x$ (API 200 Chemieluminescent $NO_x$ Analyser)
- $O_3$ (een API 400 Absorbtion $O_3$ Analyser) were measured and

*momentary (at 3 locations in the repository) two analyses were applied:*

- VOC (tenax-GC/MS)
- Aldehydes (DNPH cartridges/HPLC)

**Table 1.** The choosen repositories.

| No. | Code | Type repository |
|---|---|---|
| **1** | 01A | Books 19th century |
| **2** | 01C | Newspaper repository |
| **3** | 02E | Modern magazines |
| **4** | 2B | Rare collections |

## 3 Conclusion

The outdoor VOC pattern is different from the indoor VOC pattern. Indoor pollutants as formaldehyde are being produced by the materials.

The emission from the stored materials contributes seriously to the indoor air quality of the repositories. This contribution depends also on the type of materials.

Outdoor pollutants are found indoors and may affect the collection negatively, for example the $NO_x$ concentration was frequently higher than 25 ppb (recommendation National Archival Act).

# Dosimetry for Characterization of Environmental Conditions for Paintings in Microclimate Frames

T. Grøntoft[1], E. Dahlin[2], M. Odlyha[3], P. Mottner[4], M. Scharff[5], G. Andrade[6], M. Obarzanowski[7], S. Hackney[8], D. Thickett[9], J. Wadum[10] and M. P. Colombini[11]

[1] Norwegian Institute for Air Research (NILU), P.O.box 100, NO-2027 Kjeller, Norway
teg@nilu.no http://www.nilu.no/
[2] Norwegian Institute for Air Research (NILU), P.O.box 100, NO-2027 Kjeller, Norway
[3] Birkbeck College, Malet St. Bloomsbury, London WC1E 7HX, UK
[4] Fraunhofer Institute for Silicate Research (ISC), Bronnbach Branch, D-97877 Wertheim-Bronnbach, Germany
[5] Danish School of Conservation, Royal Danish Academy of fine arts (RDAFA.SC), Esplanaden 34, DK 1263 Copenhagen K, Denmark
[6] SIT Transportes Internacionales S.A., Avda. Fuentemar, 13, 28820 Coslada, Madrid, Spain
[7] National Museum in Kraków, ul. Krupnicza 26, 31-123 Karków, Poland
[8] Tate Britain, Millbank, London SWIP, 4RG, UK
[9] English Heritage, 1 Waterhouse Square, 138 Holborn, London EC1N 2ST, UK
[10] Statens Museum for Kunst (SMK), Sølvgade 48-50, DK-1307 Copenhagen K, Denmark
[11] Dipartimento di Chimica e Chimica Industriale, Università di Pisa, via Risorgimento 35, 56126 Pisa, Italy

***Keywords:*** *microclimate frames, paintings, air pollution, conservation*

## 1 Introduction

The use of microclimate frames for paintings during exhibition, storage and transport has become common in many European museums. The frames are used to protect the paintings physically, against externally generated pollutants and to give climate buffering. The positive effects are considered to outweigh the negative effects of added weight, difficulty of handling, risk of breakage, trapping of internally generated pollutants and cost. This paper will focus on the study of microclimates generated within selected microclimate frames used for the preservation of paintings and is based on preliminary results obtained in the EC project PROPAINT (FP6 SSPI no 044254).

## 2 Pollutant concentrations in microclimate frames and expected degradation effects on paintings

Pollutants can enter microclimate frames from outside the microclimates or can be emitted inside frames. Ventilation of frames can vary from several times per day to once a week depending on how well sealed they are. Externally generated pollutants can diffuse into frames, and pollutants may be generated inside the frames. Usually the low ventilation rates of microclimate frames give low concentrations of externally generated, but potentially high concentrations of internally generated pollutants.

Measurements of pollutants, in particular $NO_2$ and acetic acid levels, and relative humidity (RH) and temperature (T) were performed inside and just outside various state of the art microclimate frames in 8 museums in Europe. Three different dosimeter technologies were used having a range of sensitivities towards the pollutants. A range of passive air pollution samplers was also used. Preliminary results showed very different responses of the dosimeters inside and outside of the frames. These were complementary, with respect to inorganic gases, mostly infiltrating from outside, and organic gases, mostly being emitted inside the frames.

The expected outcome of the project is a set of dosimeters for the evaluation of the synergistic action of environmental influences on paintings and museum objects. This will provide more knowledge about the performance of different designs of microclimate frames, especially with regard to RH, T and pollutants inside the frames, and contribute to environmental standards for paintings in microclimate frames.

# Alteration of Cultural Heritage Artefacts in Museum Environments: A Few Case Studies

C. Degrigny

Haute école d'arts appliqués Arc – Filière conservation-restauration,
60 rue de la Paix, 2301 La Chaux-de-Fonds, CH
christian.degrigny@gmail.com www.he-arc.ch

***Keywords:*** *archaeological and historic artefacts, preventive conservation, museum environment, case studies*

## Abstract

Archaeological and historic artefacts have often suffered from the environment in which they were conserved before their transfer to a museum collection. Indeed archaeological artefacts from a terrestrial (waterlogged or not), subaquatic or marine site have lost part of their original surface, strength and properties. Historic artefacts are tarnished, sometimes worn out and therefore fragile. Still some kind of equilibrium between the artefacts and their local environment has normally been obtained, leading then to a quite slow alteration progress with time.

A drastic change of exposure conditions may follow the recovery of an archaeological artefact or the transfer of the historic artefact to a museum environment. Conservation strategies are normally designed to clean, stabilize and protect them from any further damage. Once the artefacts have finally joined the museum collection they should be in good hands. The new environment (either showcases or storage areas) should ensure their long term conservation.

In reality it is far from being the truth. Many artefacts are suffering from inadequate exhibition and storage conditions. Paintings on canvas might be exposed to fluctuating relative humidity (RH) and temperature that favour the mechanical damage of the paint layer and biological decay. Textile fabrics and photographs fade when exposed to over lighting conditions. Tapestries hanged to the wall warp. Wood and leather shrink when the RH is too low. Archaeological iron or copper based artefacts not fully stabilised become active in high RH atmospheres while historic silver objects tarnish in S rich atmospheres and lead objects develop active corrosion if exposed to aggressive organic vapours produced by some wood species, newly applied paint or gluing systems, materials and compounds often encountered in showcases and storage cabinets.

Well planned preventive conservation strategy is the best way to limit or prevent any damage of cultural heritage artefacts. It seems obvious but it is rarely applied due to the lack of expertise of the persons in charge of the collections and lack of funds to setup such a strategy and establish a regular monitoring of the collection. Furthermore artefacts are often complicated objects that would require specific conservation recommendations. For similar artefacts these recommendations are easy to follow but when the collection is constituted of different kind of materials that should be exhibited in the same showcase or the same room, adequate environments have to be created around each object or compromises have to be made to limit to the minimum any damage of the most fragile material.

Conservation conditions are never 100 % perfect and some slow forms of alteration might occur. Being not visible by conservation professionals, dosimeters or early warning systems placed next to the artefacts are a good way to monitor properly the collections and detect any slight change due to inappropriate exhibition or storage conditions.

These different aspects of the life of museum objects will be covered within this paper and will be illustrated by well chosen case studies.

# The Influence of Dust on Indoor Metal Corrosion at Heritage Sites

D. Thickett[1] and V. Costa[2]

[1]English Heritage, 1 Waterhouse Square, 138 Holborn, London, EC1N 2ST
david.thickett@english-heritage.org.uk http://www.english-heritage.org.uk
[2]Conservare, 29 rue de Paris, 77420 Champs sur Marne

***Keywords:*** *corrosion, dust*

## 1 Introduction

Vernon first described the accelerating effect of dust on metal corrosion in polluted environments [1]. Heritage sites often have large deposition rates of coarse dust due to large numbers of visitors [2]. Additionally many sites were originally defensive in nature and placed beside the sea, bringing an additional dust deposition burden with sea salt aerosol.

## 2 Experimental set-up

The effects of dust on the corrosion rate of three historically significant metals, sterling silver, copper, and lead has been studied by exposing coupons at 45 ° with sufficient air circulation behind them to ensure similar RHs and chemical pollutant doses. The dust deposition rate in such a situation is approximately one third on the underneath of the coupon, compared to the top surface. A method for measuring dust deposition on each surface has been developed. The two surfaces of each coupon were analysed after three and six months and twelve months with linear scanning voltametry and after six and twelve months with SEM-EDX, reflection-absorption FTIR and XRD. The deposited dust was analysed with image analysis and SEM-EDX. The extractable anions were determined with ion chromatography. Airborne dust samples were collected and their chemical composition determined with ATR-FTIR. The pollution concentrations at each exposure site were determined with diffusion tubes.

## 3 Results

A very strong accelerating effect of dust was observed for the tarnish of sterling silver in high, greater than 0.5 ppm hydrogen sulphide environments. Whilst in lower hydrogen sulphide environments this did not occur. The corrosion of copper was similarly accelerated at highly polluted and maritime sites, but not at lower pollution concentrations or inside showcases.

## References

[1] Vernon, J., (1935). A laboratory study of the atmospheric corrosion of metals: Part II, iron: the primary oxide film; Part III, the secondary product or rust (influence of sulphur dioxide, carbon dioxide, and suspended particles on the rusting of iron). *Transactions of the Faraday Society*, 31, 1668-1700.
[2] Howell, D., Brimblecombe, P., Lloyd, H., Frame, K., Knight, B., (2002). Monitoring dust in historic houses. In: Townsend, J.H., Eremin, K., Adriaens A. (eds.), *Conservation Science 2002*, London. Archetype, pp. 8-11.

# The Application and Further Development of Piezoelectric Quartz Crystal (PQC) -Based Dosimeters for Monitoring Microclimates

M.Odlyha[1], S.Jakiela[1], C.Theodorakopoulos[1], J.M.Slater[1], A.Caviccioli[2], D.L.A. de Faria[2] A.Niklasson[3], A.Schieweck[4] and D.Thickett[5]

[1]Birkbeck College, University of London, Malet Street, London WC1E 7HX, United Kingdom
m.odlyha@bbk.ac.uk
[2]School of Arts, Sciences and Humanities, Av. Arlindo Bettio 1000, University of Sao Paulo, Brazil
[3]Department of Chemical and Biological Engineering, Chalmers University of Technology, SE-412 96 Göteborg, Sweden
[4]Fraunhofer Wilhelm-Klauditz-Institute (WKI), Material Analysis and Indoor Chemistry (MAIC), Bienroder Weg 54 E, 38108 Braunschweig, Germany
[5]English Heritage, 1 Waterhouse Square, 138 Holborn, London EC1N 2ST

***Keywords:*** *piezoelectric quartz crystals, microclimate, organ pipes, corrosion*

## Abstract

This paper reports on the exposure of lead coated PQC crystals in the windchest of two historical pipe organs, St. Botolph without Aldgate, London, and in the Minor Basilica of St. Andrew the Apostle, Olkusz, Poland, and is part of the SENSORGAN project (contract no. 022695, http://www.goart.gu.se/sensorgan). Crystal arrays were exposed in holders, as described elsewhere [1], together with lead coupons and RH, T data loggers and measured at monthly periods up to 12 months. The lead coated crystal arrays showed a larger shift in frequency and corresponding mass change in the arrays in St. Botolph than in Olkusz, and there were higher levels of corrosion of the lead coupons. These were analysed by Raman and Infra-red spectroscopy, and ion chromatography; acetates, formates and trace amounts of chlorides and sulphates were found to be present. Climate data monitoring showed that the average RH in Olkusz was significantly higher and the temperature was lower than in St. Botolph. Levels of acetic acid in the windchest in St. Botolph were found to be higher than in the windchest in Olkusz. Differences between sites were recorded for the same period (winter to spring) and for each site for different periods (winter to spring to summer). Monitored exposures have demonstrated that the lead coated crystal arrays show a differential response to different levels of acetic acid which is influenced by the climate data.

Further developments have been made to miniaturize the continuously recording crystal array system used in the previous MIMIC project (contract no. EVK4-2000-22058 [1]). A small circular holder (diameter: 30 mm) for three crystals and associated electronic components has been constructed and when connected to a PC it is capable of real time monitoring. Since the aim is to monitor the microclimate in selected organ pipes the holder is supported between the toe of the pipe and the organ windchest. Current laboratory and site evaluations of this system are in progress and will be reported.

This paper also reports on the behaviour of lead coated PQC crystal arrays in microclimate frames, which is part of the PROPAINT project "Improved Protection of Paintings during Exhibition, Storage and Transit" (http://propaint.nilu.no). In the PROPAINT project preliminary exposure of the arrays have been made in microclimate frames containing a recently prepared panel painting where predictably high levels of acetic acid were recorded. The crystal arrays showed high levels of change and this was confirmed by the high level of corrosion of the lead coupons in the 3 month test period. Further tests involving real paintings in frames and then frames with and without paintings will be presented.

## Reference

[1] Odlyha, M., Ryhl-Svendsen, M., Padfield, T., (2005). Microclimate indoor monitoring: damage assessment for cultural heritage preservation. In: *ICOM-CC Preprints 14th Triennial Meeting,* Vol. II, The Hague, Sept. 2005, pp. 670-676.

# Sulfur and Iron Contaminants in Marine Archaeological Wood

Y. Fors[1], F. Jalilehvand[2], E. Damian Risberg[1] and M. Sandström[1]

[1]Department of Physical, Inorganic and Structural Chemistry, Stockholm University, SE-10691 Stockholm, Sweden
yvonne@fos.su.se http://www.fos.su.se
[2]Department of Chemistry, University of Calgary, 2500 University Dr. NW, Calgary, Alberta, Canada T2N 1N4

***Keywords:*** *Marine archaeological wood, sulfur spectroscopy, thiols, iron sulfides*

## Abstract

Considerable accumulation of sulfur in reduced forms, typically up to a few mass-percent, occurs in marine archaeological wood preserved in seawater. Synchrotron-based sulfur x-ray absorption spectroscopy reveals two major pathways in wood on the seabed for reactions with bacterially produced hydrogen sulfide. Within lignin-rich parts organic sulfur compounds containing thiol (-SH) groups are produced, while particles of pyrite and other iron(II) sulfides develop in the presence of corroding iron. In the museum atmosphere oxidation processes, catalysed by iron(II) ions and promoted by humidity variations, increase acidity and may degrade both the wood components and polyethylene glycol, the bulking agent used at the conservation. The oxidation of pyrite and iron(II) sulfides is the most conspicuous process leading to outbreaks of sulfate salt on acidic wooden surfaces (see Figure 1). Results from studies of historical shipwrecks, e.g., the *Vasa,* Sweden, the *Mary Rose,* U.K., and the *Batavia,* Western Australia, which has especially iron-rich wood, will be discussed. The effects of neutralization treatments with ammonia and with sodium bicarbonate solutions, as well as new iron extraction procedures, will be reviewed.

**Figure 1.** End of oak beam at orlop deck within the *Vasa*, with precipitates of natrojarosite, $NaFe^{III}_3(SO_4)_2(OH)_6$, and gypsum, $CaSO_4 \cdot 2H_2O$, identified by X-ray powder diffraction.

## References

[1] Sandström, M., Jalilehvand, F., Damian, E., Fors, Y., Gelius, U., Jones, M., Salomé, M., (2005). Sulfur accumulation in the timbers of King Henry VIII's warship *Mary Rose*: a pathway in the sulfur cycle of conservation concern. *Proc. National Academy of Sciences, USA (PNAS)*, 102, 14165–14170.
[2] Fors, Y., Sandström, M., (2006). Sulfur and iron in shipwrecks cause conservation concerns. *Chem. Soc. Rev.*, 35, 309-415.

# Assessment and Ranking of Parchment Deterioration by an Integrated Macro to Mesoscopic Approach

G. Della Gatta[1], E. Badea[1], M Saczuk[1], M. Odlyha[2], C. Theodorakopoulos[2], K. Mühlen[3] and R. Larsen[3]

[1]Department of Chemistry IFM, University of Turin, via P. Giuria 9, I-10125 Turin, Italy
giuseppe.dellagatta@unito.it http://www.unito.it
[2]Birkbeck College, University of London, Malet Street, Bloomsbury, London WC1E 7HX, United Kingdom
[3] The Royal Danish Academy of Fine Arts, School of Conservation, Esplanaden 34, DK-1263 Copenhagen, Denmark

***Keywords:*** *parchment, ageing, physical-chemical and structural changes, damage ranking*

Advanced visual assessment protocol and physical-chemical techniques, such as differential scanning calorimetry (DSC), thermogravimetry (TG), ATR-FTIR spectroscopy, scanning electron microscopy (SEM) were employed to assess deterioration processes occurring in the hierarchical structure of parchment. Changes in the structural and physical-chemical parameters of parchment due to interaction with the environment were used for a qualitative analysis and a quantitative determination of damage. This paper reports some of the approaches we have adopted to achieve quantitative outputs (decrease of thermal stability, amorphous/crystalline percent of collagen, triple helix degradation, etc.) through *in-situ* non-invasive or micro-invasive measurements.

Visual assessment provides detection of surface damage and material characteristics, examination of microscopic changes of the fibre structure and micro determination of the hydrothermal stability of the fibres following established protocols reported in the IDAP project [1]. Local high resolution images of the surface morphology of parchments were obtained by SEM. Their examination reveals weakening and disruption of the hierarchical organisation of collagen fibres and is thus a means of monitoring the impact of its environment on a parchment. DSC provides a highly accurate and sensible method to determine the stability of parchment from the energetic balance of its thermal denaturation. Thermodynamic parameters associated with denaturation were used to define a set of indices to grade the level of damage in parchments [2]. TG measures its thermo-oxidative characteristics and quantifies the presence of $CaCO_3$ [3]. A direct correlation between thermal stability and presence of lipids was put in evidence [4]. ATR-FTIR spectroscopy was used to measure changes in the amide I band that reflects alterations in the triple helical structure of collagen.

