IAQ Prague 2014

11th International Conference Indoor Air Quality in Heritage and Historic Environments

Prague, Kaiserštejn Palace April 13 – 16, 2014

Programme and Abstract book

www.iaq2014.cz

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11th International Conference Indoor Air Quality in Heritage and Historic Environments

Prague, Czech Republic

April 13 – 16, 2014

Programme

Abstracts

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ABSTRACT BOOK

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Bogdan Filip Zerek, The National Library of Poland, Warszawa, Poland

GENERAL INFORMATION

REGISTRATION DESK / VENUE

Kaiserštejn Palace
Malostranské náměstí 37/23
Prague – Malá Strana
Czech Republic

REGISTRATION HOURS

Sunday, April 13	14:00 – 19:00
Monday, April 14	08:00 – 18:00
Tuesday, April 15	08:30 – 14:00
Wednesday, April 16	08:30 – 18:00

CONFERENCE SECRETARIAT

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REGISTRATION DESK

(Emergency numbers)
+420 606 918 277
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REGISTRATION FEE INCLUDES

Admission to the scientific programme
Conference materials
Coffee breaks
Welcome coctail on April 13, 2014 at Kaiserštejn Palace
Afternoon excursion
Book of abstracts
Farewell Reception

PROGRAMME

Sunday, April 13th

14:00 – 19:00	Registration at Kaiserštejn Palace
18:00	Welcome reception – 1st floor Kaiserštejn Palace

Monday, April 14th

08:00 – 18.00	Registration
9:00 – 9:15	Opening ceremony – Kaiserštejn Palace, 2nd floor
9:15 – 10:20	**Plenary lecture** Chair: David Thickett **Johanna Leissner** • Climate for culture – assessing climate change impacts resulting from modelled future indoor climates in historic buildings
10:20 – 10:40	Coffee break
10:40 – 12:20	**Session 1** Chair: John Havermans **Lorraine Gibson** • Examination of VOC emissions from polymer objects **Alexandra Schieweck** • Low-VOC and zero-VOC products – helpful tools on the way to a "Green" Museum? **Marianne Odlyha** • Pollutants in indoor environments: damage assessment and preservation of organic-based cultural heritage **Valérie Desauziers** • Innovative analytical tools and modeling methodology for impact prediction and assessment of the contribution of materials on indoor air quality **Katherine Curran** • Evaluation of the cross-infection effect of polymers
12:20 – 14:00	Lunch
14:00 –	Workshop **Jiří Smolík** • Methodology of evaluation of air quality effect on library and archival collections **Ludmila Mašková** • Ventilation rate in the indoor environment of different types of archives • Relationship between indoor and outdoor concentration of aerosol particles in different types of archives **Jiří Smolík** • Chemical composition of indoor particulate matter • Assessment of airborne biocontaminants **Francesca Vichi** • Assessment of air quality by diffusive sampling at two Czech archives

14:00 –	**Vladimír Havránek** • Analysis of aerosols deposits by ion beam techniques **Jakub Ondráček** • BASAMATIKUM – Aerosol spectrometer for wide size range indoor/outdoor measurements **Hana Grossmannová** • BASAMATIKUM – Aerosol spectrometer tested by end users in the Technical Museum in Brno Coffee break Workshop **Milan Kouřil** • Monitoring of indoor air quality in libraries and archives **Dirk Lichtblau** • SurveNIR – the non-destructive evaluation of material conditions in conservation **Magda Součková** • Comparing of identical incunabula stored in depositories with different quality of air **Marie Benešová** • Application of dust particles on model samples of paper and testing efficiency of mechanical cleaning

Tuesday, April 15th

8:30 – 14:00	Registration
9:00 – 10:20	**Session 2** Chair: Alexandra Schieweck **John Havermans** • The impact of a historical conservation method for the preservation of entomological collections on the indoor air quality of repositories **Michel Dubus** • Historic wooden archival boxes: to discard or not to discard? **John Havermans** • The emission of mercury from mercuric chloride treated herbariums **Willemien Anaf** • Vermilion turning black? Blame mercury!
10:20 – 10:40	Coffee break
10:40 – 12:40	**Session 3** Chair: Tomáš Vyhlídal **Jiří Smolík** • Modelling of particulate matter infiltration in the Baroque Library Hall in Prague **Francesca Vichi** • Simultaneous measurement of nitric and nitrous acids by means of a novel multipollutant diffusive sampler **Laura Cartechini** • Pollution sources in museum environments: integrated real-time and off-line measurements to investigate indoor-outdoor exchange dynamics **Dehkordi Manijeh Hadian** • Ozone monitoring in museum environments by elastomeric dosimeter field experiences

10:40 – 12:40	**Georgios Panagiaris** • Indoor/outdoor particulate matter concentrations and microbial load in museums **Johanna Diehl** • Pollutant prevention in the newly reopened Kunstkammer of the Kunsthistorisches Museum, Vienna
12:40 – 14:00	Lunch
15:00 –	Excursion

Wednesday, April 16th

8:30 – 18.00	Registration
9:00 – 10:20	**Session 4** Chair: Jean Tétreault **Lorraine Gibson** • Novel sensors for detection of selected pesticides on museum objects **Franco Palla** • Bioaerosol in indoor cultural heritage environments: potential risks for historical-artistic manifacts and human health **Justyna Skóra, Katarzyna Pietrzak** • Evaluation of the microbial quality and air disinfection effectiveness in museums and libraries **Bogdan Filip Zerek** • Taxa of microorganisms isolated in the indoor and outdoor air of the National Library of Poland
10:20-10:40	Coffee break
10:40 – 12:20	**Session 5** Chair: Georgios Panagiaris **Benjamin Bartl** • The effect of dust particles on cellulose degradation **Josep Grau-Bové** • The effect of particulate matter on paper degradation **Jean Tetreault** • Degradation of paper under various adverse environmental conditions **Tera Ferial** • Photodegradation of some coloured artificial archaelogical mimic silk samples in relation to indoor air quality parameters **Frank Ligterink** • Are short exposures at high concentrations equivalent to long exposures at low concentrations?
12:40 – 14:00	Lunch
14:00 – 15:40	**Session 6** Chair: Lorraine Gibson **Alexandra Schieweck** • Performance of adsorbent media for sustainable mitigation of organic pollutants

14:00 – 15:40	**Terje Grøntoft** • The “MEMORI technology”: Measurements,effect assessment and mitigation of pollutant impact on movable cultural assets, innovative research for market transfer **Paul Lankester** • The MEMORI pollutant measurement, effect assessment and mitigation decision support model **Tsukada Masahiko** • Quantitation of target compounds in Oddy Test Vessels with SPME-GCMS
15:40 – 16:00	Coffee break
16:00 – 17:20	**Session 7** Chair: Bogdan Zerek **Matthias Schmidt, Annika Dix** • Preventive strategy and control measurement procedure in two recently opened exhibitions at the Germanisches Nationalmuseum in Nuremberg **Tomáš Vyhlídal** • Decision support tool for mitigation, adaptation and preservation strategies of indoor-climate in historic buildings **Magnus Wessberg** • Energy efficient climate control in historic buildings **Chris Ecob** • Real-world laboratory testing of molecular filters
17:20 –	Conference conclusion
	Farewell reception

SOCIAL PROGRAMME

WELCOME RECEPTION

Sunday, April 13, 18:00

Kaiserštejn Palace – 1st floor
Malostranské náměstí 23/37, Prague 1
Included in the registration fee.

EXCURSION – The Langweil model of Prague

Tuesday, April 15, 15:00

The City of Prague Museum
Na Poříčí 52/1554, Prague 8
How to get there: From Kaiserštejn Palace take tram number 22 from station "Malostranské náměstí" to station "Národní třída". Then go by walk 4 min to station "Lazarská" and from this station take tram number 3 to station "Florenc" (approx. 25 min)

The Langweil model of Prague
The Langweil model, created in 1826 – 1834, is a unique exhibit and the most attractive one in the museum.Once it had been cleaned and new lighting had been added it was reopened to the public on 12th April 2007.
It provides unique evidence of how the Old Town, Malá Strana and Prague Castle looked before the redevelopment of Prague at the end of the 19th and start of the 20th centuries.
Included in the registration fee, registration needed.

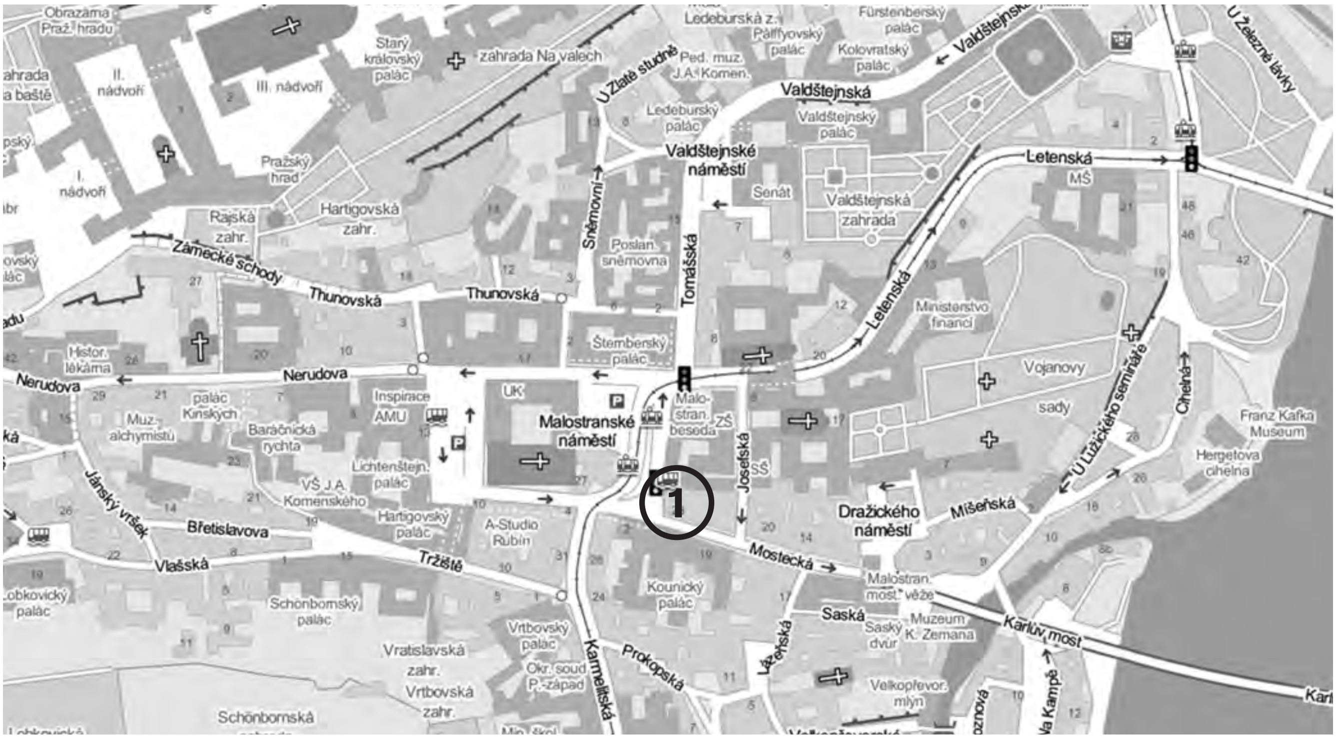
CONFERENCE DINNER

Tuesday, April 15, 20:00

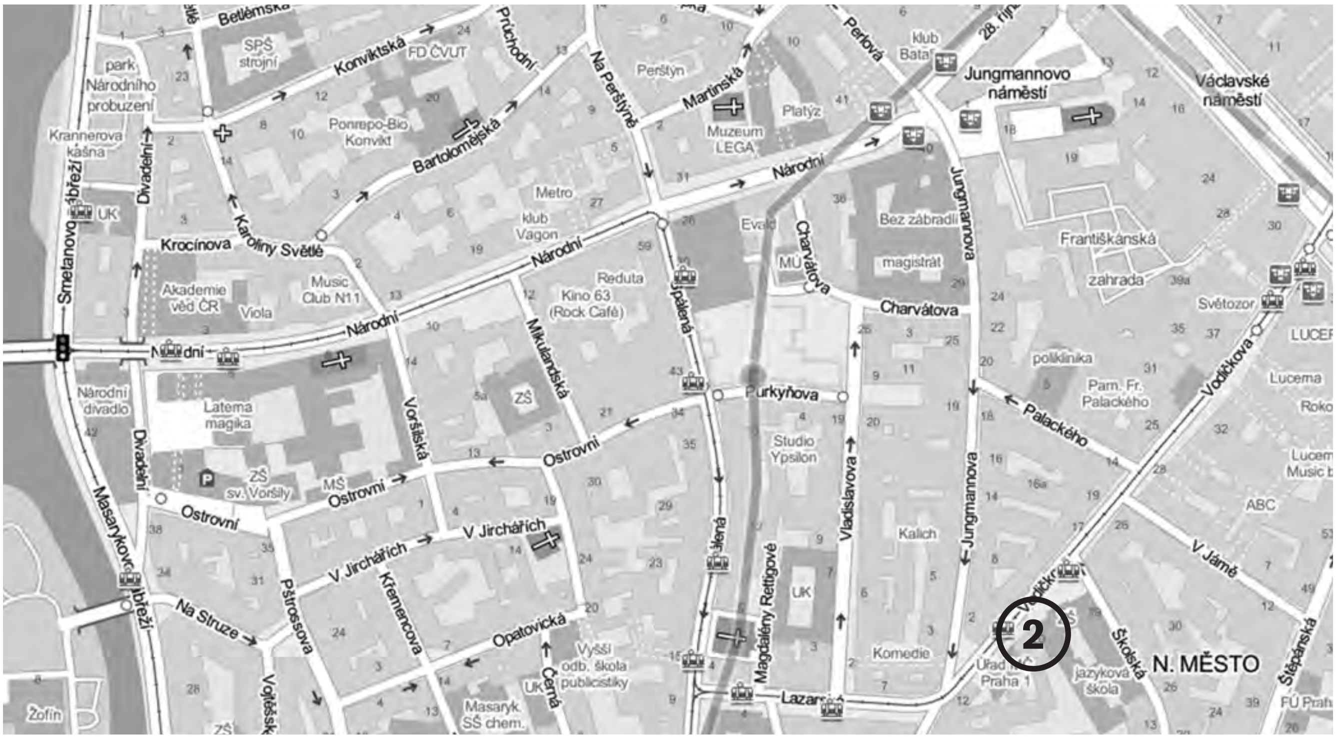
Restaurant "NOVOMĚSTSKÝ PIVOVAR"
Vodičkova 20, Prague 1
Price: 40 EUR

LOCATION MAPS

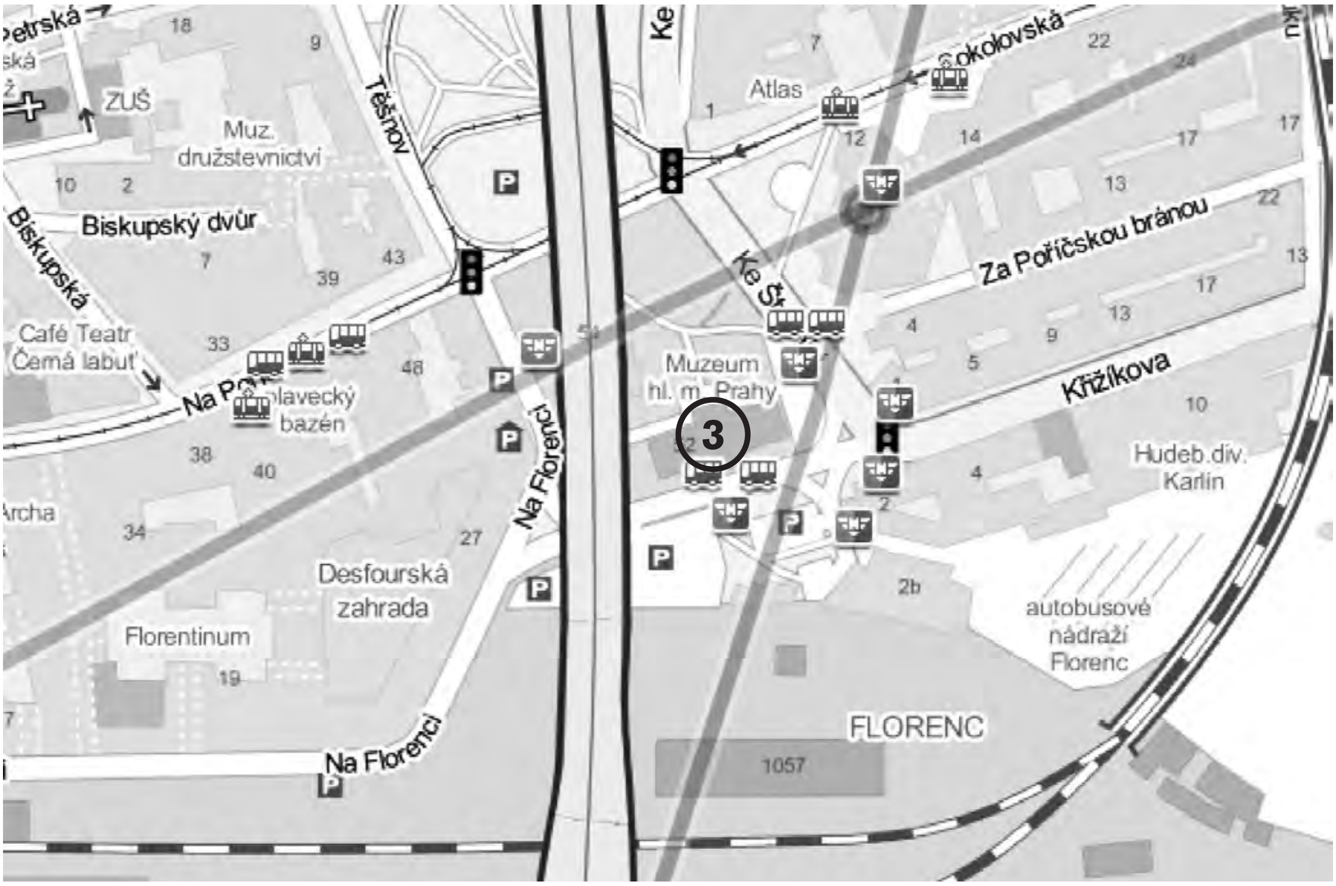
1) Conference venue – Kaiserštejn Palace



2) Conference Dinner – Novoměstský Pivovar



3) Conference Excursion – The City of Prague Museum



ABSTRACT BOOK

Lectures are sorted by Programme, Posters are sorted by poster numbers.

Texts of abstracts have not undergone neither linguistic nor editorial correction.