A comprehensive investigation has been made on a set of $14^{th}$ to $15^{th}$ century parchment rolls from the State Archives of Turin and of bookbindings from the "Secret Archives" Collection of the State Archives of Genoa which allowed us to discriminate and rank even small differences in their level of damage.

This research was supported by the Italian Piedmont Region through Project D39, Old Parchment: Evaluating Restoration and Analysis (OPERA).

## Acknowledgments

Authors are very grateful to the State Archives of Turin and State Archives of Genoa for providing parchment samples.

## References

[1] Larsen, R. (ed.), *Improved Damage Assessment of Parchment (IDAP) Collection and Sharing of Knowledge*, Directorate-General for Research, Directorate Environment, European Communities, Bruxeles, Belgium, ISBN 987-92-79-05378-8, *passim*.

[2] Badea, E., Della Gatta, G., (2007) Assessment of the thermal stability of collagen in parchment by differential scanning calorimetry in excess water. In: Albu., L. (ed.), *Advanced Materials and Processes for Ecological Manufacturing of Leathers*, Performantica, Iasi, Romania, ISBN: 978-973-730-409-4, pp. 14-28.

[3] Odlyha, M., Cohen, N.S., Foster, G.M., Campana, R. (2002). Characterization of historic and unaged parchments using thermomechanical and thermogravimetric techniques. In: Larsen, R. (ed.), *Microanalysis of Parchment*, Archetype Publications, London, pp. 73-89.

[4] Ghioni, C., Hiller, J.C., Kennedy, C., Aliev, A.E., Odlyha, M., Boulton, M., Wess, T.J., (2005). Evidence of a distinct lipid fraction in historical parchments: a potential role in degradation, *Journal of Lipid Research*, 46, 2726-2734.

# Relation Between Indoor Air Quality in Wilanów - Museum Palace and Potential Biodeterioration of Genuine Suede

A. Leśkiewicz-Laudy[1], M. Kotarska[2] and A. Skłodowska[2]

[1]Wilanów Museum-Palace, Kostki Potockiego10/16, Warsaw 02-958, Poland
[2]Laboratory of Environmental Pollution Analysis, Faculty of Biology, Warsaw University, Miecznikowa 1, Warsaw 02-096, Poland
asklodowska@biol.uw.edu.pl www.biol.uw.edu.pl; www.cemera.pl

***Keywords:*** *air quality, silk, biodeterioration, bacteria*

The indoor environment in the interior of Wilanów Museum Palace was carefully investigated over four seasons. Different factors have been checked – microbial contamination of ancient objects, the indoor environment parameters as relative humidity (RH), temperature (T) and microbial air pollution (cfu/$m^3$). This study was focused to identify, if there is any correlation between the level of microbial air contamination and an enzymatic activity of bacteria living on silk fibres [1, 2]. Therefore the genuine suede was examined and samples from the silk fibres were tested.

Actually there was not found any correlation between the presence of proteolitic bacteria isolated from the genuine suede and the presence of visitors in the museum. It seems that the presence of proteolitic bacteria to be likely caused by the specific colonization processes going on in genuine silk placed on walls. Process of proteolysis of silk fibres was documented and it was shown that excretion of exoproteases by microorganisms isolated from genuine suede was the result of the adaptation to the specific environment of this silk textile. Biodeterioration of silk fibres by one of the isolates is presented in Figure 1 A, B.

However, there is still a very clear correlation between opening windows in extremely hot weather, the presence or absence of visitors etc. and the number of cfu/$m^3$ isolated in the air sampling tests. The indoor and outdoor microbial contamination is greater in the summertime and on hot days in Spring or Autumn, because of the fact, that windows are more frequently opened to allow the getting down of the inside temperature and improve ventilation of rooms and indoor spaces. The presence of visitors and role of "mass tourism" problem was defined as influencing both: biological and physical factors of the indoor environment.

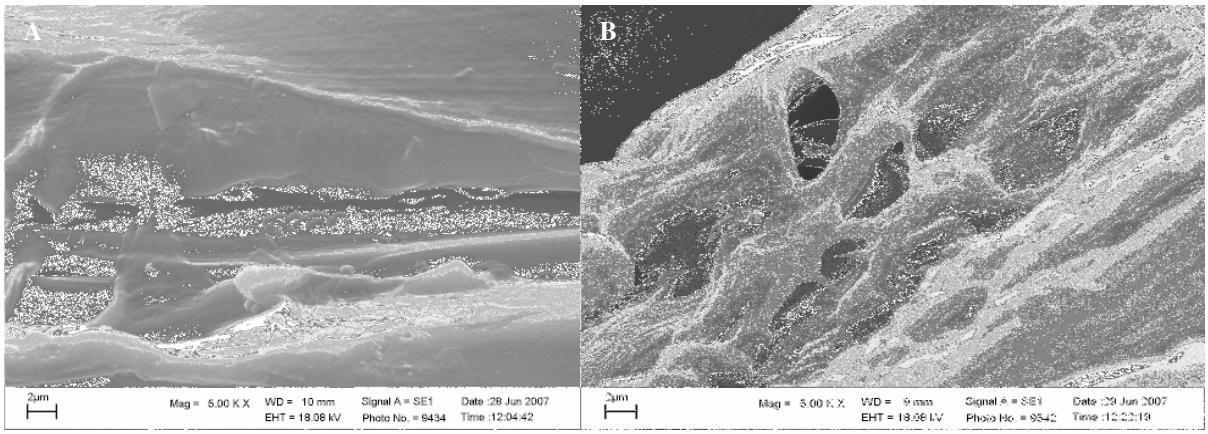



**Figure 1.** Biodeterioration of silk fibres by *Bacillus sp*. isolated from genuine suede: A - after 1 hr of incubation in laboratory conditions; B - after 24 hrs of incubation.

## References

[1] Allsopp, D., Seal, K.J., Gaylarde, Ch. C., (2004). *Introduction to Biodeterioration* (2nd edition), Cambridge University Press.
[2] Forlani, G., Seves, A.M., Ciferri, O., (2000). A bacterial extracellular proteinases degrading silk fibroin. *International Biodegradation & Biodeterioration*, 46, 271-275.

# Monitoring of Fungi in Museums and Depots as a Major Tool to Prevent Contamination and Biodeterioration

K. Sterflinger

University of Agricultural Sciences, Department of Biotechnology, Muthgasse 18, A-1190 Vienna
Katja.Sterflinger@boku.ac.at http://www.boku.ac.at

***Keywords:*** *fungi, depots, monitoring, microbiological methods*

## 1 Introduction

Fungi play a major role in the deterioration of pieces of art [1, 2] because of two major reasons: (1) Fungi are able to degrade a wide range of organic materials as paper, cotton, canvas, skin glue, egg, casein, oil, modified cellulose, *gummi arabicum* and many others, and (2) many fungi tolerate and grow at low levels of relative humidity thus being able to develop in museums and their depots in spite of air-conditioning and climate control. To prevent the contamination of objects in a museum it is necessary to detect fungi and their spores in the indoor environment before they are able to settle on the objects and to cause decay and alterations. To this aim a series of micro-biological investigations can be applied in order to be able to monitor the indoor quality in museums with focus on fungi and their spores.

## 2 Abstract

Fungal development in museums and their depots occurs in all types of museum buildings: old buildings often have humid walls due to water penetration or condensation of water thus causing fungal growth on the walls, which in consequence leads to release of spores into the air and finally to contamination of the objects. New museum buildings might cause fungal growth due to lack of aeration, wrong climatization or contamination of air-conditioning systems through which fungal spores might be distributed over a whole building with many different exhibition rooms and depots. In order to be able to prevent contamination of objects caused by the building environment a combination of measures can be carried out: (1) The constructional conditions of a building must be analyzed and optimized with focus on both building physics and microbiology in order to find out where fungal development can potentially start. This might be the case at thermal bridges or on wall coatings containing organic additives (e.g. latex coatings); (2) The regular measurement of fungal spores in the air, in dust precipitations, in ventilation slots and the regular observation of walls and construction elements; and (3) to avoid the influx of fungi from the outdoor environment by appropriate filters, by quarantining contaminated objects; and (4) by using appropriate materials for the construction of museum buildings and fittings (e.g. avoiding wall coatings containing organics, use of storage racks that can easily be cleaned, avoiding plastic boxes or gas tight plastic foils to wrap objects). It is the aim of the presentation to show the chances and possibilities as well as the limitations of microbiological, biophysical and hygienic measures to prevent fungal contamination in museum environments. Case studies from different museum types in Vienna and surroundings with historic and modern exhibition rooms and depots will be presented.

## References

[1] Sterflinger, K., Sert, H, (2006). Biodeterioration and Practice of Restoration. In: Lefèvre, R.A. (ed.), *The Materials of Cultural Heritage in their Environment*, pp. 157-166.
[2] Mandrioli, P., Caneva, G., Sabbioni, C. (eds.), (2003). *Cutural Heritage and Aerobiology*, Kluwer Academic Publishers, Dordrecht, p. 243.

# The Protective Role of Titanium Dioxide Pigments on Pictorial Artworks in Contaminated Indoor Environments

E. A. Varella[1], A. Antoniadis[1], Z. Eirini Papliaka[1] and N. Wendland[2]

[1]Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
varella@chem.auth.gr
[2]Europa Fachhochschule Fresenius, Limburger Straße 2, 65510 Idstein, Germany

***Keywords:*** *contemporary pictorial artworks, titanium dioxide, photo catalytic protection*

## Abstract

Recently, heterogeneous photo catalytic detoxification methodologies proved very promising for the treatment and disinfection of contaminated air. It is well established that irradiating a $TiO_2$ suspension with light at an energetic level greater than the band gap energy of the semiconductor ($E_g > 3.2$ eV) results in the generation of conduction band electrons ($e^-$) and valence band holes ($h^+$). Part of the photo generated carriers recombine in the bulk, while the rest are reaching the surface of the semiconductor, where they act as powerful oxidants and reductants, respectively. The photo generated electrons react with the absorbed $O_2$ on the Ti(III)-sites, reducing it to a superoxide radical anion ($O_2^-$), while the photo generated holes can oxidize either organic molecules directly, or the $OH^-$ ions and the $H_2O$ molecules absorbed at the $TiO_2$ surface to $^{\cdot}OH$ radicals. These radicals together with other highly oxidant species are reported to be responsible for the primary oxidizing step in photo catalysis. The $^{\cdot}OH$ radicals formed on the illuminated semiconductor surface are very strong oxidizing agents, with a standard reduction potential of 2.8 eV. These can easily attack absorbed organic molecules or those located close to the surface of the catalyst, at length leading to their complete mineralization. The efficiency of the photo catalytic oxidation on $TiO_2$, is strongly dependent on the experimental conditions – presence of oxygen, temperature, relevant concentrations, light intensity, presence of electron donors and acceptors.

Since $TiO_2$ is broadly used in modern and contemporary pictorial art, acting both as a pure white pigment or a moderator of hue and saturation, the present paper is trying to investigate the dioxide's role in the inherent protection of polychrome works of art, proposing thus an additional application of heterogeneous photo catalytic detoxification ($TiO_2$/UV-A). For testing the possibility, Hansa yellow and verdigris were selected as two colorants bearing extensively studied degradation processes, and having structures easily correlated to further chemically related pigments. Various types of $TiO_2$ – rutile; $TiO_2$ P-25 Degussa, anatase/rutile 3.6/1, surface area 56 $m^2g^{-1}$, nonporous; and a commercially available $TiO_2$ (A), Tronox A, McGee, 100 % anatase – were examined at several light intensities as to their role in protecting Hansa yellow (Kremer Pigmente) and verdigris (Kremer Pigmente). In order to reproduce a sequence of typical indoor environments, the distortion was measured with reference to samples not containing $TiO_2$ on a series of experimental simulations of paintings at various proportions of $TiO_2$/colorant, placed in an isolated chamber filled with contaminated air and irradiated.

# Sterile Air Humidification with MOL System

A. Machmüller

MCRT GmbH, Ludwig-Rinn-Str. 14-16, 35452 Heuchelheim, Germany
andreas.machmueller@mcrt.de info@mcrt.de

## Abstract

The humidification of air-conditioning systems, in particular for large-scale plants and houses, with more than 10,000 m³/h is very problematic, critical issues being for example:

- Quality of the fresh water
- Quality of the fresh air flowing through or into the rooms
- Energy costs for electricity and conditioned water
- Bio-films and other bacteria accumulating within the air ducts and plants
- Maintenance and maintenance costs for the humidifier
- Time for maintenance, cleaning and disinfection

So the choice between steam and water humidification depends on different points and opinions, so according consideration has been given to a energy saving system without power heating and involving a minimum of time and effort for cleaning and maintenance work, and also considering all other running costs like fresh or deionised water or cleaning and disinfection substances.

With regard to the cleanroom industry it is of paramount importance to have a non-infectious air system. This also applies to the pharmaceutical and medical industry as well as to all other industries and plants where people, substances, exhibits and/or products come into contact with the humidified air.

Now the problem itself is not the production of the humidifier. No, in most cases it is the maintenance and the effectiveness of maintenance, cleaning and disinfection. The crucial point is: This work has been carried out, but what can be done to extend the intervals between maintenance work? Is there a method which can be used for new and older airwashers alike?

Yes there is! And this is the point I would like to speak about. A method or system which airwashers can run on making sterile air and reducing and degrading bio-films.

To put it briefly: It`s not a secret but it is a mixture of catalyser and a chemical substance.

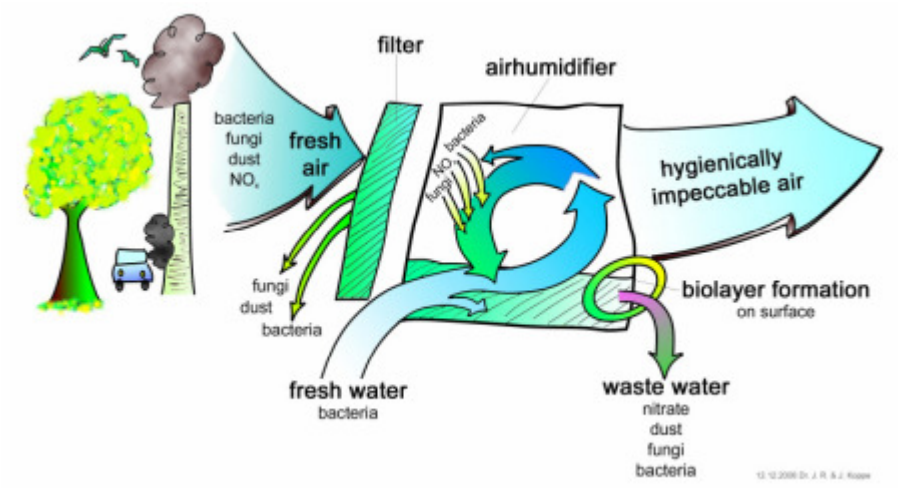



**Figure 1.** MOL System: Produced by ThyssenKrupp MOL Katalysatortechnik GmbH; Leunastr. 6; 06258 Schkopau, Germany.

# Air Quality Monitoring and Preservation of Collections: 10 Years since Glasgow and IAQ98

C. Grzywacz

Getty Conservation Institute, 1200 Getty Center Drive, Suite 700, Los Angeles, CA 90049-1684, USA
cgrzywacz@getty.edu http://www.getty.edu/conservation

***Keywords:*** *IAQ – indoor air quality, pollutants, collections preservation, cultural heritage*

## Abstract

The first Indoor Air Quality in Museums and Archives meeting was held June 1998 in Glasgow, Scotland and focused on detection and mitigation of organic carbonyl pollutants – acetic acid, formic acid and formaldehyde [1]. It evolved from a collaborative research project between Lorraine Gibson at the University of Strathclyde, Agnes Brokerhof at ICN, Simon Watts at Oxford-Brookes University and me to the Indoor Air Pollution Working Group. At this meeting Morten Ryhl-Svendsen started the website which is now hosted by the National Museum of Denmark: iaq.dk. There have been many developments in these last 10 years not the least of which is 8 IAQ meetings. Research has resulted in many articles and several books. Regulations that demand good indoor air quality for human occupancy have positively impacted collections preservation. The trend towards green buildings and sustainability will influence current research. This presentation will reflect on the needs discussed in Glasgow and comment on future concerns.

## References

[1] Gibson, L., (1999). Foreword, Introduction, Aims, and Summary of Conclusions. In: Gibson, L. (ed.), *Presentation Abstracts and Additional Notes of Indoor air pollution - detection and mitigation of carbonyls held at Strathclyde University, Glasgow, Scotland 17-18 June 1998*, 3-5, Glasgow, Scotland, June 16-18, 1998.

# Miniaturised Optical Fibre Sensor to Detect Condensation Inside/Outside Organ Pipes

D. Camuffo[1], A. della Valle[1], F. Baldini[2], R. Falciai[2], A. Mencaglia[2] and F. Senesi[2]

[1]CNR-ISAC, Padova, Italy
d.camuffo@isac.cnr.it
[2]CNR-IFAC, Florence, Italy

***Keywords:*** *condensation, wetting, organ pipe corrosion, time-of-wetness, microclimate, sensor*

## Abstract

The EU project SENSORGAN (Contract 022695) is aimed to study the deterioration of organ pipes due to unfavourable environmental conditions in churches, e.g. crowded services and concerts, winter heating, external and indoor pollution. Variations of Temperature (T), Relative Humidity (RH) and formation of condensation contribute to many kind of physical and chemical disruptive processes, e.g. wooden crack for exceeding dryness or corrosion of pipes for condensation. Accurate measurements of these quantities inside and outside organs will allow to study the local microclimate in relation to the use of the church and the organ itself, detecting when and where the risk of damage is highest.

The objectives are:
(1) to develop a new miniaturised dew sensor for use inside and outside organs;
(2) to study the environmental conditions leading to major risk for damage to organs;
(3) to get microclimate data for a better understanding of the physical and chemical decay mechanisms affecting the organs, especially inside the organ pipes.

In practice, a number of constraints limit the action. These are as follows. Sensors should have miniaturized (micro-invasive) size and a quick time response to environmental changes. Sensors should work under wetting conditions and below 0 °C as well. Sensors should be waterproof and resistant to acidic environments (e.g. acetic and formic acid which are naturally released by wood). No interference between sensors and metal pipes, no disturbance during playing. Short wiring length between sensors inside the pipe and outside interface. Sensors should be in some way attached inside the organ pipes, without damaging them. Uncertainty in measuring might derive when the contact angle of the water droplet on the sensor differs from the oxidized pipe surface. It is preferable to measure condensation on the actual pipe, which may be covered with corrosion products, not on the sensor.

Commercial miniaturized sensors can be used to measure T on the surface and in the air, and RH as well. From these data it is possible to compute the dew point. However, inside the oxidised metal pipes, the condensation may occur earlier, being favoured by the presence of hygroscopic oxides and micropores. Information about T and RH is of fundamental relevance, but not sufficient in itself to determine whether water is present in the liquid or solid phase. It is therefore necessary to perform direct measurements concerning water condensation, or frosting, possibly on the target surface, not on a transducer. Finally, metals are covered with a number of water layers that is increasing with RH, and vice-versa, and depends on the surface characteristics. A very improved sensor might monitor the early formation of water monolayers and, finally, the macroscopic condensation.

An innovative optical fibre sensor has been developed to this aim. The working principle is based on the change in the reflectivity of the optical fibre, following the formation of a water layer on its distal end. Two optical fibres (core/clad diameter: 200/230 μm) allow the connection of the sensing fibre (core/clad diameter: 400/430 μm) to the laser diode and to the photodetector, respectively.This system observes the condensation occurring on the actual organ pipe surface to which the sensing fibres are into contact. No problem with the acidic environment. The sensor operates equally well in the case of ice needles formation, which may occur when the church interior drops below the freezig point. Laboratory testing was performed to control and relate the output of the optical fibre sensors to T and RH cycles.

When T drops, RH increases and monolayers of water form inside the organ pipe with the effect of dispersing light from the sensors, i.e. the end of the optical fibres. At the dew point, the output reaches a minimum. Any increase in T is followed by evaporation and the light intensity suddenly rises. After these satisfactory lab tests, the sensor will be further controlled in the field before use.

# Automated Atmospheric Corrosion Sensors for Real Time Monitoring: Sensitivity and First Practical Experiences

T. Prosek[1], M. Kouril[2], Y. Degres[3], D. Thierry[1] and K. Doubravova[2]

[1]Institut de la Corrosion / French Corrosion Institute, 220 rue Pierre Rivoalon, 29200 Brest, France
tomas.prosek@institut-corrosion.fr www.institut-corrosion.fr, www.corrlog.com
[2]Institute of Chemical Technology, Dept. of Metals and Corros. Eng., Technická 5, 166 28 Praha 6, Czech Republic
[3]nke, rue Gutenberg, ZI Kerandré, 56700 Hennebont, France

***Keywords:*** *atmospheric corrosion, monitoring, air corrosivity*

## 1 Introduction

The main factors affecting air corrosivity are temperature, relative humidity, the concentration of pollutants such as $SO_2$, $NO_x$, $O_3$, $NH_3$, HCl, $H_2S$, dispersed chlorides, organic acids, other volatile compounds and dust particles. However, it is only the relative humidity and temperature that are usually controlled and monitored. Additional anti-corrosion measures can be applied when valuable and often irreplaceable historical objects have already been affected. Since control of the air without the application of any monitoring technique (giving rapid feedback on the air quality), might be either inadequate or excessive, and thus too costly, information on the actual corrosivity of the atmosphere is crucial to effective corrosion protection.

## 2 CORRLOG monitoring system

A monitoring system aimed at enabling continuous measurement of the metal corrosion rate was developed. The system works on well-established, reliable electrical resistance principles which have been refined and improved over time. The concept of the measuring device is simple. The electronic unit measures and registers the changes over time in the electrical resistance of a thin metal track applied on an insulating substrate. If the metal corrodes, the cross-sectional area of the track decreases and electrical resistance increases. Collected and stored data can be transferred to a computer via a non-contact inductive data reader, even through the showcase glass. An optional GPRS/GSM unit allows for remote data access and control with automatic data delivery via e-mail.

## 3 Sensitivity of measurement

The sensitivity and response time of the unit while working with different sensors was evaluated in a number of tests. The minimal change in the corrosion depth that could be obtained from the data ranges from 1–11 nm according to the type of a sensor. This data confirms that the apparatus is able to respond rapidly to changing climatic conditions with sufficient sensitivity. For more details, see refs. [1,2].

## 4 End-users testing

In 2007, end-user testing started in collaboration with a range of partners including the Louvre, the Swiss National Museum, the National Museum of Denmark, Prague Castle and others. The overall goal was to evaluate the application limits of the monitoring system and use customer feedback to improve the product. Loggers and sensors were placed at museums and depositories under different conditions. Results of the end-users testing will be presented.

## References

[1] Prosek, T., Kouril, M., Hilbert, L.R., Degres, Y., Blazek, V., Thierry, D., Hansen, M.Ø., (2008). Real time corrosion monitoring in the atmosphere using automated battery-driven corrosion loggers. *Corrosion Engineering Science and Technology*, accepted for publication.
[2] Kouril, M., Prosek, T., Thierry, D., Hilbert, L.R., Hansen, M.Ø., Degres, Y., Blazek, V., (2007). Automated corrosion sensors for on-line real time monitoring of corrosion rate in indoor and outdoor atmosphere, In: Degrigny, C., van Langh, R., Ankermist, B., Joosten I. (eds.), *Proceedings of Metal 07*, Amsterdam, Rijskmuseum Amsterdam, The Netherlands, September 17–21, 2007, 5, pp. 78-82.

*A research project supported by the European Commission under the Sixth Framework Programme, Co-operative Research (CRAFT), under the contract number 018207.*

# A New Particulate Deposition Monitor: Investigating the Synergistic Effects of RH and Dust

K. Hallett[1], P. Brimblecombe[2], H. Lloyd[3] and D. Thickett[4]

[1]Historic Royal Palaces, UK
kathryn.hallett@hrp.org.uk www.hrp.org.uk
[2]University of East Anglia, UK
[3]The National Trust, UK
[4]English Heritage, UK

***Keywords:*** *dust, fibres, relative humidity, monitoring*

## 1 Introduction

A novel deposition monitor is improving technologies available for measuring dust levels in cultural heritage institutions. The monitor uses automatic programmable digital imaging to capture high-resolution image files of particulate deposition at the monitoring location. Downloaded image files may be viewed as a sequential 'filmstrip' to visually depict particulate accumulation. Additionally, the images can be interrogated using widely available image analysis software to determine the number of particles, or percentage area coverage of particulate materials on the monitor surface. A comparison of particulate characteristics, such as circularity, can be determined to provide information on the relative abundance of fibres and particles in the accumulated dust.

## 2 Results

The paper will present examples of output from the prototype monitors, ten of which are currently undergoing trials at a number of historic sites across England. Comparison will be made with other available particulate monitoring technologies, including microscope slide deposition analyses based upon measurements of loss of gloss, or more sophisticated image analysis and commercially available particulate monitors which count particulates extracted from airborne suspensions. The enhanced sensitivity and resolution offered by the prototype monitors will be demonstrated through correlation of dust coverage rates with relative humidity values, visitor number/flow, and meteorological factors such as rainfall and external relative humidity (RH). Visualisation and quantification of particulate materials using the novel monitor provide increased understanding of the interaction between relative humidity, particles and other indoor climate factors, with respect to the growth, adhesion and cementation of dust on a model surface. The relationship between dust and RH trends will be explored through the study of coincidence in peak RH levels in autumn with dust cementation processes and increased mould propagation. Predictions of future occurrences, based on current trends, emerging observations of a changing seasonal cycle, and existing knowledge of how external RH conditions propagate indoors, will be discussed.

**Figure 1.** Prototype particulate deposition monitor.

The particulate deposition monitor (PDM), currently at an advanced prototype stage, has already demonstrated significant advantages for the cultural heritage sector over commercially available particulate meters, in capturing only those particulate fractions which deposit on surfaces; and in providing some interpretation regarding the nature (and hence derivation/source) of the contaminant – e.g. fibre vs. particle. Additionally, the enhanced sensitivity of data capture times of the PDM over existing lower-tech solutions provides a step-change in the potential of data correlation to other 'real-time' monitored factors, such as RH.

# Emission Rates of VOC from Paper versus Cellulose Degradation: an Integrated Approach to Paper Characterisation

O. Ramalho[1], A.-L. Dupont[2], C. Egasse[2] and A. Lattuati-Derieux[2]

[1]Centre Scientifique et Technique du Bâtiment, 84, avenue Jean Jaurès BP2
77447 Marne-la-Vallée Cedex 2
olivier.ramalho@cstb.fr http://www.cstb.fr
[2]Centre de Recherche sur la Conservation des Collections, Muséum National d'Histoire Naturelle, CNRS, MCC,
36 rue Geoffroy-Saint-Hilaire – 75005 France

***Keywords:*** *paper, cellulose, degradation, VOC, emission rate*

## Abstract

The aim of this ongoing research is to investigate possible correlations between two levels of chemical degradation of cellulose, *i.e.* the macromolecular level, particular to the polymer, and the molecular level, which leads to the formation of volatile organic compounds (VOC), end-products from oxidation and hydrolysis reactions of cellulose. The objective of developing an integrated approach for evaluating paper degradation is also to establish novel non-destructive stategies for the diagnostic of the conservation state of works on paper.

Size-Exclusion Chromatography with Multiangle Laser Light Scattering (SEC/MALS) was used for the macromolecular characterisation of cellulose in model papers, unaged and artificially aged [1]. Indeed, ultimately it is the average length of the cellulose molecules that governs the physical properties of paper, which are related to the material mechanical resistance and brittleness. However, even working on a micro-destructive scale, SEC/MALS analysis requires sampling, which can become problematic in light of the cultural value of paper documents.

The VOC production of the model papers, and especially their emission rates, were studied using Field Laboratory Emission Cells (FLEC) [2]. The VOCs were gathered using Solid Phase Extraction (SPE) on two specific sorbent packings, 2,4-Dinitrophenylhydrazine (DNPH) derivatised silica and Tenax TA. The analysis of the VOCs was carried out with either Liquid Chromatography (LC/UV) or Thermal Desorption and Gas Chromatography with dual detection of Flame Ionisation and Mass Spectrometry (TD-GC/FID/MS). These techniques allowed to bypass physical sampling. Capillary Zone Electrophoresis (CZE/UV) was also used to identify and quantify small organic acids and carbohydrates in the papers in order to correlate the results with those of the emission rates.

The techniques developed led to the identification of numerous VOC from paper and the determination of their emission rates. Among the most abundant compounds (eg. furfural and other heterocycles, formaldehyde, formic acid, acetic acid, vanillin,...) some showed a linear production during accelerated ageing, and others displayed a more complex evolution, which will be discussed in light of the degradation state.

## References

[1] Dupont, A.-L., (2003). Cellulose in lithium chloride/*N*,*N*-dimethylacetamide, optimisation of a dissolution method using paper substrates and stability of the solutions. *Polymer*, 44, 15, 4117-4126.
[2] Wolkoff, P., Clausen, P.A., Nielsen, P.A., (1995). Application of Field and Laboratory Emission Cell "FLEC" - Performance Study, Intercomparison Study, and Case Study of Damaged Linoleum, *Indoor Air*, 5, 196-203.

# Volatile Compounds Emitted from Paper

M. Strlič[1], I. Kralj Cigić[2], J. Kolar[3] and G. de Bruin[4]

[1]University College London, Centre for Sustainable Heritage, The Bartlett School of Graduate Studies, Gower Street, London WCIE 6BT, UK
m.strlic@ucl.ac.uk
[2]University of Ljubljana, Faculty of Chemistry and Chemical Technology, Askerceva cesta 5, SI-1000 Ljubljana, Slovenia
[3]National and University Library, Turjaska 1, 1000 Ljubljana, Slovenia
[4]Nationaal Archief, The Hague, The Netherlands

***Keywords:*** *VOC, historic papers, emission, degradation*

## Abstract

A number of factors are known to influence degradation of historical paper, among which the environment undoubtedly plays a crucial role, along with paper composition. During paper degradation, a variety of low molecular weight products are formed, several of which are volatile and thus have an increased mobility not only within the material, but also within a collection.

Volatile organic compounds (VOCs) formed during paper degradation are numerous and varied [1,2], and their identity and quantity depends on paper composition [3]. Thus, VOCs may be regarded as a source of information on paper quality. On the other hand, many simple organic acids, aldehydes and even aromatic compounds, which have been shown to form during degradation, may also initiate or accelerate degradation of cellulose.

The usual and often used technique for analysis of VOCs in paper makes use of solid-phase micro-extraction (SPME) coupled to GC-MS [2,3], although other ways of sampling have also been employed, e.g. cryo-trapping [1] and thermal desorption.

Studies of the impact of several identified VOCs on degradation of paper can easily be performed in closed vessels at elevated temperatures. We evaluated the impact of the following: furfural, iso-butylbenzol, 1,4-diethylbenzen, acetic acid, formic acid, toluene, hexanal, 2-pentylfuran, formaldehyde and vanillin, on papers of three different qualities. Apart from volatile acids, a statistically significant negative effect of all compounds with a carbonyl group in the structure was noticed.

The effect of removal of VOCs using VOC scavengers or absorbent media can also be studied in closed vessels at elevated temperature. Similarly, the effect of oxygen removal can also be evaluated. In our study, we included several commercially available products and compared their effect on degradation of cellulose in a closed vessel at an elevated temperature.

The complex role of volatile degradation products in mixed paper collections should not be underestimated. Our research shows that the effect of cross-infection due to emission and re-absorption of these compounds may be significant and strategies for removal of VOCs from storage facilities should be given due consideration.

## Acknowledgement

The authors gratefully acknowledge financial support of the Ministry of Higher Education, Science and Technology, Republic of Slovenia, Programme no. P1-0153, and project PaperVOC, partly funded also by the National Archives, The Netherlands.

## References

[1] Levart, A., Strlič, M., Kolar, J., Pihlar, B., Veber, M., (1999). Determination of Volatile Cellulose Degradation Products by HPLC, IEC and CE Using Cryo-Trap Sampling; *Balaton symposium on high-performance separation methods*, September 1-3, 1999, Siófok, Hungary, Book of abstracts, P-154.
[2] Lattuati-Derieux, A., Bonnassies-Termes, S., Lavédrine, B., (2004). Identification of volatile organic compounds emitted by a naturally aged book using solid-phase microextraction/gas chromatography/mass spectrometry. *J. Chrom. A*, 1026, 9-18.
[2] Strlič, M., Kralj-Cigic, I., Kolar, J., De Bruin, G., Pihlar, B., (2007). Non-Destructive Evaluation of Historical Paper Based on pH Estimation from VOC Emissions, *Sensors*, 7, 3136-3145.

# Investigation of Paper Surface and Sub-Surface Regions by LA ICP MS

B. Wagner[1], A. Drewniak[1], E. Bulska[1], D. Rams[2] and W. Sobucki[2]

[1]University of Warsaw, Faculty of Chemistry, Pasteura 1, PL- 02 093, Warsaw, Poland
barbog@chem.uw.edu.pl
[2]National Library, Al. Niepodległosci 213, PL- 02 086, Warsaw, Poland

***Keywords:*** *LA ICP MS, elemental analysis, paper*

## Abstract

In the last decade Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA ICP MS) has been regarded as one of the very promising analytical methods, which could be applied for the investigation of works of art in respect of their protection and conservation. Inductively coupled plasma mass spectrometry (ICP MS) alone or with laser ablation (LA) belongs to methods which could be very useful in archaeometry, mainly because of its capability to perform multielemental, ultra-trace and isotope analysis. LA ICP MS is a micro-destructive technique which allows a direct analysis of solids, it requires almost no sample preparation and utilises minute amounts of analyzed material, which can be used for local analysis with high spatial resolution.

It should be stressed that the technique has several limitations mainly due to the limited number of suitable certified reference materials of a similar matrix composition to the analyzed samples. Beside the fact, that various approaches have been proposed in the literature to overcome this problem, it can be still concluded that LA ICP MS is a perfect technique for monitoring trends or semi-quantitative analysis, with emphasis that the obtained results depend on the homogeneity of the analysed sample. Therefore, a comparison with other supporting analytical methods is usually expected.

The main issue of the presented studies was to design and optimise the procedure of determination of the elemental composition of bulk samples as well as evaluation of the spatial distribution of chosen elements on surface and sub-surface domains of paper. The analytical strategy was evaluated to support the project devoted to monitoring changes of paper samples exposed to indoor air pollution for 12 years in the National Library in Warsaw. Apart from the information about the mechanical and optical properties of paper monitored during the project, the information about the total uptake of chosen elements (Al, S, Ti, Mn, Fe, Co, Ni, Cu, As, Cd, Pb, Sn, Bi) and their distribution over the samples surface will be given on the basis of the results obtained by means of LA ICP MS followed by ICP MS analysis of the same samples after microwave digestion ($HNO_3$:$H_2O$, 1:1).