CLIMATE FOR CULTURE – ASSESSING CLIMATE CHANGE IMPACTS RESULTING FROM MODELLED FUTURE INDOOR CLIMATES IN HISTORIC BUILDINGS

J. Leissner[1], R. Kilian[1], T. Broström[2], J. Ashley-Smith[3], H. L. Schellen[4], M. Martens[4], F. Antretter[1], M. Winkler[1], C. Bertolin[5], D. Camuffo[5] and T. Vyhlidal[6]

[1]Fraunhofer Gesellschaft, Germany; [2]Uppsala University, Gotland, Sweden; [3]Cambridge, United Kingdom; [4]Technical University Eindhoven, The Netherlands; [5]CNR-ISAC Padova, Italy; [6]Czech Technical University, Prague, Czech Republic

In order to assess the most substantial risks of changing climate conditions on historic artifacts, the large-scale integrated EU-Project CLIMATE FOR CULTURE has taken the approach of correlating high resolution regional climate modeling with building simulation tools to produce scenarios of indoor climates in historic buildings from the recent past to the far future (until the year 2100). Risks to the building and to the interiors with valuable artifacts resulting from the changing indoor environment are assessed by damage functions. A set of generic buildings based on data from existing buildings are used to transfer outdoor climate conditions to indoor conditions using high resolution climate projections for Europe and the Mediterranean. This allows producing risk maps of future climate induced risks to historic buildings and their interiors, see figure 1. The results can be used for climate change impact assessments and for planning adaption and mitigation measures of the built cultural heritage.

Climate change, the worldwide energy and resource deficiency problem together with environmental pollution are

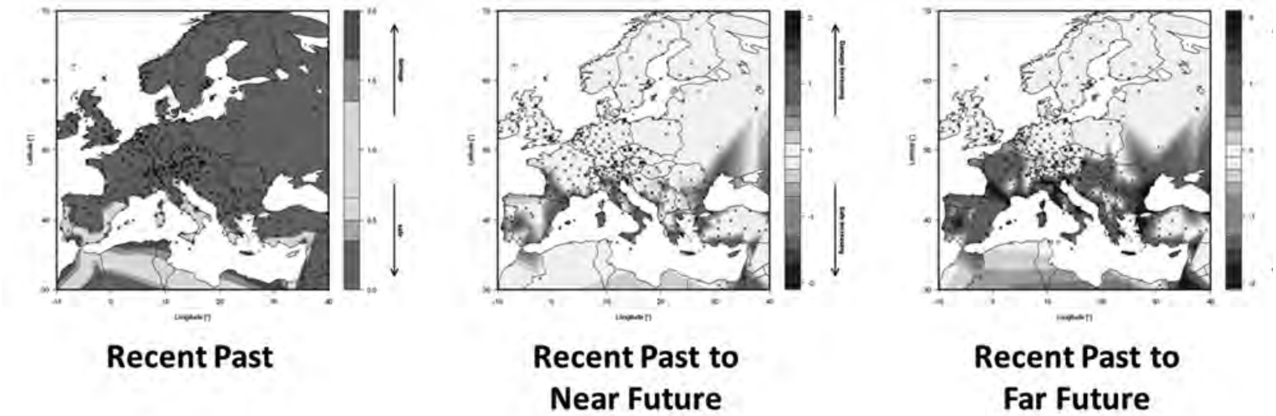


Fig. 1: Example of a prototype risk map (left) and resulting maps for the near and far future periods showing the degree of changes according to climate changes. The data are arbitrarily chosen and are not real values.

serious threats of our time. For a sustainable management of our cultural heritage, it is vital to know how the future changing climate will influence the indoor climates in buildings. As a non-renewable resource of intrinsic importance to our identity, there is a need to develop more effective and efficient sustainable adaptation and mitigation strategies in order to preserve these invaluable cultural assets for the long-term future. More reliable assessments will lead to better prediction models, which in turn will enable preventive measures to be taken, thus reducing energy and the use of resources. For this purpose the CLIMATE FOR CULTURE (CfC) project is connecting new high resolution climate change evolution scenarios with whole building simulation tools to identify the most urgent risks for specific regions. A further innovation of the project lies in the elaboration of a more systematic and reliable damage/risk assessment which will be deduced by correlating the projected future climate data with whole building simulation models and new damage assessment functions. Thus not only the impact on historic buildings and future energy demands can be evaluated, but also the possible effects on the related indoor climates in which the valuable works of art are kept. In situ measurements and investigations at cultural heritage sites throughout Europe and the Mediterranean allows for a more precise and integrated assessment of the real damage impact of climate change on cultural heritage at regional scale. Sustainable (energy and resource efficient) and appropriate mitigation/adaptation strategies, are further developed and applied on the basis of these findings simultaneously. We will present a method to assess future risks resulting from the indoor climate in historic buildings.

ORAL PRESENTATIONS

EXAMINATION OF VOC EMISSIONS FROM POLYMER OBJECTS

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Keywords: VOCs, polymer, emission, Tenax-TA, GC-MS

Elucidating the source of a particular pollutant in the indoor air space of a museum collection can be difficult, but it is now understood that heritage objects can act as an emissive source; for example the harmful cross-contamination effects of emissions from plastic objects is generally well known [1,2]. Moreover, the prevalence of plastics in our day-to-day lives has raised safety concerns in relation to the emission of volatile organic compounds (VOCs) and their effect on human health [3]. Being recognised as a potential emission source, heritage institutions have investigated the chemical compounds released from a wide range of plastic objects and how the detected VOCs might affect the stability of other heritage objects held in close proximity to the emitting object or human health [4-7]. This research further explored this important phenomenon and focused on VOC emissions from a range of plastics commonly found within heritage collections; cellulose acetate, cellulose nitrate, polyurethane, polycarbonate, rubber, poly(vinyl chloride), polyethylene, polypropylene and polystyrene. In total 41 samples (at least three per polymer type) were heated to 23 ˚C or 70 ˚C. and emissions were collected onto Tenax-TA sampling tubes at 23 ˚C Selected samples were also photodegraded by exposure to UV light for one h followed by exposure to visible light at 36 ˚C with an irradiance of 750 Wm^{-2} for 168 h, before emissions were re-evaluated. The relative humidity of the Atlas Suntest XLS+ chamber was 50 %.
The results of this study strongly support the use of Tenax-TA as an in-situ, non-invasive collecting device for VOCs emitted by plastic objects, and their subsequent identification by gas chromatography-mass spectrometry. As the Tenax-TA adsorbent is held in a stainless steel housing unit it was easily shipped to and from sampling sites (this was the method of shipping used to collect vapours above museum objects). The emissions collected from samples at 23 ˚C could be used to identify plastic type (cellulose acetate, polyurethane, cellulose nitrate, rubber, polyethylene, polypropylene and styrene based polymers) and the stability of objects under study. However, it should be noted that emissions from poly(vinyl chloride) or polycarbonate samples were shown to be 'non-specific' (the emitted VOCs are commonly found in indoor air profiles), therefore could not be used to positively identify these polymer types. Finally case studies will be reported to demonstrate the success of this method of analysis.

This work was supported by The Science and Heritage Programme of the AHRC/EPSRC under grant AH/H032630/1.