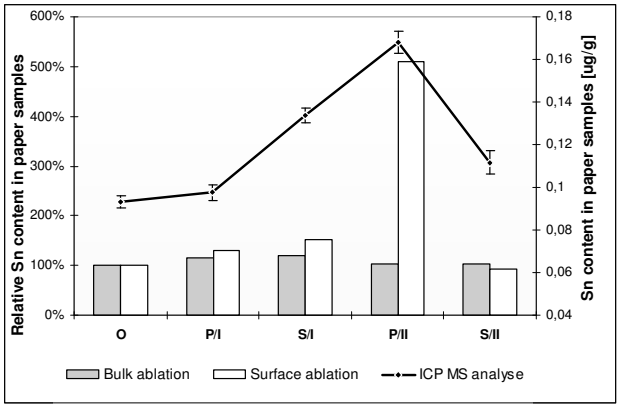



**Figure1.** Comparison of exemplary LA ICP MS (relative Sn content) and ICP MS (Sn content in paper) results obtained for paper samples stored in different locations within the time of the project:

O – reference sample, P/I, S/I, P/II and S/II – samples of paper stored at the first (I) or second (II) level of the National Library from the street (S) or park (P) side of the building.

■ Bulk ablation – analytical signals were registered after ablation through the whole paper thickness.
□ Surface ablation – analytical signals were registered after ablation of the paper surface.

# Requirements for the Preventative Conservation of Works of Art and New Solutions for Air Conditioning of Display Cases

C. Engemann-Wendt and M. John

Staatlichen Kunstsammlungen Dresden, Taschenberg 2, 01067 Dresden
michael.john@skd-dresden.de
christine.engemann-wendt@skd-dresden.de
http://www.skd-dresden.de

***Keywords:*** *conference, preventative conservation, air conditioning*

## 1 Introduction

The paper describes the planning process of the display cases of the treasury "Green Vault" with the special view on pollutions and the climatic conditions.

## 2 Abstract

The Green Vault is one of the most important collections of treasury art in Europe. Its return to the reconstructed Palace in Dresden can also be viewed from the perspective of preventative conservation. In particular, investigation of the cause of damage to enamel on Baroque jeweled sculptural works affected the planning of the installation of the collection in both of its exhibition settings: the New Green Vault and the Historic Green Vault. These considerations made it necessary to insure a special, individual "climate" within each display case, one which would reflect the materials of the art works to be displayed, their combination, and their state of preservation. In addition, air within the display cases was to be kept as free as possible from pollutants. For this purpose it was necessary not only to consider materials used in constructing the display cases but also substances that had been used in earlier restorations, all of which could have a negative influence on the environment of the works of art. These concerns led to the development and adoption of a technically complex solution, one which requires constant monitoring of the air quality and emissions. Results up to now, however, show that the effort expended has been worthwhile.

Based on the results of the research described, it was necessary to react to the difficult and unique conservation demands of the exhibits. A complete and full-equipped HVAC system was planned for the area outside of the display cases. The input air is provided from small exhaust elements integrated into the ceiling; the output air is also taken from the room near the ceiling. The climate-control unit is organized within the roof and features a special protection and leak detection system (necessitated by the presence of water-filled pipes and devices in the vicinity of art objects on the upper floors).The relative humidity is regulated by special steam units in a master-slave-system. Filtration of gaseous substances and of all organic and potentially damaging organisms such as mold and bacteria is accomplished by a special ionization of the air. Within a separately accessible service area in the upper part of the display cases is integrated a passive air conditioning in a stainless-steel box for the passive air conditioning. The aim is to stabilize the relative humidity in the area of the exhibits and to trap possibly dangerous gaseous substances with activated charcoal. In addition, some display cases with special requirements are equipped with an active system not only to stabilize the air around the exhibits, but also to maintain special levels of relative humidity in accord with the conservation requirements of particular exhibits. The planning of the HVAC system for the rooms and the passive and active air conditioning systems integrated into the display cases was conducted by the engineering planning office "Gebäudetechnik Dresden GmbH" with the help of simulation. This is the topic of the subsequent presentation.

## References

[1] Dr. Müller, W., (1995). Modellhafte Untersuchungen zu Umweltschädigungen in Innenräumen anhand des Grünen Gewölbes. *BAM, Forschungsbericht 215*, 51 pages.
[2] (2000). Emailprojekt, *Restauro*, Ausgabe 6 – September 2000, 73 pages.

# Concept Development of IAQ in Museums Using Computer Simulation by CFD-Methods

P. Vogel, T. Waurick and F. Schumann

GTD GmbH, Stübelallee 49c, D-01309 Dresden
Peter.Vogel@g-t-d.de http://www.g-t-d.de

***Keywords:*** *air quality, CFD-Simulation, museum collections*

## 1 Introduction

There are different climatic conditions required for museum collections, different influx of visitors and the special needs of the historical architecture too – normally there are no approved concepts of airconditioning.

If you want to make sure, you will need a lot of measurement in laboratories or you use the new methods of CFD-Simulation.

The so called "Oldest Museum of the World" the famous museum "Grünes Gewölbe (Green Vault)" was restored by using the methods of computer simulation. The museum was reopened in September 2006.

## 2 Results and Discussion

When making a concept for a museum, it is important that there are some answers to the questions of the conservators what is happening in several situations.

Is it useful to have a wall of glass all over the room? For the concept of exhibition it is much better to have only a parapet. But what happens with the climate conditions at the exhibit?

With the method of CFD you can decide quite quickly which of the concepts you can choose. With CFD-Simulation there it is also possible to optimize the air conditioning parameters, as it was done in the "Green Vault".

Another topic of our work is the development of individual air conditioned showcases. Normally there is only a hygroscopical material like PRO-Sorb or something else for a constant humidity in showcases. But it does not work properly. In consequence of lightning for the objects there are some microclimatic differences. With a recirculation airconditioning system, based on a CFD-Simulation, it is possible to get showcases without microclimatic differences influencing the exhibits.

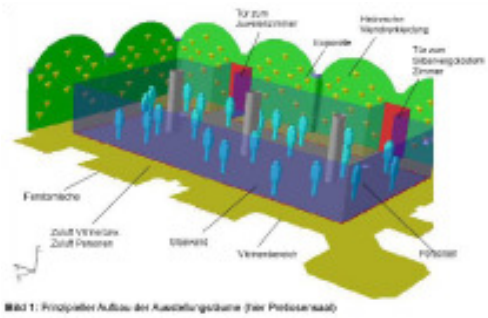


**Figure 1.** 3-D-Model for simulation.

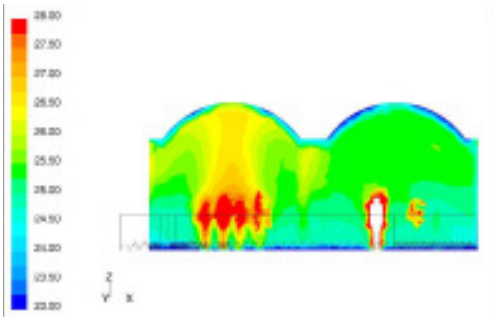
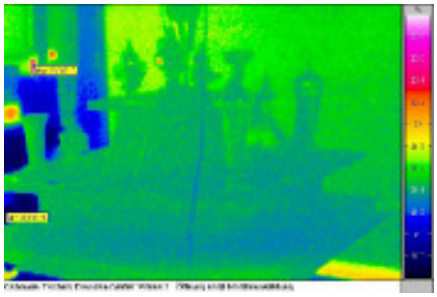


**Figure 2.** Results of simulation; distribution of air temperatures.



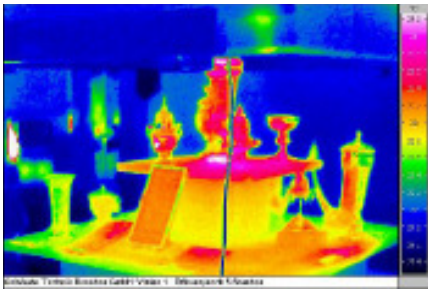


**Figure 3 and 4.** Thermal imaging pictures (opening and 5 hrs later).

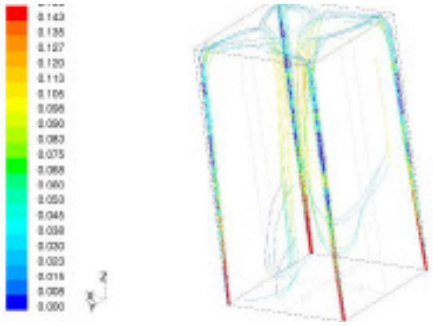


**Figure 5.** Streamlines, colored for velocity, in a CFD-Model of a showcase.

## 3 Conclusion

Especially on the topic of air conditioning of museums it is very useful to simulate air conditioning systems for the whole rooms or the showcases with methods of CFD. The measurement that was done in the "Green Vault" validates the simulated results. In the "Green Vault" there is today a nearly constant micro climate at the exhibits.

## References

[1] Vogel, P., Hinderer, D., (2007). Grünes Gewölbe im Dresdner Schloss, eine Kunstoase mit verborgenen Klimaraffinessen. *CCI – planen+ausführen*, 1. Ausgabe 2007, Jahrgang 2, 318 pages.

# Chemical Emissions and Secondary Reactions in Museum Showcases

A. Schieweck[1] and T. Salthammer[1,2]

[1]Fraunhofer Wilhelm-Klauditz-Institute (WKI), Material Analysis and Indoor Chemistry, Bienroder Weg 54E, 38108 Braunschweig, Germany
alexandra.schieweck@wki.fraunhofer.de http://www.wki.fraunhofer.de
[2]University of Applied Sciences Braunschweig/Wolfenbüttel, Salzdahlumer Strasse 46/48, 38302 Wolfenbüttel, Germany

***Keywords:*** *showcase, emissions, secondary reactions, materials*

## 1 Introduction

The comparison of the indoor environment as a "reaction vessel" [4] comes to a head in museum showcases and boxes. Today, most museum institutions use the so called *"box in a box-model"* [1] as underlying strategy to preserve artefacts in an ideal way. Thus, persons in charge are claiming display cases as airtight as possible. Investigations have shown that the air exchange rate inside of new showcases is almost below <0.01 $h^{-1}$. As a result, the inhibited dilution of chemical substances combined with a high surface to volume ratio involves accumulation and promotion of secondary reactions. After emission analysis of building products and decoration materials, which are today widely-used for the construction of showcases, a broad range of characteristic primary emissions could be identified [2,3]. Thus, an evaluation about synergetic effects and secondary reactions inside an air-tight showcase is urgently needed.

Primary and secondary emissions of building products for museum enclosures (lacquers, sealants, UV-curing systems, textiles, construction materials) have been studied in emission test chambers under museum conditions and inside of constructed showcases (with/without artificial lighting). The focal point was on analyzing volatile and semi-volatile organic compounds (VOC/SVOC), formaldehyde and organic acids (formic acid, acetic acid) to point out dominating emissions and reactive compounds.

## 2 Results and Discussion

Characteristic primary emissions were glycols/glycol ethers, aliphatic/aromatic hydrocarbons, (di)carboxylic esters, alcohols, aldehydes and acrylic monomers. These are typical residues of solvents and additives, widely contained in formulations of lacquers and sealants. Most of them are chemically inert under indoor room conditions and are therefore classified as "non reactive" compounds. Among these, substances causing adverse health effects were identified. Unsaturated hydrocarbons, aldehydes, acrylic monomers, organic acids and esters are evaluated as "reactive" compounds. Thus, several secondary reactions occurred. Reaction products of Diels Alder cyclic addition, alkaline *retro*-aldol addition as well as decomposition products of photoinitiators were identified. Hydrolyses of esters resulted in increased concentrations of acetic acid, whose hazardous potential on artefacts is well-known. Moreover, preliminary investigations have shown that artificial lighting inside a showcase exerts a strong influence on the indoor air quality.

## 3 Conclusion

Characteristic primary emissions for specific building products could be identified both during emission test chamber analysis and inside of modern showcases. Furthermore, it is shown that secondary reactions proceed. From these results, first information about the use of construction and decoration materials are derived. In a further step, effects on artefact materials have to be evaluated.

## References

[1] Camuffo, D., Sturaro, G., Valentino, A., (2000). Showcases: a really effective mean for protecting artworks?. *Thermochimica Acta*, 365, 65-77.
[2] Schieweck, A., Markewitz, D., Salthammer, T., (2008). Chemical substances in newly constructed showcases. *ZKK - Zeitschrift für Kunsttechnologie und Konservierung*. In press.
[3] Schieweck, A., Salthammer, T., (2008). Indoor air pollution in showcases – Part I. Chemical emissions of construction products and decoration materials. In preparation.
[4] Weschler, C.J., Shields, H.C., (1997). Potential reactions among indoor air pollutants. *Atmospheric Environment*, 31, 3487-3495.

# Edgar Degas's wax sculptures: Case studies

D. Barbour[1] and B. England[2]

[1]Object Conservation Department, National Gallery of Art, 2000B South Club Drive, Landover, MD 20785
d-barbour@nga.gov
[2]Purafil, Inc., 2654 Weaver Way, Doraville, GA 30340

## Abstract

In June 2003 the Object Conservation Department of the National Gallery of Art, Washington, D.C., began a collaborative research project with Purafil, Inc., a corporation that specializes in air quality control within museums, libraries, and archival storage areas. Intended to evaluate the air within exhibition cases of the newly renovated sculpture galleries, the study focused on sixteen exhibition cases containing multi media sculptures by Edgar Degas (1834-1917). This paper presents the preliminary results from that study.

The project was conceived in several phases. The first, now completed, included evaluating the air quality, temperature and humidity in both the Degas's sculpture galleries and the exhibition cases (micro-climate) using Corrosion Classification Coupons™ and Onguard™ atmospheric corrosion monitors. Of the sixteen exhibition cases (and their under deck chambers) evaluated, six cases were identified as having a polluted environment potentially harmful to the sculptures displayed within them. It was further determined that the poor air quality resulted directly from volatile components in some of Degas's sculptures rather than from external sources or their casework.

To date, one polluted exhibition case has been modified, introducing a fan below the deck and adding Purafil isolette sorbers™ as scavenging material. Results from this simple adjustment have been successful in terms of purifying the air inside the case. However changes to the case design in this instance have been less successful as they are specific to the one kind of exhibition case and may not be applicable in other types of cases. This talk will address the various methods used to try to purify polluted exhibition cases using active (ventilation) and passive (absorption or scavenging materials) means and the results of different approaches towards the mitigation of the contaminants identified.

# Packaging of Museum Objects: Criteria and Test Methods for Plastic Film Selection

J. Bergmair, M. Krainz and H. Fritz

***ofi***, Österreichisches Forschungsinstitut für Chemie und Technik, Brehmstraße 14a, 1110 Vienna
johannes.bergmair@ofi.at http://www.ofi.at

***Keywords:*** *packaging, plastic films, mechanical properties, permeation*

## Abstract

To pack art objects of all types in plastic films is a widely used and cost-effective method. For the selection of the plastic films it is necessary to know the requirements for the packaging material (e.g. transparency, rigidity, seal qualities...). This packaging method is also often combined with the possibility to provide the objects with a protective gas atmosphere. This helps either to kill insects and to prevent further infestation, or it is to inhibit oxidation reactions by exclusion of oxygen. For this storing method it is indispensable to generate absolutely hermetically sealed packages and to know the precise permeation-properties of the packaging material. Furthermore it is to adhere that the chosen packaging material does not emit chemical substances, which damage the filling goods again.

In our presentation, based on projects which were carried out with the Kunsthistorisches Museum (KHM) in Vienna and other Viennese museums and art-collections, we point out which material properties of plastic packaging materials are important and how these issues can be controlled by means of suitable test methods. The problem of gas permeation through plastic foils is addressed especially. The presentation is rounded with practical tips, which were received from the meanwhile 5-year-lasting engagement in the field of packaging museum objects. Thus questions of purchasing and handling of plastic foils are discussed as well as the realization of an accurate gas-flashing.

**Figure 1.** Checking the gas mixture within a package.

# Study of Old Library Dust, Trinity College Dublin

S. Bioletti[1] and R. Goodhue[2]

[1]Trinity College Dublin, Library, College Green, Dublin 2, Ireland
bioletts@tcd.ie
[2]Trinity College Dublin, Department of Geology, Dublin 2, Ireland
goodhuer@tcd.ie

***Keywords:*** *dust, XRD, gloss*

## 1 Introduction

The Old Library at Trinity College provides storage for the early printed book collection; functions as a research area; and is one of Ireland's major tourist attractions which is visited by well over 500.000 people each year. An extensive cleaning campaign, *Save the Treasures of the Long Room*, is underway with the estimated cost of € 2 million. The understanding of dust accumulation is vital to assist in the future management of the building.

The accumulation of dust on the collection is currently under investigation. A visual survey of the distribution has been completed and mapped onto a custom built 3-D computer model. Dust samples have been sieved, sorted, and weighed in order to quantify volume, and X-ray diffraction analysis has been undertaken on the crystalline fractions in order to determine source.

The present accumulation rate and distribution is being analysed by gloss measurements on an array of slides placed in the Old Library and measured at monthly intervals using a Novo-Gloss Trio gloss meter. Similar studies have been undertaken elsewhere [1].

## 2 Results and Discussion

The initial results show that a range of particle types has contributed to the accumulation of the dust (Figure 1). Some particles, such as leather and wood are derived from the decay of the collection and shelves. Others, such as the crystalline components and fibres may have a mixture of sources, both internal and external to the building. The distribution of these components in the Old Library building depends on their size, the cleaning regimes over decades and the direction of the prevailing wind which has led to heightened accumulation on the windward side.

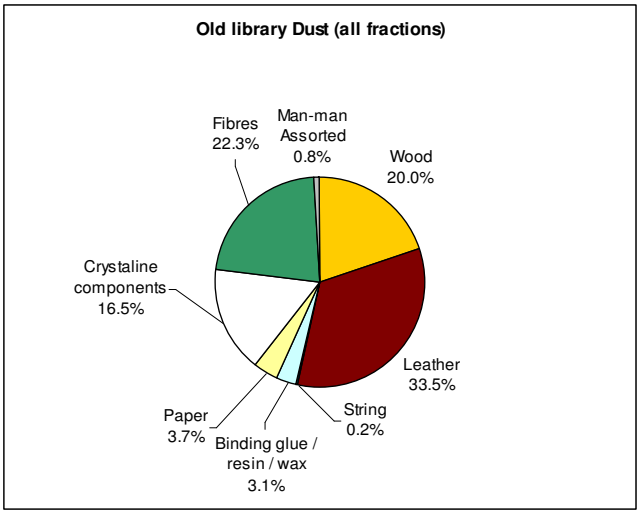



**Figure 1.** Old Library dust. Percentage by weight.

## References

[1] Wei, W., Joosten, I., Keim, K., Douna, H., Reuss, M. and Wagemakers, J., (2006). Experience with Dust Measurements in Three Dutch Museums. *Indoor Air Quality in Museums and Archives*, Wilhelm-Klauditz-Institut, Braunschweig, Germany.

# A Survey of VOCs in UK Library and Archive Stores

C.V.Horie[1] and L.T.Gibson[2]

[1]Research Project Manager, The British Library, 96 Euston Rd. London, NW1 2DB, UK
Velson.horie@bl.uk www.bl.uk
[2]Senior Lecturer in Analytical Chemistry, Department of Pure and Applied Chemistry, University of Strathclyde, 295 Cathedral Street, Glasgow G1 1XL

***Keywords:*** *volatile organic chemical, paper, book, analysis, air*

## 1 Introduction

The British Library is leading a partnership of 8 major libraries and archives in the British Isles studying the condition of their collections in a project funded by the Andrew Mellon Foundation. One major strand of the research is the identification of the volatile organic chemicals in the books and store rooms, and how the VOCs can be correlated with the condition of the collection. The other major strand is the comparison of condition of 400 identical books in each of the libraries, with the aim of correlating their VOC emissions with their condition.

There are three stages to VOC study: concentrations are measured in 2 stores in each institution and compared with the stored collection condition; techniques for measuring the absolute amounts of VOCs present in books are developed; the VOCs measured in books are correlated with their condition. Part of the added value for this project is introducing and training conservators in research techniques.

## 2 Abstract

The 6 UK legal deposit libraries (British Library, the National Libraries of Wales and Scotland, the libraries of Oxford and Cambridge Universities and University College Dublin) and the National Archives of England and Scotland have each chosen 2 store rooms for study and undertaken the Preservation Assessment Survey of the National Preservation Office [1]. This involves a visual assessment of a random sample of 400 items from the collection, which provides a good measure across the whole collection.

Three different sampling regimes have been used to collect a wide range of volatile organic compounds (VOCs), including acetic and formic acids and formaldehyde vapour. Passive sampling tubes are used to collect acids and aldehydes, however, site visits will be required to test the VOC levels on location. At each location, three separate sets of measurements are obtained, 2 sets in the predetermined stores, with the final set (placed outside the sampling site) providing background concentrations for comparative purposes. The passive sampling tubes have been prepared in Strathclyde and have been analysed there. The sampling tubes have been placed in position by a research assistant in collaboration with the institutions' conservators, who have also been responsible for carrying out the PAS.

The analysis has been performed by ion chromatography (acid analysis), high performance liquid chromatography (formaldehyde analysis) and gas chromatography-mass spectrometry (VOC analysis). The interpretation of the data has been carried out in collaboration between the research assistant and the conservators on the spot.

Results will be detailed at the conference.

## References

[1] Walker, A., et.al., (2006). *Preservation Assessment Survey for Libraries and Archives*, National Preservation Office.

# A-Bios System for Air Purification from Biological Contaminants in the Indoor Environments

C. Fanelli[1], F. Pinzari[2], P. Valenti[2], S. Zjalic[1] and M. Reverberi[1]

[1]Dipartimento di biologia Vegetale, Università di Roma "La Sapienza", Largo Cristina di Svezia 24, 00165 Rome, Italy
corrado.fanelli@uniroma1.it www.uniroma1.it
[2]Istituto Centrale per la Patologia del Libro - Ministero per i Beni e le Attività Culturali, Via Milano, 76, 00184 Rome, Italy

***Keywords:*** *air purification, moulds, fungal spores, A-bios*

## 1 Introduction

A new easy-to-use air purification system, A-bios-based on UV radiation with the addition of special graphite filters to eliminate traces of ozone, for the indoor environment has been developed in the framework of the EU financed project No. 032192. The objectives of the research presented in this abstract were to evaluate the relative efficiency of the A-bios air purification system in the abatement of airborne fungal spores' vitality and to determine the effect of time exposure to A-bios on the fungal CFU recovery. Aerobiological monitoring was conducted in the "David Lubin memorial library" of the FAO in Rome before and after A-bios functioning.

## 2 Methods and Results

The A-bios device is based on UV technology with special graphite filters based on manganese dioxide to eliminate traces of ozone. Air samples were collected with a SAS (Surface Air System Super 180TM, in accordance to the ACGIH, Guideline for the Assessment of Bioaerosols in the Indoor Environment) under undisturbed conditions before, and after three and six hours of continuous A-bios functioning in the room. Human activity, which could result in retrieval of significantly higher concentrations of airborne spores, was avoided both before and during A-bios functioning [1-2]. Sampling was performed using two different substrates in the SAS plates and two air-sampling volumes (60 and 100 $dm^3$). Fungal spores were collected on MEA (Malt Extract Agar, Oxoid SpA, Milano) and on Sabouraud Agar (DIFCO, Becton Dickinson, USA) and incubated at 26 °C. Three replicates for each agar type, sampling volume and sampling time were considered. The plates used in the SAS were 84 mm polystyrene contact Petri dishes. The count of the Colony Forming Units appearing on the agar plates during the incubation time was performed daily for two weeks by means of a trans-illuminator with a magnification device.

The difference between sampling time t0 (control) and t3 is significant according to both the statistical tests used (Tukey), as well as the difference between t0 and t6 (Table 1). The difference between sampling time t3 and t6 were not significant, indicating that after three hours of A-bios functioning the results are comparable with that obtained after 6 hours of air purification. These results cannot be extrapolated, of course, to all the environments since the wideness and the degree of fungal air contamination can require different times of air filtration to obtain a significant abatement of CFUs. The results obtained in these tests indicate that the difference between fungal airborne concentration data before and after A-bios functioning are independent both on the agar type (substrate) used for spores collection, and the sampled air volume.

**Table 1.** Comparison between sampling times. Tukey (HSD). Confidence interval of 95 %.
In the last column the significance of the difference between couples of data is indicated.

| Contrast | Difference | Standardized difference | Critical value | Pr > Diff | Significant |
|---|---|---|---|---|---|
| t 0 vs t 6 | 2.875 | 5.634 | 2.521 | < 0.0001 | Yes |
| t 0 vs t 3 | 2.375 | 4.654 | 2.521 | 0.000 | Yes |
| t 3 vs t 6 | 0.500 | 0.980 | 2.521 | 0.597 | No |
| | Tukey's d critical value: | | 3.565 | | |

## References

[1] An, H.R., Mainelis, G., Yao, M., (2004). Evaluation of a high-volume portable bioaerosol sampler in laboratory and field environments. *Indoor Air*, 14:6, 385–393.
[2] Lee, K.S., Bartlett, K.H., Brauer, M., Stephens, G.M., Black, W.A., Teschke, K., (2004). A field comparison of four samplers for enumerating fungal aerosols I. Sampling characteristics. *Indoor Air*, 14:5, 360–366.

# Climate Change in the Museum, or the Attempt to Foresee What the Museum's Exhibits Can Expect from a Passive House

V. Ljubic

Conservation Department, Technisches Museum Wien, Mariahilferstr. 212, A-1140 Vienna
valentina.ljubic@tmw.at

## ZU(G)BAU, 45,000 m³ of space for big- and small-sized exhibits

After the completion of the overall renovation during the mid 90ties and the new installation of the exhibition collection in 2005, the Technical Museum took up the issue of building a housing annex to the main Museum halls again. The original idea was to construct an annex for housing the most valuable exhibits of the railway traffic collection, as well as set up an interactive exhibition on Renewable Energy and Passive Houses.

The idea of an energy exhibition developed from ongoing deliberations about optimum conservation conditions for locomotives, railway cars and smaller-sized exhibits, as well as a comfortable room temperature and air quality for the visitors and low running costs in the future.

Thus, the new 5,800 $m^2$ building was supposed to be built according to the standards of a passive house. It should therefore suit the requirements of preventive conservation, fulfilling all requirements with regard to energy values and air quality.

The goal values for the air temperatures within the hall are set at a maximum of 26 °C in summer (at an outside temperature of 32 °C), and a minimum of 20 °C in winter. A maximum increase or decrease in temperature within the hall is set at 1 °C per hour, and the relative air humidity will be set at 35 to 45 %. The heating demand to be below 15 kWH/m² and the primary energy demand to be below 120 kWh/m² per year (in the main building this value is about 250 kWh/m²).

Regarding the air quality, it was agreed to ensure dust-free/filtered air (F9 filtering), which is going to be pre-tempered via tubes located about 100 metres under the ground. A daily exchange of the entire air volume should serve to avoid damages to the exhibits caused by pollutants that may be released by objects or building material.

Due to the circumstances that the objects have to be protected from sunlight, a new light design has been developed and was tested by the means of a warehouse model under the artificial sky.

Furthermore, simulations of positions of the sun were accomplished, where exact those places were defined, on which sunlight could fall on the objects in the course of a year. Those parts should have been covered up by secondary fixtures (e.g. exhibition set-up).

After two years of planning this project has been terminated by the Ministry of Education, Art and Culture in July 2007, due to the changed cultural and political environment. The project will thus not be completed in the initially planned frame.

# Archival Boxes' Chemical Microenvironments

T. Łojewski and T. Sawoszczuk

Jagiellonian University, Faculty of Chemistry, 30-060 Kraków (Poland), Ingardena 3
lojewski@chemia.uj.edu.pl http://www.chemia.uj.edu.pl/~kp

***Keywords:*** *archival boxes, air pollution, VOC*

## Abstract

Archival boxes meant to protect materials stored in them could lead to formation of chemical microenvironments damaging to its holdings. Volatile Organic Compounds (VOC), ozone and acidic gases ($SO_2$, $NO_X$) are the main chemical exogenous factors responsible for degradation of stored artifacts. VOCs could be emitted not only from deteriorating objects put inside the box and from the box itself but also from outside sources like furniture, building materials or cleaning agents used in storage rooms.

The main purpose of our work was to analyze the Volatile Organic Compounds inside archival boxes that are used in various storage rooms (libraries, archives). Quantitative and semi-qualitative analyses were carried-out using two different sampling techniques, sorption tubes and Solid Phase Micro Extraction (SPME), followed by GC/MS analysis. An attempt was made to correlated the composition of VOCs in given box (1) with the type of objects stored inside, (2) with the profile of VOCs in the open air of a given storage room, (3) and with the type of box (type of cardboard used, app. air exchange rate). Similar analyses were performed for acidic gases ($SO_2$, $NO_x$) and ozone inside and outside archival boxes, this time indicating tubes were used.

## Acknowledgement

This work was supported by the grant from Polish Ministry of Science and Higher Education (SPUB 205/6 P.R. UE/2006/7).

# Museum Storage Areas:
# Microclimate and Air Quality Short-Term Monitoring Program

E. Giani[1], A. Giovagnoli[1] and M.P. Nugari[1]

[1]Istituto Centrale per il Restauro, Piazza San Francesco di Paola, 9 – 00184 Rome, Italy
mariapia.nugari @tiscali.it

***Keywords:**, storage areas, air quality, museum, monitoring.*

## 1 Introduction

The National Gallery of Modern Art in Rome – Italy is located in the city, near the Villa Borghese park. The storage area of the Gallery is at the underground level. Different kind of modern artworks, such as paintings on wood and on canvas, textiles, poly-material objects are conserved. The study regards the environmental conditions of the storage area with the aim of improving the conservation level of the collection [1, 2].

## 2 Abstract

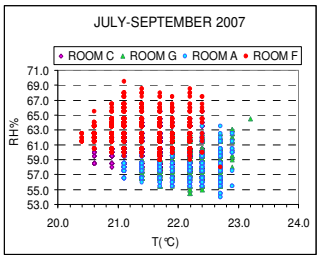
The method used consists in short-term monitoring programs: microclimatic and air quality control. The air quality has been evaluated from chemical and biological aspects.

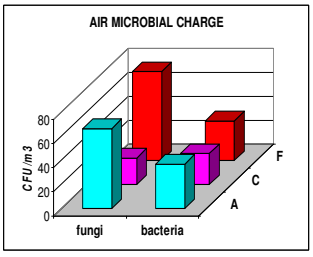
1. The microclimatic monitoring has been carried out during the most critical period (summer-autumn) chosen on the basis of historical climatic data of Rome geographic area. The aim of the control was to evaluate the efficiency of the air conditioning system of the storage area.

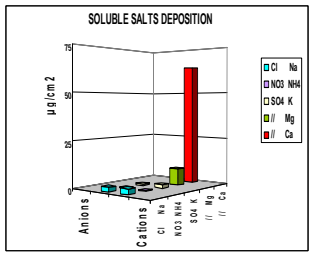
2. For chemical control, the evaluation of the total deposited particulate matter was carried out in room F, using a prototype instrument [1, 2] to estimate the brilliance variation (trichromatic parameters L*, a*, b*) of 15 white marble samples exposed to the deposition. The monitoring lasted 30 days. The presence of soluble salts in the deposited powder layer was determined by ion chromatography.

3. For the biological control, aerobiological analyses were carried out to detect biodeteriogen microorganisms; on the basis of microclimate results the air samplings were performed at the end of September.

The rooms have different critical aspects: embankment behind a wall (room A), central part of the storage area (room C), rising water for capillarity and soluble salts in the walls (room F), close to the entrance (room G).




Microclimatic monitoring has pointed out values frequently near the upper threshold for paintings conservation (RH > 60 %, T > 20 °C). These conditions favored microbial colonization on some paintings especially in room F (the most critical for thermohygrometric parameters). The air conditioning plant, with low air flow, results inappropriate for the relative humidity control but, on the other hand, reduces the airborne spore diffusion. The presence of soluble salts in the dust should be associated with efflorescence on the walls. This evidence could be related with the evaporation processes. On the basis of these results and further environmental investigations, a new system for air purification and conditioning should be projected.

### References

[1] Accardo, G., Cacace, C., Giani, E., Giovagnoli, A., Nugari, M.P., (2003). Museum collections: data sheets for improved management. In*: Conservation Science 2002 Papers from the Conference*, Edinburgh,, 22-24 May 2002, pp. 39-43.

[2] Giani, E., Giovagnoli, A., Nugari, M.P., Ruschioni, E., Gordini, L**.,** (2006). The use of an environmental data sheet: the case of Musei Civici of Pesaro (Italy). In: Fort, Alvarez de Buergo, Gomez-Heras & Vazquez-Calvo (eds.), *Proceedings of the International Conference on Heritage, Weathering and Conservation , HWC-2006.*, Madrid, Spain, 21-24 June 2006, pp. 463-467.

# Circulation or Layering? – Behavior of Air Inside Museum Enclosures and its Influence on Indoor Air Quality

A. Schieweck[1], P. Meinlschmidt[1], E. Uhde[1] and T. Salthammer[1,2]

[1]Fraunhofer Wilhelm-Klauditz-Institute (WKI), Material Analysis and Indoor Chemistry, Bienroder Weg 54E, 38108 Braunschweig, Germany
alexandra.schieweck@wki.fraunhofer.de http://www.wki.fraunhofer.de
[2]University of Applied Sciences Braunschweig/Wolfenbüttel, Salzdahlumer Strasse 46/48, 38302 Wolfenbüttel, Germany

***Keywords:*** *showcases, air circulation, air layering, artificial lighting, adsorption*

## 1 Introduction

Showcases are in general constructed as air tight as possible to create their own micro environment independent of the surrounding room. Thus, an air exchange with the outer air is almost completely cut off. Resulting from this construction type, volatile organic compounds generated from emissions by the used construction and decoration materials are able to accumulate inside. Moreover, undesired secondary reactions are promoted [1,2], For this reason, buffer materials shall minimize climatic fluctuations and different kinds of adsorption materials are used to prevent high concentrations of indoor air pollutants. Normally, these utilities are integrated into the basement. But is this really effective?

It is assumed, that the air inside tight enclosures does not circulate but is layered. However, circulation is necessary to ensure continuous contact between the air and the buffer and adsorption material, respectively. In the case of layering, buffering and adsorption would not be effective due to the missing air exchange.

It is thinkable, that one of the parameters influencing the state of the air inside a showcase is artificial lighting. Many showcases are equipped with an integrated lighting source. If this source sends out infrared radiation, thermal flow will be simultaneously induced. This fact would lead to air circulation. If not, a thermal gradient through the air layers can be assumed. Moreover, this thermal gradient would influence material emissions as these depend amongst others from temperature and relative humidity [3].