[1] Curran K, Mozir A, Underhill M, Gibson LT, Fearn T, Strlic M. Cross-Infection Effect of Polymers of Historic and Heritage Significance on the Degradation of a Cellulose Reference Test Material. Polymer Degradation and Stability (in press). 2013, DOI 10.1016/j.polymdegradstab.2013.12.019
[2] Curran K, Strlic M. Polymers and volatiles: Using VOC analysis for the conservation of plastic and rubber objects Studies in Conservation (in press). 2013, DOI 10.1179/2047058413Y.0000000125
[3] E. Leary, Youssef C. Hazards at home? In: B. Keneghan, Egan L, editors. Plastics- Looking to the Future and Learning from the Past. London2007.
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[5] Thiébaut B, A. Lattuati-Derieux, M. Hocevar, Vilmont L-B. Application of headspace SPME-GC-MS in characterisation of odorous volatile organic compounds emitted from magnetic tape coatings based on poly(urethane-ester) after natural and artificial ageing. Polym Test. 2007;26:243-56.
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LOW-VOC AND ZERO-VOC PRODUCTS – HELPFUL TOOLS ON THE WAY TO A "GREEN" MUSEUM?

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Keywords: emissions, low-VOC, zero-VOC, "Green" museums

Nowadays, the need for "green" museums is globally an important topic. The discussion covers not only ecological and economic solutions of running a museum building, but also how to create an indoor environment both beneficial to museum collections and to human health.
As a consequence of this global going green movement, products which are advertised as emitting no volatile organic compounds into indoor air are increasingly released to the market. These so called "low-VOC" or "zero-VOC" products are suggesting a high environmental benefit to the user and are therefore also under consideration for the application in museum interiors [1]. The question therefore arises whether these products deliver what they promise and if they might be a helpful tool on the way to a "Green" Museum?
Therefore, the emission potential of low-VOC and zero-VOC paints was investigated as well as the efficiency of paints which shall purify the air by degrading pollutants or blocking formaldehyde emissions from medium density fiberboard (MDF).
The talk will present the results and will highlight the potential benefit of these paints by comparing their ingredients and emission potential with those of conventional products, such as solvent borne and water borne paints [2]. Moreover, helpful and reasonable strategies for achieving low-polluted indoor air will be discussed as well as the frequently demanded necessity for environmental standards and guidelines [3].

This work was supported by Fraunhofer-Gesellschaft (in-house research).

[1] Tétreault, J., (2011). Sustainable use of coatins in museums and archives – some critical observations. *e-PreservationScience*, 8, 39-48.
[2] Schieweck, A., Low-VOC and zero-VOC products – helpful tools on the way to a „Green“ Museum? *In preparation.*
[3] Schieweck, A., The need of air quality guidelines and reference values in the museum environment – a curse or a blessing? *In preparation.*

POLLUTANTS IN INDOOR ENVIRONMENTS: DAMAGE ASSESSMENT AND PRESERVATION OF ORGANIC-BASED CULTURAL HERITAGE

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Keywords: damage assessment, artists' varnishes, documents, canvas

The effect of pollutants in indoor environments has been studied in order to understand the likely damage that may occur during exhibition and storage in museum environments In particular the effects of acetic and formic acids were studied as results in a previous project had highlighted the occurrence of higher concentrations of volatile organic acids within enclosures than in the rooms [1]. This then raised the question as to the allowable dose to which organic-based cultural objects should be exposed. The current MEMORI project (Measurement, Effect Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets) addressed this problem and part of the objectives were to determine dose response functions for a range of organic-based cultural heritage materials. Results for artists'varnishes and collagen-based materials (parchment) will be presented in this paper. For all the varnishes studied, dammar, resin mastic, Regalrez 1094, Laropal A81 and dammar with a coating of Regalrez 1094, changes were observed after exposure to organic acids relative to the unexposed samples. Accelerated ageing was performed for periods up to 4 weeks of acetic acid (40mg/m3) at 75 %RH. Increase in glass transition temperatures (*Tg)* values of the varnishes were observed by dynamic mechanical (DMA) and micro-thermal analysis (micro-TA), and changes in the chemical composition at the molecular level using gas chromatography and mass spectrometry (GC/MS) indicated that oxidation had occurred in the natural resins . For synthetic varnishes less damage was observed than for the natural resins and was mainly measured using X-ray surface analytical techniques.

Varnishes samples were also exposed at selected sites: in a transport packing case at Tate store (UK) and in a display case at Chesters museum (English Heritage) where levels of pollutants, RH, T and light were monitored. Data showed that varnish samples exposed within the packing case in Tate store were damaged as a result of their exposure to the level of organic acids present in the packing case. At Chesters where the varnish samples were exposed not only to similar levels of organic acids but also to light the damage was higher. This indicates the synergistic action of light and organic pollutants.

For parchment, the effect of exposure to acetic acid ($c \leq 400$ mg/m3) at 75 % RH up to 16 weeks caused acid to be trapped inside the parchments; this was illustrated by a significant drop in the hydrothermal stability and by a significant drop in pH accompanied by swelling of the parchment structure. However, after a degassing period of at least two weeks only a slight but significant decrease in the hydrothermal stability could be detected in parchment. Although the hydrothermal stability of historical parchment seemed to be almost unaffected by the acid exposure, the drop in pH and swelling as well as shrinkage of its fibre structure during exposure were also significant Atomic force microscopy (AFM) showed progressive gelatinization with acid exposure and this was confirmed by micro-thermal analysis. Samples were also tested by exposure to elevated RH (75 %) alone and a somewhat longer exposure time was required to cause similar morphological changes and similar changes in the hydrothermal stability of the fibres [2].

Within the NANOFORART project "Nano-materials for the conservation and preservation of movable and immovable artworks" project (FP7 No. 282816), one of the aims is to protect collagen-based artefacts with novel nanoparticle formulations. The basic idea is to adjust pH and prevent the collagen from being exposed to low or high pH values at which damage occurs. Some case studies will be presented as well as results of deacidification studies on other materials including historic paper and 19th cent. canvases.

The MEMORI project (Grant Agreement no. 265132) and the NANOFORART projects (Grant agreement no. No. 282816) are both funded by the 7th Framework Program of the European Commission.