## 2 Experimental set-up

An experimental set-up is accomplished in a newly constructed museum showcase in the laboratory of the Fraunhofer WKI. By the aid of chemical and physical examination methods (e.g. active air sampling, air exchange rate, thermography, temperature measurements), the following questions arise:

- Behavior of indoor air inside a showcase without artificial lighting (circulation or layering?)
- Behavior of indoor air inside a showcase with artificial lighting (inducing of thermal flow)?
- Temperature gradient inside the showcase?
- Influences on material emissions?
- Consequences for the use of buffering and adsorption materials, respectively

## References

[1] Schieweck, A., Salthammer, T., (2008). Primary and secondary emissions in museum showcases – Impact on exhibits. *11th International Conference on Indoor Air Quality and Climate*, August 17-22, 2008, Copenhagen/Denmark. In press.
[2] Schieweck, A., Salthammer, T., (2008). Influence of artificial lighting on emissions of volatile organic compounds (VOC) in enclosed spaces. *11th International Conference on Indoor Air Quality and Climate*, August 17-22, 2008, Copenhagen/Denmark. In press.
[3] Van der Wal, J.F., Hoogeveen, A.W., Wouda, P., (1997). The influence of temperature on the emission of volatile organic compounds from PVC flooring, carpet, and paint. *Indoor Air*, 7, 215-221.

# From Symptom to Diagnosis – The Classification of Damage Symptoms as an Instrument for Efficient Damage Material Analysis

E. Spiegel[1], R. Drewello[1] and U. Drewello[2]

[1]University of Bamberg, Institute for Archaeology, Building and Heritage Conservation,
Am Kranen 14, 96045 Bamberg, Germany
elise.spiegel@uni-bamberg.de http://www.restaurierungswissenschaft.de
[2]Laboratory Drewello & Weißmann, Ausstraße 29, 96047 Bamberg, Germany

***Keywords:*** *preventive conservation, air pollutant, skimmed linings*

## 1 Introduction

Destructive environmental influences are amongst the most pressing problems currently threatening works of art and culture. Restoration oriented precautions, i.e. preventative conservation, significantly reduces the influence of such destructive factors when applied as early as possible within the life of any particular work. Good conservation measures naturally include, of course, well-founded and pre-emptive diagnoses. The search for the source of any damage can be exceedingly complex and can often be compared to the infamous search for "a needle in the haystack". This attempt to pro-actively categorise damage phenomena should offer assistance to conservation scientists when forming their analysis program diagnoses.

## 2 Abstract

"Prevention" describes the complete range of measures encompassed by the term "precaution" when interpreted in its widest possible sense. Pro-actively applied restorative measures can mitigate any negative effects on works of art and culture. The basic pre-requisite, therefore, is the recognition and diagnosis of material changes that are not accounted for by the natural aging processes. These changes may consequently be considered as forming part of the damage process or processes themselves.

It shows itself repeatedly throughout numerous examples that come to hand in practice where the difficult nature of historical bedrock substances effected by pollutants, old restoration techniques, exploitation, problematic exhibition concepts and overly ambitious drive to continually place objects on exhibition exist. The typical symptoms are skimmed linings in the form of scums, the existence of contaminants, "black magic dust", microbe infestations and/or the presence of unexplained corrosion bi-products. The reasons for these damage symptoms are multifarious. More often than not, it is typically found to be the result of common interactive factors that present themselves to the scientist as a complex problem where the objects condition has been decoded and made difficult to evaluate.

Conscious observation and appropriate research of such phenomena (i.e. the various damage symptoms) can be subsequently used to develop preventative conservation measures and act as the basis for the formation of relevant diagnoses within analysis programs. The categorisation of skimmed linings can be a helpful instrument when previously applied to identifying the relevant variable(s) and to subsequently target the search for damaging substances. Such techniques should be incorporated into current practice and applied to the wide variety of examples that will be appearing in laboratories over time.

# Microclimate and Environmental Study of the Painting Gallery in Fano (Italy)

M. Letizia Amadori[1], U. Giostra[2], M. Letizia Andreazzo[1], S. Barcelli[1]

[1]Institute of Chemical Science, University of Urbino, P.za Rinascimento, 6, 61029 Urbino, Italy
m.letizia@uniurb.it
[2]Environmental Modelling Centre, University of Urbino, loc. Crocicchia, 61029 Urbino, Italy

***Keywords:*** *Palazzo Malatestiano, microclimate, temperatures, humidity*

## 1 Introduction

The handmade works of art, located in closed environments, undergo a potentially minor exposure to the aggressiveness of environmental factors, however the museum can not always be considered as a suitable conservation place.

Museum environment has been the centre of a debate in Italy, during last ten years, that lets perceive the need of a clearer definition of its organisation, minimum existence requirements and purpose. A lot of documents and researches have been published with the aim to individuate museums and collections problems and define the solutions to create suitable micro environmental conditions. (D. M. 10 May 2001; UNI Norm 10829, 1999; UNI Norm 10969, 2002).

## 2 Abstract

The microclimate and environmental study of the exhibition halls in the Painting Gallery of Fano, is part of a project carried out since 2004, that proposes, through a remote management system, the creation of an easily accessible method for managers and curators of museums, picture galleries and collections in general, finalized to the monitoring and optimization of environmental conditions in obedience to reference standards.

The microclimate campaign was conducted during an entire year in three exhibition rooms of the Picture Gallery of Fano: *Sala del Caminetto*, *Sala Grande* and *Sala Morganti*; with measurements of temperature, relative humidity and illumination, through four cordless-sensor connected to a Babuc ABC.

This investigation allowed to identify the seasonal trends of the different investigated parameters and the daily ranges considered more damaging for the exposed works of arts. In this way it has been possible to compare the resulting data with museal standards suggested by the existing recommendations and therefore to trace intervention strategies to be adopted in order to improve the conservation situation of the museum exhibition rooms.

In general the museum shows different conservation problems caused mainly by the variability of thermo-hygrometric conditions, highly influenced by external factors. The Painting Gallery of Fano does not use neither heating and air-conditioning systems, nor solutions for the temperature passive control.

Therefore, not all the exhibition rooms fulfil all the requirements suggested by the law for a suitable museum environment. The temperature in the Picture Gallery is highly variable and follows a stressed seasonal trend (Figure 1). The minimum registered temperature was 2.3 °C, the maximum 31.2 °C.

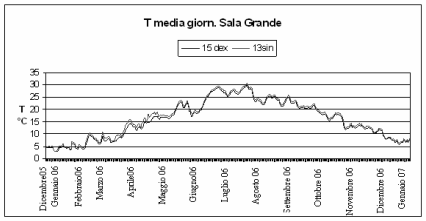



**Figure 1.** Temperature trend in the *Sala Grande* detected by two cordless-sensors.

In general, it is interesting to highlight that, in all exhibition rooms, the relative humidity is always high with daily average variations that exceed the values suggested by the law, the minimum registered value of relative humidity was 33.6 %, the maximum 90.3 %.

The environmental study of exhibition halls and the collection of microclimate data, run parallel to the compilation, for each work of art, of a conservative card containing all useful data for a potential maintenance and restoration intervention. These cards are relative to the work exposed in two of the three exhibition rooms, where the annual microclimate campaign is taking place.

The results of this research represent the basis of a preventive conservation policy that will assure to works of art the most suitable environment, corresponding to the characteristics of their constituent materials.

# Degradation of Collagen in Parchments by $NO_x$ and $SO_2$

E. Badea[1], G. Della Gatta[1], D.V. Poulsen[2], A. Mašić[1], L. Miu[3], M. Giurginca[4] and P. Budrugeac[5]

[1]Department of Chemistry IFM, University of Turin, via P. Giuria 9, I-10125 Turin, Italy
elena.badea@unito.it http://www.unito.it
[2]The Royal Danish Academy of Fine Arts, School of Conservation, Esplanaden 34, DK-1263 Copenhagen, Denmark
[2]National Research and Development Institute for Textile and Leather, str Ion Minulescu 93, 031215 Bucharest, Romania
[4]University "POLITEHNICA" of Bucharest, str. Polizu 1, 011061, Bucharest, Romania
[5]National Institute for Research and Development ICPE-CA, Splaiul Unirii 313, 030138 Bucharest, Romania

***Keywords:*** *parchment, accelerated ageing, pollutants, physical-chemical investigation*

From the end of 19th century, atmospheric pollution became typical of many urban areas and enhanced parchment degradation in addition to the common environmental factors such as humidity, temperature and light. For better understanding how atmospheric pollution may influence structural and thermal stability of collagen and cause damage to parchment we simulated an accelerated ageing by exposing new parchments to high levels (50 ppm) of $NO_x$ and/or $SO_2$ for increasing times. In addition, combinations of pollutant exposure and visible light irradiation (1.7 $10^5$ lx, illuminance), and heating at 100 °C were also applied. A comprehensive investigation has been made on three series of artificially aged parchment. Each series was divided in 4 sub-series, each of them being exposed to: (i) pollutant (1 to 16 weeks); (ii) visible light (4 to 32 hours) and pollutant; (iii) heating (4 to 32 days) and pollutant; (iv) visible light, heating and pollutant.

Collagen in parchment has a discrete structural hierarchy and deterioration at any level of its structure is critical for the integrity of parchments and threaten their stability. Advanced physical-chemical techniques, such as differential scanning calorimetry (DSC), thermogravimetry (TG/DTG), infrared spectroscopy (FTIR, NIR), scanning electron microscopy (SEM) and unilateral nuclear magnetic resonance (NMR) were employed to assess deterioration processes occurring at individual levels of parchment structure (Figure 1).

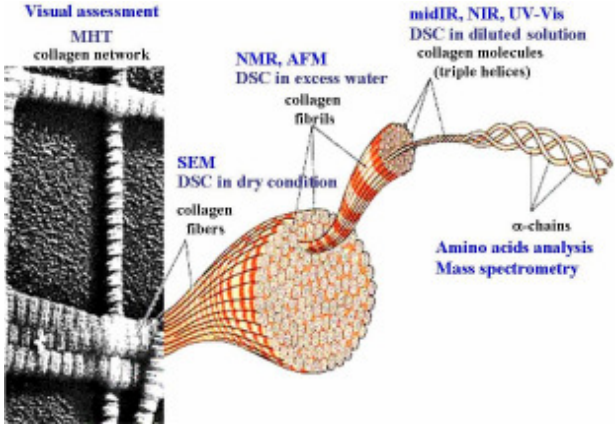



**Figure 1.** Investigation of collagen at different structural levels from macroscopic to the nanoscopic level.

Our earlier studies indicated relationships between the damage picture as expressed by physical properties at macroscopic and microscopic scales, and the alterations revealed by the structural, thermochemical and chemical analysis at meso- and nanoscale [1-2]. Correlation analysis of the physical-chemical data and macroscopic features enabled us to make a detailed study of the characteristics and evolution patterns of deterioration caused by air pollutants.

Results obtained are of great importance in preventing deterioration from becoming an extreme, uncontrolled event within the preservation and conservation context of historical parchment records and objects.

## References

[1] Della Gatta, G., Badea, E., Mašić, A., Ceccarelli, R., (2007). Structural and thermals stability of collagen within parchment: a mesoscopic and molecular approach. In: Larsen, R. (Ed.), *Improved Damage Assessment of Parchment (IDAP) Collection and Sharing of Knowledge*, Directorate-General for Research, Directorate Environment, European Communities, Brussels, Belgium, ISBN 987-92-79-05378-8, p. 51-60.

[2] Badea, E., Miu, L.; Budrugeac, P., Giurginca, M., Mašić, A., Badea, N., Della Gatta, G., (2007). 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.*, DOI:10.1007/s10973-007-8513-x.

# COLLAPSE
# Corrosion of Lead and Lead-Tin Alloys of Organ Pipes in Europe

A. Niklasson, L.-G. Johansson and J.-E. Svensson

Department of Chemical and Biological Engineering,
Chalmers University of Technology, SE-412 96 Göteborg, Sweden
annikan@chalmers.se www.goart.gu.se/collapse

***Keywords:*** *atmospheric corrosion, lead, historical organs, organic acid*

## Abstract

The atmospheric corrosion of lead is investigated, with the aim to improve the understanding of the environmental degradation of historical organ pipes. Fieldwork is combined with laboratory investigations. The field studies included characterization of the organ environment and exposures of lead coupons. The environment inside the organ wind system of instruments suffering corrosion was mapped and compared with instruments unaffected by corrosion, in five countries in Europe. In the heavily corroded organs, relatively high concentrations of acetic and formic acid vapours were present, and large amounts of carboxylates accumulated on the lead coupons [1]. The organic acids are emitted from woodwork in the organs.

The effect of acetic and formic acid vapours in the ppb range of the atmospheric corrosion of pure lead was investigated under well controlled conditions in the laboratory. The combined effect of acetic and formic acid vapours was also examined. The influences of temperature, relative humidity, inorganic air pollutants ($NO_2$ and $SO_2$) and particulates (NaCl) were studied as well. Corrosion rate was measured gravimetrically and the corrosion products were analysed by XRD, ESEM, FIB, ion chromatography and quantitative carbonate analysis. The mechanism of corrosion attack is addressed.

Traces of acetic acid vapour strongly accelerate lead corrosion. Mass gain is linear with time and depends linearly on the acetic acid concentration. Corrosion showed a relatively weak dependence on relative humidity in the range 50 - 95 %. Lead corrosion was inversely related to temperature; mass gain was 50% higher at 4.0 ºC than at 22.0 ºC. The corrosion rate increased with decreasing temperature in the range 22.0 - 4.0 ºC. It is proposed that lead suffers electrochemical corrosion in the presence of traces of acetic acid vapour. The corrosion products were unevenly distributed. Lead acetate oxide hydrate ($Pb(CH_3COO)_2 \cdot 2PbO \cdot H_2O$), plumbonacrite ($Pb_{10}O(OH)_6(CO_3)_6$), litharge (α-PbO) and massicot (β-PbO) were identified by X-ray diffraction [2].

Formic acid vapour is also corrosive towards lead, although somewhat less so than acetic acid. In this instance the corrosion products, consisting of plumbonacrite and lead formate hydroxide (Pb(HCOO)(OH)), are evenly distributed. The combination of acetic and formic acid has a slightly synergistic effect on lead corrosion, which resulted in a more localized attack than for the acetic and formic acid exposures.

The results show that acetic and formic acid vapours emitted from woodwork in the organs are decisive in the corrosion of historical organs. Methods for mitigating organ corrosion are discussed. The work in this project is a basis for formulating conservation strategies for historical organs.

## References

[1] Niklasson, A., Langer, S., Arrhenius, K., Rosell, L., Bergsten, C.J., Johansson L.-G. and Svensson, J.-E., (2007). Air pollutant concentrations and atmospheric corrosion of organ pipes in European church environments". Accepted for publication in Studies in Conservation.

[2] Niklasson, A., Johansson L.-G., Svensson, J.-E., (2005). The Influence of Acetic Acid Vapour on the Atmospheric Corrosion of Lead*, J. Electrochem. Soc,* 152 (12), pp. B519-B525.

# Polycyclic Aromatic Hydrocarbons in Indoor Air in India

K.S. Patel[1], R. Baghel[1], J. Lintelmann[2], G. Matuschek[2]

[1]School of Studies in Chemistry, Pt. Ravishankar Shukla University,
Raipur-492010, CG, India
patelks55@hotmail.com
[2]GSF-Forschungszentrum für Umwelt und Gesundheit GmbH, Institut für Ökologische Chemie,
Ingolstädter Landstr. 1, D-85764 Neuherberg, Germany

***Key words**: indoor pollution, polycyclic aromatic hydrocarbons, India*

## 1 Introduction

In a developing country like India, the indoor air pollution is at least four times more serious than outdoor air pollution, affecting especially poor women and small children [1]. According to the WHO, smoke from burning solid fuels is estimated to be responsible for 1.6 million deaths each year in the world's poorest countries. Indoor air pollution affects poor women and small children far more than any other sectors of society, killing almost 1 million children under five every year. Almost one half of the world's population still rely on solid fuels for their everyday cooking and heating; some 2.4 billion people burn biomass (wood, crop residues, charcoal and dung) and a further 0.6 billion burn coal. While biomass is considered a renewable fuel, the inefficient and unhealthy use of these solid fuels in the home is putting millions of the world's poorest families at risk. Particles from burning wood and charcoal make lungs vulnerable to acute lower respiratory infections, such as pneumonia and chronic obstructive pulmonary disease, and there is evidence linking indoor air pollution to asthma, tuberculosis, cataracts, low birth weight and infant mortality. Pollutants in coal smoke can cause lung cancer, arsenic poisoning and fluorosis.

## 2 Abstract

The solid fuel i.e. coal and biomass are burnt in India for cooking and energy generation with emitting trace gases, volatile organic compounds, polycyclic aromatic hydrocarbons, black carbons, trace elements, etc. into the environment. In the present work, the mass distribution of carcinogenic DNA damaging chemicals – polycyclic aromatic hydrocarbons (PAHs) associated to the particulate matter – in the microenvironment kitchen is described. Thirteen PAHs, i.e. phenanthrene, anthracene, fluoranthene, pyrene, chrysene, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, dibenz(ah)anthracene, indeno-1,2,3(cd)pyrene and coronene, of toxicological interest are quantified with the technique HPLC. The main indoor air pollution exposed to the women and children population and their health hazard are discussed.

## References

[1] Smith, K.R., (2000). Indoor air pollution implicated in alarming health problems. In: *Indoor Air Pollution – Energy and Health for the Poor.* Newsletter published by World Bank, p. 1.

# Indoor Air Quality Measurements in a Criminological Museum in Athens, Greece

D. Saraga[1], T. Maggos[1], S. Pateraki[1], K. Bairachtari[1], J. Michopoulos and C. Vasilakos[1]

[1]Environmental Research Laboratory, INT-RP, National Centre for Scientific Research "DEMOKRITOS", 15310 Aghia Paraskevi, Athens, Greece
Tel. +30 2106503716, Fax: +30 2106525004
dsaraga@ipta.demokritos.gr

***Keywords:*** *museum, PM, VOC, inorganic pollutants*

## Abstract

Recently, increasing attention has focused on the damage to museum collections due to indoor air pollutants. In the present study, representative pollutants' measurements were conducted during the period between 22nd June and 2nd July 2007 in the indoor environment of a museum, located in Goudi, an urban area of Athens, Greece. The museum belongs to the forensic department of University of Athens and most exhibits are old weapons and criminological findings, many of which are conserved in containers with formalin. It has to be mentioned that the entrance is not permitted for the public; the exhibitions are for educational purposes only. As recorded in questionnaires, the materials from which most of the items of the exhibition are constructed are wood, plaster, iron and the presence of formalin is intense too. During the sampling period, the ventilation of the indoor area was performed through 2 semi-open windows while no air conditioning system existed. Finally, a wall to wall carpet covers all the floor of the building.