[1] PROPAINT 2010. Improved Protection of Paintings during Exhibition, Storage and Transit Final Activity Report (http://propaint.nilu.no/Portals/23/PROPAINT-Final Report.pdf)
[2] Dahlin,E.,(ed) Final report MEMORI project http://www.memoriproject.eu/memori_news.html (accessed 8th Feb 2014)

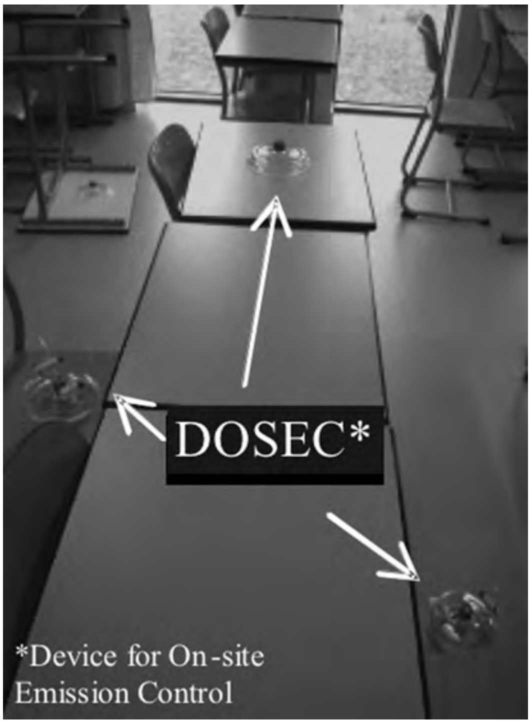
INNOVATIVE ANALYTICAL TOOLS AND MODELING METHODOLOGY FOR IMPACT PREDICTION AND ASSESSMENT OF THE CONTRIBUTION OF MATERIALS ON INDOOR AIR QUALITY

V. Desauziers[1], D. Bourdin[1,2], P. Mocho[3], H. Plaisance[1]

[1]Centre des Matériaux (C2MA), Ecole des mines d'Alès, Hélioparc, 2 avenue P. Angot, 64000 Pau (France)
[2]Nobatek, 67 avenue de Mirambeau, 64600 Anglet (France)
[3]Laboratoire Thermique Energétique et Procédés (LaTEP), Université de Pau et des Pays de l'Adour, rue Jules Ferry, 64000 Pau (France)

Presenting author email: valerie.desauziers@mines-ales.fr
Keywords: VOC, material emission, measurement, modeling

The combination of more and more airtight buildings and the emission of volatile organic compounds (VOCs) and formaldehyde by building, decoration and furniture materials lead to damage indoor air quality [1,2]. Hence, it is an important challenge for public health but also for the preservation of cultural heritage, as for example, artworks in museum showcases. Indeed, some VOCs such as organic acids or carbonyl compounds may play a role in the degradation of some metallic objects or historic papers.
Thus, simple and cost effective sampling tools are required to meet the recent and growing demand of on-site diagnostic of indoor air quality, including emission source identification and their ranking. In this aim, we developed new tools based on passive sampling (Solid-Phase Micro Extraction, SPME) to measure VOCs and carbonyls compounds (including formaldehyde)[3], both in indoor air and at the material/air interface [4]. The coupling of SPME with a specially designed emission cell, so called DOSEC (figure 1), allows the screening and the quantification of the VOCs emitted by building, decoration or furniture materials.



In parallel, indoor air is simply analysed using new vacuum vial sampling combined with VOCs pre-concentration by SPME [5]. These alternative sampling methods are energy free, compact, silent and easy to implement for on-site measurements. They show satisfactory analytical performance as detection limits for most VOCs are in the µg/m^3 range. They already have been applied to public buildings for a 6 months monitoring of indoor air quality and building material emissions [6]. The data obtained were in agreement with a physical monozonal model which considers building materials both as VOC sources and sinks and air exchange rate in one single room ("box model") [4]. Results are promising, even if more data are required to complete validation, and the model could be envisaged as a predictive tool for indoor air quality. This new integrated approach involving measurements and modeling could be easily transposed to historic environments and to the preservation of cultural heritage.

Figure 1. In situ sampling of material emission using the DOSEC--SPME coupling

References:
[1] D.A Missia, E. Dimitriou, N. Michael, E.I. Tolis and J.G. Bartzis. Indoor exposure from building material emissions: a field study. *Atmospheric Environment* 44 (2010) 4388-4395.
[2] A. Hodgson and A.F. Rudd. Volatile organic compounds and emission rates in new manufactured and site-built houses. *Indoor Air* 10 (2010) 178-192
[3] D. Bourdin and V. Desauziers, Development of SPME on-fiber derivatization for the sampling of formaldehyde and other carbonyl compounds in indoor air, *Anal. Bioanal. Chem*., 406 (2014) 317-328
[4] D. Bourdin, Volatile Organic Compounds emitted by building materials: impact on indoor air quality, *PhD thesis* (2013)
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EVALUATION OF THE CROSS-INFECTION EFFECT OF POLYMERS

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Keywords: Cross-infection,Volatile Organic Compounds (VOCs), Gas Chromatography, Preventive Conservation

The phenomenon of cross-infectious material degradation is well-known within the heritage sector, having been observed as early as the 1890s.[1] Infections are spread via reactive species, such as radicals or volatile organic compounds (VOCs), which can be emitted from display and storage materials or from historic objects themselves. Because of this, new packaging and display case materials are routinely tested to assess their potential hazards.[2,3] It has recently been shown that the degradation of historic paper can be accelerated by reactive species emitted from both iron gall inks and from the paper itself. [4,5]
The cross-infection effect of "modern materials" i.e. synthetic and semi-synthetic polymers produced from the mid-nineteenth century onwards has also been observed. A wide range of VOCs is known to be released from modern materials and certain emissions are known to have a cross-infection effect on historic objects.[6,7] For example, "vinegar syndrome", whereby the release of acetic acid from degrading cellulose acetate (CA) objects, accelerates the degradation of other CA-based objects in the vicinity, is well-documented.[8] However, a wide-ranging study of the cross-infection effect of different "modern" polymers relevant within collections has not been performed to date.
In this work, the cross-infection effect of 105 polymer samples was studied, using cellulose as a reference test material. In total 14 polymer types were studied, comprising "modern materials" commonly found in historic and artistic collections. These include: CA, cellulose nitrate (CN) poly(vinyl chloride) (PVC), and a selection of specialised packaging materials used in art and heritage conservation. Polymer samples were placed in glass vials containing a piece of the cellulose reference and vials were sealed before heating to 80 °C for 14 days. The cross-infection effect on the cellulose was measured using viscometry to calculate the degree of polymerisation relative to that of a control reference. A classification system of the cross-infection effect of the materials studied is proposed:

(i) Preservation effect – materials with a positive impact on the stability of the reference material
(ii) Neutral effect – materials with no significant impact on the reference material
(iii) Moderate cross-infection effect
(iv) Significant cross-infection effect
(v) Severe cross-infection effect

Solid phase micro-extraction (SPME)-GC/MS was used to detect and identify emitted VOCs from a selection of polymer samples. CN was identified as the polymer with the most severe cross-infection effect while others e.g. polycarbonate (PC) had no effect or even a beneficial effect. Acetic acid was the most characteristic emission detected from the most severely cross-infecting materials.

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METHODOLOGY OF EVALUATION OF AIR QUALITY EFFECT ON LIBRARY AND ARCHIVAL COLLECTIONS

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Keywords: indoor air quality, gaseous pollutants, airborne particles, damaging effect on collections

The Ministry of Culture of the Czech Republic supports in the period 2011-15 project "Methodology of evaluation of air quality effect on library and archival collections". The project has been carried out in collaboration of three Institutions: the Institute of Chemical Process Fundamentals ASCR, National Archives, and National Library of the Czech Republic. The aims of this project are (i) development of evaluation methods for indoor air quality in libraries and archives, targeted at reduction of damages on library and archival collections caused by adverse effect of environment and (ii) gaining detailed knowledge of direct dependences between damage of library and archival collections and surrounding environment, leading to precautions reducing the adverse effects of deteriorated environment.

The initial part of the study includes interaction between indoor and outdoor environment, detailed characterisation of indoor pollutants, and their transport indoors. For this purpose advanced monitoring of the air quality has been carried out in four archives in the Czech Republic, representing different outdoor environments: Zlatá Koruna (rural), Třeboň (small town), Teplice (industrial area), and Prague (large city with traffic). The monitoring comprises gaseous pollutants SO_2, NO_2, O_3, HNO_3, NH_3, and formic and acetic acids measured both indoors and outdoors using passive dosimeters, and temporal and spatial variation of size-resolved indoor and outdoor particulate matter (PM). For this purpose a simple aerosol spectrometer for wide particle size range suitable for indoor application has been constructed. To determine size-resolved chemical composition of PM, airborne particles have been sampled using two Berner type low pressure impactors and/or PM1 and PM10 Leckel samplers. The chemical composition has included determination of water soluble inorganic ions (Ion Chromatography), elements (PIXE), and elemental and organic carbon (EC/OC, Total optical Transmittance). Further, accompanying parameters, such as ventilation rate, temperature, relative humidity, and presence of bioaerosols has been monitored. In addition corrosivity of indoor and outdoor environment has been determined using OnGuard instruments, Purafil, Ag, Au, Pb coupons, and EWO dosimeters.

Inherent part of the project is exposition of different materials to the indoor air, typical for libraries and archives. Samples included paper, cardboard, binding leather and parchment, pigments and binding agents, and photographic materials. Parallel to these measurements free deposition of indoor PM on Teflon and quartz filters with different orientation has been investigated. Another study included sampling of indoor PM1 and PM10 particles on Whatman filters that were later on artificially aged. The aim has been to determine if there is any degradation of cellulose, caused by fine PM. During the project identical incunabula stored in depositories with different quality of air has been also compared. For this purpose the non-destructive evaluation of material conditions using SurveNIR instrument has been performed. Efficiency of mechanical cleaning after application of dust particles on model samples of paper has been also investigated.

Acknowledgements
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VENTILATION RATE IN THE INDOOR ENVIRONMENT OF DIFFERENT TYPES OF ARCHIVES

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Keywords: ventilation rate, indoor environment, tracing gas

Ventilation rate in museums and archives is very important for assessment of interaction of indoor and outdoor environment and especially for estimation of amount of pollutants penetrating indoors from the outdoor air. This study was focused on measurements of the natural ventilation rate in the depositories of the State Regional Archives in Třeboň, the Research Library of South Bohemia at Zlatá Koruna and the Library of the Regional Museum in Teplice.
The ventilation rate was measured using tracing gas by the Indoor Air Quality Monitor PS32 (Sensotron, Poland), which measured temperature, relative humidity and concentration of CO_2. The CO_2 concentration in the indoor environment was initially increased (by the evaporation of dry ice in Zlatá Koruna and Teplice and by launch from a cylinder in Třeboň). After that the ventilation rate was calculated from the decrease of CO_2 concentration using Eq. 1 An example of tracing gas concentration decrease during the experiment and fit by Eq. 1 is shown in Fig. 1. where $C_{in}(t)$ is the tracer gas concentration, C_0 is the tracer gas concentration in the beginning of the time period, C_∞ is the tracer gas concentration in the infinite time, t is time, and λ^* is the ventilation rate.

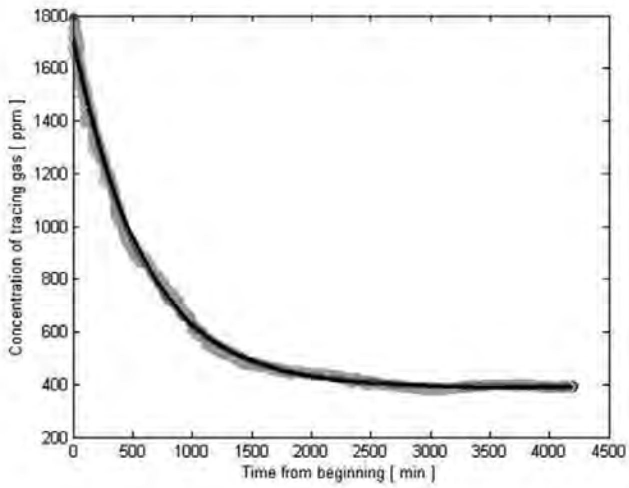

Figure 1. Example of the tracing gas concentration decrease.

The results revealed that the ventilation rate in Třeboň was in average three times higher than in Zlatá Koruna and four times higher than in Teplice (Tab. 1). It was probably caused by the fact that the archive in Třeboň is equipped only with simple windows with gaps while archives in Zlatá Koruna and Teplice have double glassed windows. A difference was also between seasons. The ventilation rate was lower in summer than in winter at every archive, probably due to lower temperature difference between indoor and outdoor environment.

Table 1. Ventilation rate [h^{-1}] during different seasons of the year in archives in Třeboň, Zlatá Koruna and Teplice.