24-hour measurements for PM2.5 concentrations were conducted daily in the interior of the museum. Particulate matter (PM) mass and number concentration in several size ranges as well as NO, $NO_X$ and $SO_2$ levels were continuously monitored, too. Furthermore, a 2-hour sample of carbonyl compounds (formaldehyde and acetaldehyde) was taken daily. Finally, two 20-minutes samples of VOCs were taken simultaneously in two sites of the interior of the museum.

The average daily value for PM2.5 ranged between 17.4 and 25.5 μg/m$^3$ with insignificant differences among the sampling days due to the fact that the museum remained closed for the public during all days of sampling and outdoor PM sources' contribution was eliminated. The main indoor PM source can be the wall to wall carpet which, through resuspension, can provide the internal atmosphere with significant concentrations of particulate matter. Furthermore, a Grimm 1.108 spectrometer measured the concentrations for a particle diameter size range from 0.23 μm to over 20 μm, in sixteen different channels. Results showed that particle concentration levels presented daily small variations during all day except for a period of two hours where specially smaller particles reached the high concentration of 760 μg/m$^3$ and 160,000 particles/liter, probably due to penetration from our entrance in the museum. The average values for formaldehyde and acetaldehyde were 50.5 μg/m$^3$ and 19.0 μg/m$^3$, respectively, for the period of the experimental campaign, while the corresponding WHO's limit for residential indoor air is 101μg/m$^3$. Regarding the inorganic compounds measurements, NO concentration levels ranged between 0.48 and 91.9 μg/m$^3$ while $NO_2$ levels ranged between 0.76 and 151.2 μg/m$^3$. The minimum value for $SO_2$ was 1.90μg/m$^3$ while the maximum value was 13.5μg/m$^3$.

The scope of the present study is to characterize the indoor air quality of a museum where the exhibitions are for educational purpose only and the entrance is not permitted for the public. Accordingly, the contribution of sources as the emissions from the equipment materials, emissions from exhibits' preservatives, penetration and outdoor environment is examined.

# The Investigation of Mercury Emissions from Historic Tin-Mercury Mirrors

M.Torge[1], S. Krug[1], M. Bücker[1], J. Birkhahn[2] and H. Witthuhn[2]

[1]Federal Institute for Materials Research and Testing (BAM), Division IV.2 Environmental Material and Product Properties, Richard-Willstätter-Straße 11, 12489 Berlin
manfred.torge@bam.de http://www.bam.de
[2] Federal Institute for Materials Research and Testing (BAM), Division I.1 Inorganic Chemical Analysis, Richard-Willstätter-Straße 11, 12489 Berlin

***Keywords:*** *tin-mercury, emission, amalgam mirrors*

## Abstract

In 1516 in Venice a procedure was developed, where a thin tin foil was flooded with mercury. Tin and mercury react and form an amalgam. With the implementation of casting mirror glass in 1688 in France, it was possible to produce big plates of high quality glass. In that time the hall of mirrors was built in Versailles, an example for several European courts. The manufacturing of the mirrors induced the poisoning with the high toxic mercury. The toxication was recognized in the 19th century. In 1855 *Justus von Liebig* discovered the silver-backed mirrors. This method was the fundament for the industrial fabrication till today and replaced the amalgam mirrors [1].

Today tin-mercury mirrors are still an element in baroques castles. But there are just a few indoor measurements of mercury emission known. Damages on mirrors are not unusual, so that conservation is necessary. Conservators have to follow strict precaution while they are exposed to the amalgam mirrors, because of the mercury emission and corrosion of the amalgam, where elemental mercury accumulates in the constructions of the mirror frames. In a project, which is supported by the "Arbeitsgemeinschaft industrieller Forschungs-einrichtungen" (AiF), the quantity of the mercury emissions from historic mirrors is examined and a technique to decrease these emissions will be developed.

First measurements of the mercury emission were made under laboratory conditions on amalgam mirrors (10 x 10 $cm^2$). The mirrors were stored in a desiccator at 40 °C and 45 %RH. There was an enrichment of mercury in the closed desiccator volume during 24 hours. After that the desiccator was evacuated and the air passed through a fritted wash bottle with nitric acid (33 %), where the mercury content was absorbed. The determination of the mercury content in the solution of nitric acid was realized by the atomic fluorescence spectrometry with cold-vapour technique (CV-AFS). In contrast to absorption the fluorescence will be measured, which is directly emitted by the sample. So the intensity of the emitted radiation is proportional to the intensity of the light source. The fluorescence will be excited by an energy-rich mercury lamp. The sensitivity of the method significantly increases with the high light intensity of this lamp [2]. After a calibration of the measuring device with standard solutions, the diluted (1:5) samples were analyzed to determine the mercury content.

**Table 1.** Hg-content in solutions of nitric acid (33 %).

| Test No. | Time of evacuation | Hg-content [µg/$m^3$] |
|---|---|---|
| 1 | 5 min | 221 |
| 2 | 5 h | 372 |
| 3 | 10 h | 233 |
| 4 | 20 h | 400 |

The result of Test 1 shows a high mercury content after a short time of evacuation . The increase of evacuation time shows no linear effect with increasing mercury content. Mercury emits under environmental conditions, so the amalgam mirrors get damaged. Further investigations should examine whether the mercury emission could be significantly reduced by depositing absorption materials.

## References

[1] Fränkler-Ballhorn, K., (1999). Historische Spiegel in Schlössern. *Restauro*, 3, 171-178.
[2] Becker A., (2005). Quecksilberbestimmung im sub-ng/L-Bereich. *LaborPraxis*, 64-66.

# Monitoring and Controlling of Fungal Deterioration on Textile Collection in Museum of Jordanian Heritage

O. Abdel-Kareem

Conservation Department, Faculty of Archaeology and Anthropology, Yarmouk University, Irbid, Jordan
Omaa67@yahoo.com

## Abstract

Museum of Jordanian Heritage is considered one of the most important museums in Jordan, as it shows the evolutionary stages of civilization within time sequence. The textile collection in this museum is displayed and stored in inappropriate environmental condition. This condition encourages the deterioration of textile objects by fungi.

This study is carried out to monitor the most dominant fungal stains on the textile collection in Museum of Jordanian Heritage to help us in establishing a strategy to prevent the fungal deterioration on this collection. In this study valuable deteriorated textile samples, collected from different areas in storage rooms and display halls in Museum of Jordanian Heritage, were used for isolating fungi. Different methods were used for isolating and identifying fungi on these samples. Both, plate method with manual key and direct observation by SEM were used for the identification of the fungi.

The results show that the most dominant fungi isolated from tested samples, belong to *Aspergillus, Penicillium, Chaetomium and Alternaria* species. All kinds of textile fibers in both storage rooms and display halls in Museum of Jordanian Heritage are liable to fungal attack. This study confirms that the textile collection is displayed and stored in very poor environmental conditions. Finally this study established a strategy and introduced some guidelines to solve and prevent the fungal deterioration problem in Museum of Jordanian Heritage. This strategy depends on the control of the environmental conditions surrounding the objects in display showcases and storage cabinets. However for active infestation the study suggested some fungicides that are safe for both textile objects and conservators.

# Identification of Fungi associated with Foxing on Paper, Based on Analysis of the Sequences of the Internal Transcribed Spacer (ITS) Regions

A. Michaelsen[1*], F. Pinzari[2] and G. Piñar[3]

[1]Department of Microbial Ecology, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria*
*Current address: University of New South Wales (UNSW), Centre for Marine Biofouling and Bio-Innovation, Sydney, Australia
[2] Istituto Centrale per la Patologia del Libro, Laboratorio di Biologia, Via Milano 76, 00184 Rome, Italy
[3]Institute of Applied Microbiology, Universität für Bodenkultur, Muthgasse 18, 1190 Vienna, Austria
guadalupe.pinar@univie.ac.at

***Keywords:*** *fungi, foxing, paper materials, molecular methods*

## Abstract

Archives and libraries from all over the world are subjected to deterioration phenomena caused by microorganisms, especially fungi. A frequent deteriorative modification of paper occurs in the form of brown-reddish spots that stain the substrate, known as foxing stains. The cause of foxing is not yet completely understood. There are a number of studies ascribing this phenomenon to mould growth or chemical alteration and even some of the foxing-causing fungi have been identified by conventional cultivation and microscopic techniques [1]. However, very little has been done to investigate foxing by the application of culture-independent molecular methods.

The variable non-coding ribosomal-DNA internally transcribed spacer region (ITS) which is nested in the nuclear rDNA repeat of the eukaryotic genome, provides greater taxonomic resolution for fungi than coding regions like 18S rRNA. Non-coding regions generally benefit from a fast rate of evolution which results in higher variation in sequence between closely related species, in comparison with the more conserved coding regions of the rRNA genes. Therefore, a nucleic-acid-based strategy targeting the ITS1 region was developed and applied to investigate fungi colonising paper materials [2].

In this study, a combination of conventional methods as SEM analysis, chemical analysis and culture-independent molecular methods were applied to identify fungi on a real case paper sample showing foxing deterioration. As a control, areas of the paper showing no visible alteration were investigated as well for fungal colonisation. Community fingerprints using Denaturing Gradient Gel Electrophoresis (DGGE) were obtained from both, foxing areas and not visually altered areas, and were followed by cloning strategies. Sequence analysis revealed the existence of fungi in both areas that could not be cultivated with traditional methods.

In summary, the molecular approach applied in this study seems to overcome some important problems as culture limitations or destructive sampling and offers the potential benefits of highly sensitive and rapid detection of fungi in paper material.

## References

[1] Arai, H., (2000). Foxing caused by fungi: twenty-five years of study. *International Biodeterioration and Biodegradation*, 46, 181-188.
[2] Michaelsen, A., Pinzari, F., Ripka, K., Lubitz, W., Piñar, G., (2006). Application of molecular techniques for the identification of fungal communities colonising paper material. *International Biodeterioration and Biodegradation*, 58, 133-141.

# Measurement of the Micro-Aeroflora Deteriorating Potentialities in the Indoor Environments

F. Pinzari, V. Cialej and N. Barbabietola

Istituto Centrale per la Patologia del Libro - Dipartimento per la ricerca, l'innovazione e l'organizzazione - Ministero per i Beni e le Attività Culturali, Via Milano, 76, 00184 Rome, Italy
Tel: +39-06-48291215. Fax: +39-06-4814968
flavia.pinzari@beniculturali.it

***Keywords:*** *micro-aeroflora, dust, biodeterioration*

## 1 Introduction

Aerobiological studies applied in the prevention of biodeterioration in conservation environments consist in extensive programmes for the sampling and identification of micro-organisms that cannot very readily be applied when tackling urgent problems affecting cultural heritage. Moreover, classical aerobiological studies do not provide information on functional diversity (metabolic potential) of the microbial communities inhabiting dust, and therefore are often useless in terms of "forecasting the potential dangerousness" of different environments.

A possible tool for the evaluation of the risk to stored library materials in association with the metabolic diversity of the microbial community inhabiting dust deposits on storage space surfaces is discussed here. The method consists in the direct inoculation of environmental samples into commercial microtiter plates and involves colour formation by reduction of a tetrazolium dye to assess utilization of 95 separate sole carbon sources during a 4–10 day incubation period. There are problems as well as benefits [1] in using this approach. An example of the use of the method is given in this paper.

## 2 Results and Discussion

The results of this study demonstrated that samples of dust, corresponding to different "conservation" situations, were successfully discriminated based on the "fingerprint" of the fungal/bacterial communities inhabiting the shelves where samples were collected. The substrata in the microplate that appeared outstanding, and which distinguished significantly between samples, were particularly informative also on account of the peculiarity of the materials that are stored in libraries, cellobiose and cyclodextrine forming part of the microbial catabolic pathway of cellulose degradation.

The method can be used to create a "metabolic picture" or fingerprint [2] of the microbial or fungal "community" present in different environmental samples.

With currently available techniques, the fingerprint method is suitable for the study of aerobic and anaerobic bacteria, actinomycetes, yeasts, and filamentous fungi. The growth environment on the microplates tends to be selective for copiotrophic, fast-growing microorganisms that are not inhibited by tetrazolium salt and there is very extensive literature that describes the limits for the application of microplates in environmental studies [1]. However, most of the researchers conclude that the fingerprint method is useful for making rapid sample comparisons with a high degree of discrimination [3], especially if the environment under study is an artificial one and most of its variables can be controlled, as in conservation environments.

The fingerprint method can be used to detect fluctuations in microbial activities, species diversity and abundance, and to monitor the effectiveness of control treatments, such as air purification and dusting techniques, and practices.

## References

[1] Preston-Mafham, J., Boddy, L., Randerson, P.F., (2002). Analysis of microbial community functional diversity using sole-carbon-source utilisation profiles – a critique. *FEMS Microbiology Ecology*, 42:1, 1-14

[2] Garland, J.L., Mills, A.L., (1991). Classification and Characterization of heterotrophic microbial communities on the basis of patterns of Community-Level Sole-Carbon-Source Utilization. *Appl. and Env. Microbiol.*, 57, 2351-2359.

[3] Konopka, A., Oliver, L., Turco, R.F. Jr., (1998). The use of Carbon Substrate Utilization Patterns in Environmental and Ecological Microbiology. *Microbial Ecol.*, 35, 103-115.

# Paint Coatings as One Major Factor to Prevent or to Enhance Fungal Growth in Museums and Depots

S. Hager[1], L. Havranek[1] and K. Sterflinger[1]

[1]University of Natural Resources and Applied Life Sciences, Muthgasse 18, A-1190 Vienna
Katja.Sterflinger@boku.ac.at htpp://www.boku.ac.at

***Keywords:*** *indoor fungi, nano-technology, biocide, additives, paint*

## 1 Introduction

Fungal contamination of museum objects in exhibition rooms or in depots often has its origin in the development of mold on humid walls or construction elements. From there fungal spores are released into the room and in consequence objects are contaminated. To control fungal growth in museum buildings the physical conditions as ventilation, isolation and water proofing are decisive. However, also the choice of appropriate building materials including the type of wall coatings that might enhance or hamper fungal growth is an important factor.

## 2 Abstract

Most of the commercially available paint coatings contain significant amounts of organic additives (mostly modified cellulose) which can be degraded by fungi. Other paintings contain biocides promising a long term antifungal activity of the paint layer. Recently, the use of paint coatings based on "nano-technology", e.g. containing nano-silver particles to prevent fungal growth, is evolving also in museums. It was the aim of this study to analyze the effect of nano-technology based silver coating, of commonly used coatings containing organic additives and of paints containing biocide, on the growth of fungi and to compare this to fungal growth on purely mineral coatings (silicate based) and pure lime coatings. Tests were carried out in indoor and outdoor environments and in laboratory experiments carried out with mold and yeast strains that are common on walls. By carrying out agar diffusion testing the anti-microbial effectiveness of the different paint systems was compared. The results showed that the paint containing nano-silver particles did not reveal a real anti-fungal effect neither on the petri-dish nor on test-dummies. To simulate direct contact of paint and fungus, spore suspensions were mixed with the paint and plated on malt extract agar. This experiment supported the earlier observation, that the nano-silver-particles do not have a fungicidal effect. Finally, a third experiment confirmed previous findings: small cubes of cement were painted with the "nano-silver" paint and inoculated with spore suspension. After some weeks of incubation, it turned out that several fungal strains were able to grow. The results from *in-situ* experiments showed that organic additives can significantly increase fungal growth on walls. Best results were obtained using pure lime and mineralic paint systems. The results lead to the conclusion, that lime and mineral paint coats should be preferentially used for walls of museums and their depots in order to decrease the danger of fungal development on walls. The use of – cost intensive – nano-technology based paints, however, does not guarantee a mold-free wall.

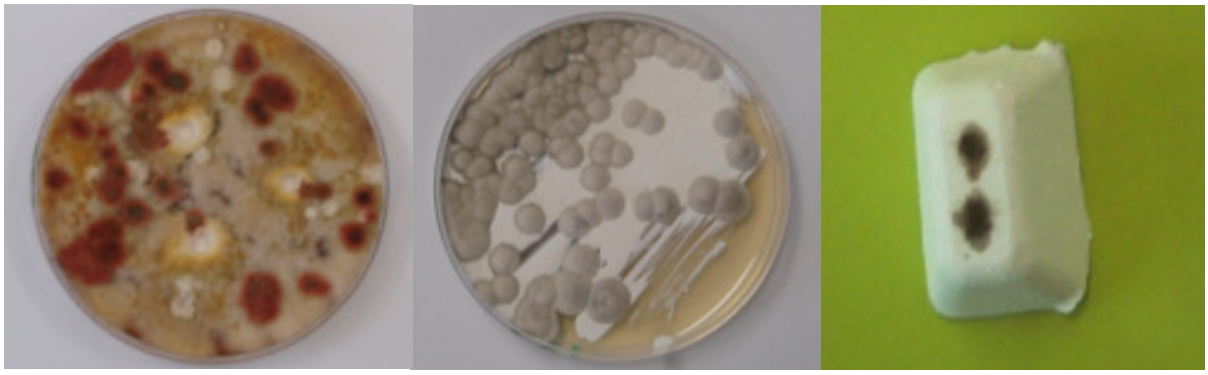


**Figure 1.** Agar diffusion test with *Epicoccum nigrum*; paint containing nano-silver particles with colonies of *Cladosporium cucumericum*; cement cube covered with nano-silver coating and inoculted with *Alternaria alternata*.

# NIR-Chemometrics: Quantification of Gelatin in Historic Papers

L. Cséfalvayová[1], M. Strlič[2], M. Pelikan[3], I. Kralj Cigić[1] and J. Kolar[4]

[1]University of Ljubljana, Faculty of Chemistry and Chemical Technology, Askerceva cesta 5, SI-1000 Ljubljana, Slovenia
linda.csefalvayova@fkkt.uni-lj.si www.fkkt.uni-lj.si
[2]University College London, Centre for Sustainable Heritage, The Bartlett School of Graduate Studies, Gower Street, London WCIE 6BT, UK
[3]University of Missouri at St. Louis, Dept. of Mathematics and Computer science, Missouri Estimation of Distribution Algorithms Lab, USA
[4]Morana RTD d.o.o., Oslica 1b, 1295 Ivančna Gorica, Slovenia

***Keywords:*** *near infrared spectroscopy, historic papers, gelatin sizing*

The technology of papermaking along with storage and environmental conditions (temperature, relative humidity, pollutants, etc.) has a significant effect on the life expectancy of paper. Papers of different composition are differently sensitive to environmental parameters and it is well known that since the advent of modern papermaking the quality of paper decreased considerably and many paper-based objects from this era are now in an advanced state of deterioration. In order to develop a deeper understanding of the ageing behaviour of early European papers, new tools and techniques are still needed considering that such materials are not available in great quantity for testing and are often very inhomogeneous.

Gelatin was a common ingredient in 15$^{th}$-18$^{th}$ century papers, and while primarily used as a sizing agent it can enhance paper mechanical properties significantly. It was shown that there is a significant correlation between the condition of several historic papers and the content of gelatine sizing [1]. In this work, we propose a method of rapid noninvasive and nondestructive quantification of gelatine content in historic papers by means of near infrared (NIR) spectroscopy using small-sized field-portable equipment. We have investigated and tested a combination of advanced chemometric methods, such as full-spectrum PLS (partial least quares) and genetic algorithm, to develop predictive models that enable us to provide high quality quantitative results when analyzing historic papers [2]. The model was calibrated against a reference chromatographic method (Figure 1). Using the proposed NIR quantitative model, 136 papers dating between the 15$^{th}$ and the 19$^{th}$ century were examined.

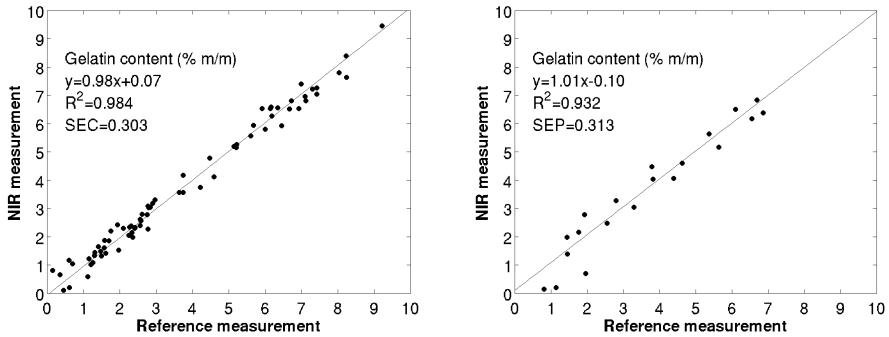



**Figure 1.** PLS calibration for prediction of gelatin content in historic paper: the developed model (left) and external validation (right).

## Acknowledgement

The authors gratefully acknowledge financial support of the Ministry of Higher Education, Science and Technology, Republic of Slovenia, Programme no. P1-0153.

## References

[1] Trafela, T., Strlič, M., Kolar, J., Lichtblau, D. A., Anders, M., Pucko Mencigar, D., Pihlar, B., (2007). Nondestructive Analysis and Dating of Historical Paper Based on IR spectroscopy and Chemometric Data Evaluation. *Analytical Chemistry*, 79(16), 6319-6323.

[2] Dupont, A.-L., (2003). Gelatin sizing of paper and its impact on the degradation of cellulose during aging. PhD thesis, University of Amsterdam, Amsterdam.

# Emissions of Volatile Compounds from Paper after Mass Deacidification

I. Kralj Cigić[1], M. Strlič[2], A. Možir[3] and J. Kolar[3]

[1]University of Ljubljana, Faculty of Chemistry and Chemical Technology, Aškerčeva cesta 5, SI-1000 Ljubljana, Slovenia
irena.kralj-cigic@fkkt.uni-lj.si
[2]University College London, Centre for Sustainable Heritage, The Bartlett School of Graduate Studies, Gower Street, London WCIE 6BT, UK
[3]National and University Library, Turjaška 1, 1000 Ljubljana, Slovenia

***Keywords:*** *VOC, historic paper, emission, mass deacidification*

## Abstract

In order to counteract paper acidity, which is undoubtedly the most important endogenous cause of paper degradation, deacidification is the accepted conservation treatment. It may proceed manually, mainly using water as a solvent, or on a mass scale. In the latter case, introduction of compounds used for deacidification proceeds using a variety of non-aqueous media, depending on the service provider and the process. The use of non-aqueous solvents is necessary in order to ensure their efficient removal and recycling.

The volatile compounds remaining in paper after deacidification may either represent solvents (alcohols, fluorinated hydrocarbons, siloxanes) or volatile products of hydrolysis of compounds used for deacidification (alcohols). Some of these compounds are easily detected even by smell, in addition, they may pose a health risk. Their determination is thus of great importance.

In order to be able to determine the excess volatiles and the rate of their emission from library materials, we tested and developed several procedures for sampling:

- Dynamic cryo-trapping/solid-phase micro-extraction,
- Direct sampling of storage area atmosphere in tedlar bags,
- Thermal desorption followed by cryo-trapping.

Using the later technique, we were able to obtain a 2D map of the remaining solvent concentration across a book page after mass deacidification using the Papersave (Zentrum für Bucherhaltung, Leipzig) process.

## Acknowledgement

The authors gratefully acknowledge the support of the European Community, 6th Framework Energy, Environment and Sustainable Development Programme, contract no. SSPI-006584 (PaperTreat). The work is the sole responsibility of the authors and does not represent the opinion of the Community. The Community is not responsible for any use that might be made of the data appearing herein.

Further financial support has been obtained from the Ministry of Higher Education, Science and Technology of Slovenia, program no. P1-0153.

# Pollution Aging of Deacidified Papers

T. Łojewski and K. Zięba

Jagiellonian University, Faculty of Chemistry, 30-060 Kraków (Poland), Ingardena 3
lojewski@chemia.uj.edu.pl http://www.chemia.uj.edu.pl/~kp

***Keywords:*** *pollution aging, paper, deacidification*

## Abstract

Samples of model papers deacidified with water-based and water-free techniques of mass-scale deacidification were aged in polluted atmospheres in two different ways:

1) in glass vials at a temperature of 100 ºC and

2) in a pollution chamber at room temperature.

It will be shown that all tested methods of deacidification protect paper against the attack of acidic gases.

The degradation was followed by:

- changes in molecular weights (SEC / cellulose tricarbanilate / THF)
- mechanical properties (zero span breaking length, folding endurance, tear index)
- optical properties (colour change).

The poster will present the comparison of the two methods of aging in polluted atmospheres:

- in a pollution chamber (standard ISO/DIS 5630-6)
- in glass vials – a new technique based on the closed vessel aging standard (ASTM D6819-02e3).

## Acknowledgement

The authors would like to acknowledge the support of the European Community, 6th Framework Energy, Environment and Sustainable Development Programme, contract no. SSPI-006584 (PaperTreat). The work is the sole responsibility of the authors and does not represent the opinion of the Community. The Community is not responsible for any use that might be made of the data appearing herein.

Further financial support has been obtained from the Polish Ministry of Science and Higher Education (SPUB 205/6 P.R. UE/2006/7).

# Diffusive Monitor for Hydrogen Sulphide Based on Colorimetric Detection

M. Anghelone[1], U. Hilfrich[2], C. Kleber[1,2], W. Vetter[2], M. Schreiner[1,2] and E. Rosenberg[1]

[1]Vienna University of Technology, Institute of Chemical Technologies and Analytics
Getreidemarkt 9/164 AC, A-1060 Vienna, Austria
erosen@mail.zserv.tuwien.ac.at http://www.cta.tuwien.ac.at
[2]Institute of Science and Technology in Art, Academy of Fine Arts, Schillerplatz 3, 1010 Vienna, Austria

***Keywords:*** *hydrogen sulphide, diffusive monitor, colorimetric detection*

## 1 Introduction

The aim of this work is to develop a new diffusive monitor for the measurement of hydrogen sulphide at relevant low concentrations as potentially encountered in museum indoor atmospheres.

The monitor is based on diffusive sampling taking place on an adsorption layer impregnated with solutions sensitive to $H_2S$. The reaction between the pollutant and the solution leads to a colour change of the substrate which enables quantification of the uptake of hydrogen sulphide either by direct reading or by using colorimetric measurements. Results from a preliminary series of experiments will be reported that have been conducted to compare the usefulness of six different colorimetric reagents under different conditions of preparation and use.

## 2 Abstract

Adsorbent layers were initially prepared by impregnating filter papers with solutions of $AgNO_3$, $Bi(NO_3)_3$, $PbAc_2$, $CdAc_2$, $Pb(NO_3)_2$, or $HgCl_2$ at 2 % concentration [1], followed by oven drying of pieces of suitable size. The such prepared samplers were exposed in vertical position in a climate cell under controlled conditions of 60 %RH and 500 ppb of $H_2S$ for 2, 4, 6, 8 and 24 hours. After each step of exposure, the sorbent layers were scanned using a regular office scanner and the greyscale value was evaluated with Photoshop CS3, furthermore colorimetric measurements were performed after 24 hours of exposure and remission spectra were acquired and L*c*h values determined using a Gretag SPM 50 spectrophotometer (parameters D65, 10 °).

The preparation of the samplers was repeated under different conditions, such as using more concentrated solutions for impregnation, or different drying times [2] in an attempt to make the samplers more reproducible. Again, the colour or greyscale change after 2, 4, 6, 8 and 24 hours was evaluated.

Already at this stage it became evident that not all reagent solutions were equally suitable for the measurements, and for this purpose, the experiments with impregnating solutions containing $Pb(NO_3)_2$ and $HgCl_2$ were no longer pursued due to the relatively small colour change and thus reduced sensitivity they would provide.

From the experiments with the more useful impregnation solutions, it is seen that exposure to 500 ppb of hydrogen sulphide for a maximum of 24 hours leads to a progressive colour change without reaching the saturation point. This establishes the basis for quantitative analysis related to concentration and exposure time.

Although the feasibility of quantitative analysis could be demonstrated in these preliminary experiments, it was also found that the conditions of exposure (that is, if the sampler was exposed on one or both sides to the pollutant, or where the exact position of the sampler was in the exposure chamber) play a significant role for the observed response. This lead us to re-consider the design of both, the sampler and the exposure chamber, to reduce the influence of sampling and exposure conditions.

## Acknowledgment

Financial support of this work through the EU Leonardo programme and through a STSM (Short Term Scientific Mission) grant from the COST Action D42 (“EnviArt”) is gratefully acknowledged.

## References

[1] De Santis, F., Allegroni, I., Bellagotti, R., (2006). Development and field evaluation of a new diffusive sampler for hydrogen sulfide in the ambient air. *Analytical and Bioanalytical Chemistry*, 384 (4), 897-901.
[2] Natush, D.F.S., Sewell, J.R., Tanner, R.L., (1974). Determination of Hydrogen Sulfide in Air – An Assessment of Impregnated Paper Tape Methods. *Analytical Chemistry*, 46 (3). 410-415.

# Sensor System for Detection of Harmful Environments for Pipe Organs

C.J. Bergsten[1], M. Odlyha[2], L. Bratasz[3] and D. Camuffo[4]

[1]Göteborg University, GOArt, Sweden
carl.johan.bergsten@hsm.gu.se http://www.goart.gu.se/sensorgan
[2]Birkbeck College, University of London, UK
[3]Polish Academy of Sciences, Cracow, Poland
[4]National Research Council of Italy, Padova, Italy

***Keywords:*** *organ, harmful environment, sensor*

## Abstract

The pipe organ is an important part of the cultural heritage of Europe. During many centuries the organ has represented state-of-the-art and its development has mirrored the technical, social and economical development in society in different regions in Europe. An organ landscape has been created, implying many common traits but also fascinating differences in construction, style and sound.

The organ heritage found in all countries of Europe includes more than 10,000 historical valuable organs.

A major threat to this heritage is indoor harmful environments. The recently completed EC funded project COLLAPSE (EVK4-CT-2002-00088) has shown that organic acid emissions from wood in the organ under certain circumstances can create lead-based corrosion inside the pipes leading to cracks and finally holes in the pipe wall.

Rapid fluctuations of the temperature can cause condensation phenomena in the organ and in the pipes. Condensation in the pipes will certainly speed up a corrosion process.

Harmful humidity conditions can create cracks or deformation in the wooden vital parts of the organ. This can lead to leakage in the organ wind system and also cause problems in the mechanical action system in the instrument.

The EC funded SENSORGAN project (contract 022695) objectives are to make available new instrumentation for monitoring and detection of harmful environments for organs through development of sensors for real time measurement.

The system will contain three different sensors to detect:

- levels of organic acids harmful to organ pipes
- environments damaging to wooden parts of organs
- possible dew formation inside organ pipes

The sensors will be designed in order to be placed in the organ or in the pipes without disturbing playing or affecting the sound. The sensor system will be applied in the historical organ from 1611 in the Minor Basilica of St. Andrew the Apostle in Olkusz, Poland. The data collected from all the sensors will be analysed, microclimatic factors creating harmful environments will be studied, and conclusions will be drawn for publications, mitigative strategies, and to support the Committee for European Standardisation.

# Recent Developments in Thermal Desorption (TD) – GCMS Technology for Further Enhancements in Trace Detection

P. G. Hughes, E. Woolfenden and M. Battes

Markes International Ltd, Gwaun Elai Medi Science Campus, Llantrisant, UK CF728XL
phughes@markes.com www.markes.com

***Keywords:*** *thermal desorption, air monitoring, passive sampling, trace detection*

## Abstract

Thermal desorption (TD) is a highly versatile, sensitive and labour-saving sample preparation technique for the measurement of volatile and semi-volatile organic compounds (VOC and SVOC) in air and materials. It provides the ultimate sample introduction technology for GC/GCMS combining selective concentration enhancement with direct extraction into the carrier gas and efficient transfer/injection all in one fully automated and labour saving package.

Thermal desorption is now recognised as the technique of choice for air monitoring (workplace and environmental) and is the subject of many international standard methods. Key examples include: EN ISO 16017, ISO 16000-6, EN 14662 (parts 1 & 4), ASTM D6196, US EPA TO-15 (canisters) & TO-17 (tubes), NIOSH 2549, UK Environment Agency guidance on landfill gas (LFGH 04) and US EPA guidance for on-line ozone precursor monitoring.

This paper will discuss recent developments in Thermal Desorption (TD) – GCMS technology for further enhancements in trace detection for air quality monitoring such as;

a) higher resolution techniques resulting in faster analysis times and higher throughout
b) higher precision developments for better reproducibility
c) novel approaches for result validity for increased confidence in analytical results
d) electronic sample / tube tagging technology for ultimate sample traceability, simplified work flow and enhanced productivity

# Laser Ablation Inductively Coupled Plasma Mass Spectrometry for Analysis of Culture Heritage Objects

A. Nowak, D. Walaszek, B. Wagner and E. Bulska

Faculty of Chemistry, Warsaw University, Pasteura 1, 02-093 Warsaw, Poland
anowak@chem.uw.edu.pl

***Keywords:*** *archaeometry, LA ICP MS, elemental composition*

## Abstract

Elemental composition of archaeological objects can support the knowledge about a single object, and its provenance, or generally about investigated materials, in respect of technological aspects of its production. Moreover, it can help us to understand different processes which occur either on the surface or in the bulk of the objects. All obtained information can improve new restoration and conservation methods for objects from museum collections. In this case not only major and minor composition is an important source of information but also trace elements.

This knowledge can be obtained in archaeometry by several instrumental methods, but the preferences are made to these techniques which allow fast, multi-elemental and very sensitive analysis. One of the modern methods which match closely to this description is LA ICP MS.

The main advantage of LA ICP MS is that we can perform measurements directly on solid surfaces and with the use of CCD camera precisely choose the area of ablation. The consumption of the sample during measurements is in micro scale and that is why almost no visual changes on the samples surfaces can be observed.

In our investigation LA ICP MS was employed to estimate the major, minor and trace elements content in samples of three different archaeological materials: ceramics, glass [1] and human skeletal remains [2]. For all investigated materials different procedures of analysis were chosen and instrumental parameters were optimized in order to obtain the desired information. Dependent from the kind of material we were able to perform a quantitative or semi-quantitative analysis of given samples. Moreover, by using different ablation modes it was possible to estimate the homogenity of the elemental distribution on the samples surface or to obtain elemental depth profiles.

By means of LA ICP MS it was possible to obtain a lot of data in a short period of time but we want to mention that historical interpretation of this results can be made only in collaboration with specialists from many disciplines of science.

## References

[1] Nowak, A., (2007). Elementary analysis of historical glass by means of laser micro-sampling. Master Thesis.
[2] Walaszek, D., (2007). Applying LA ICP MS in the analysis of excavated historical objects. Master Thesis.