	Winter	**Spring**	**Summer**	**Autumn**
Třeboň	0.44	0.34	0.28	0.43
Zlatá Koruna	0.14	0.13	0.10	0.13
Teplice		0.10	0.06	

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RELATIONSHIP BETWEEN INDOOR AND OUTDOOR CONCENTRATION OF AEROSOL PARTICLES IN DIFFERENT TYPES OF ARCHIVES

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Keywords: indoor/outdoor particles, number size distribution, penetration

Aerosol particles are one of the major pollutants in outdoor and indoor air. They may negatively influence health, but also have negative effects on ecosystems and cultural heritage. Particulate matter (PM) can be harmful for works of art by causing soiling and chemical damage, depending on particle size and chemical composition [1].
The study includes indoor/outdoor monitoring of air quality in four archives in the Czech Republic, representing different outdoor environments: Zlatá Koruna (rural), Třeboň (small town), Teplice (industrial area), and Prague (large city with traffic). The archives in Zlatá Koruna, Třeboň and Teplice are only naturally ventilated, while archive in Prague is equipped with ventilation and filtration system. The measurements were performed during 4 intensive campaigns in different seasons of the year at every location. The measurements included particle number concentrations and size distributions determined by an Ultrafine Particle Monitor (TSI, USA) and an Aerodynamic Particle Sizer (TSI, USA). Both instruments sampled alternately from indoor and outdoor, covering the size range 20–20,000 nm. In Prague only indoor measurements were performed, because the archive is absolutely isolated from the outdoor environment. The aim of this study is to investigate concentrations and sources of PM in the indoor environment of the archives, and to establish the relationship between the indoor and outdoor environment.
The results showed that concentrations of fine particles in the indoor environment of the archive in Prague were relatively stable and low (about 10^2 particles/cm^3), but concentrations of coarse particles were increased by restorers and visitors. The temporal variation of fine particles in the naturally ventilated archives (Zlatá Koruna, Třeboň, Teplice) indicated outdoor air as a main source of particles in the indoor environment. Average values for the indoor/outdoor ratios of the particle number concentration had a maximum between particle diameters of 0.1 – 1 μm (Fig. 1), which indicates a maximum penetration factor and low indoor deposition velocity of these particles. The penetration at Třeboň was higher probably due to simple windows with gaps, compared to double glassed windows at Zlatá Koruna and Teplice. The results were confirmed by measurements of the ventilation rate.

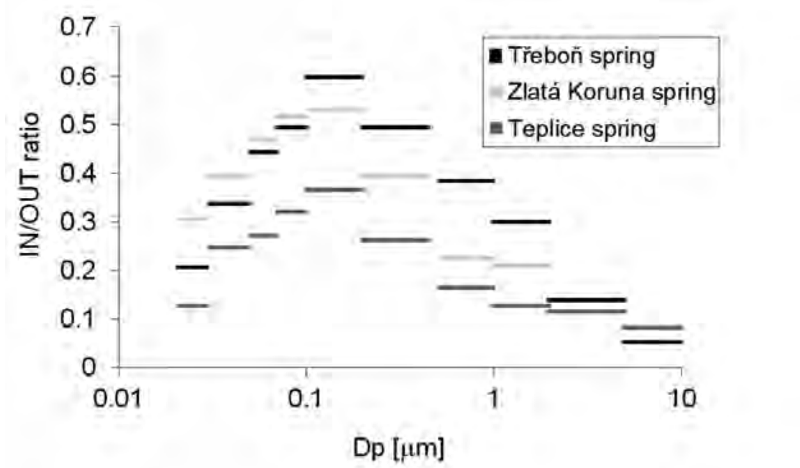

Figure 1. Indoor/outdoor ratios of particle number concentrations versus particle size during the spring campaign in Třeboň, Zlatá Koruna and Teplice.

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CHEMICAL COMPOSITION OF INDOOR PARTICULATE MATTER

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Keywords: PM, chemical composition, water soluble ions, elemental carbon, organic carbon, crustal elements

To determine chemical composition of indoor particulate matter and to assess contribution of outdoor air pollution, airborne particles have been sampled by two Berner type Low Pressure Impactors collecting and separating PM into 10 size fractions in the size range 0.025 – 10 µm. Samples have been analysed gravimetrically, by Ion Chromatography and PIXE, giving mass, ionic, and elemental size distributions. Further, indoor PM1and PM10 particles have been sampled on Whatman 41, Teflon, and quartz filters. The sampling has been carried out on daily basis with two samples collected at each location during four year season. In addition Teflon and quartz filters have been exposed to indoor air for one year to estimate free deposition of dust particles. Filters have been fixed both vertically and horizontally, with horizontal surface facing both upwards and downwards. Samples on Teflon filters have been again analysed by PIXE (elements), samples on quartz filters by IC (water soluble ions) and Total optical Trasmittance method (elemental and organic carbon).
Example of composition of indoor PM1, collected at Zlatá Koruna and Třeboň during four year seasons is shown in Fig. 1. As can be seen total mass concentrations at Zlatá Koruna are lower compared to Třeboň. This is probably caused by lower ventilation rate and lower outdoor PM1 concentrations. Dominating component on both places is organic carbon, originating probably by combustion of wood used for home heating.

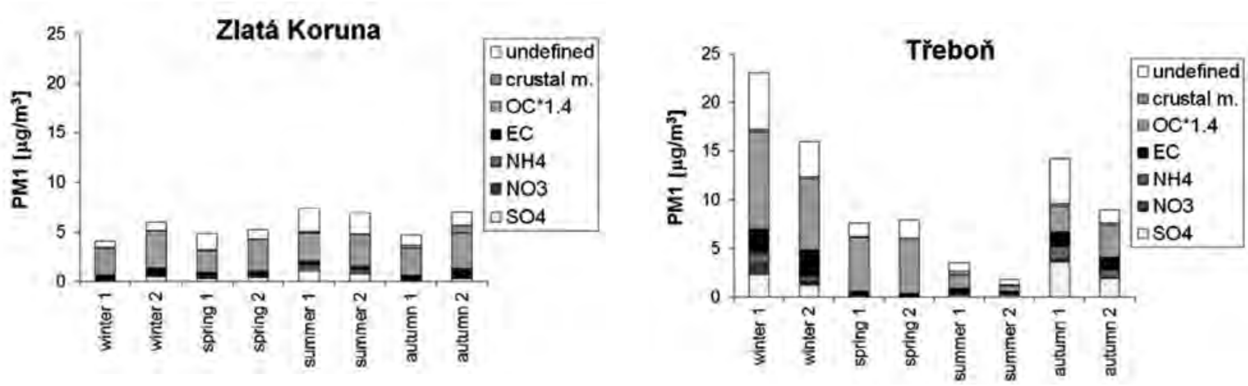

Figure 1. Example of composition of PM1, collected during four year seasons in the indoor environment of archives in Zlatá Koruna and Třeboň.

Example of free deposition of particles, containing sulphate, is shown in Fig. 2. As can be seen particles have been deposited predominantly on horizontal surfaces facing upwards due to combine effect of sedimentation and diffusion. Lower concentrations on vertical surfaces and horizontal surfaces facing downwards are due to diffusion as the only possible mechanism of deposition.

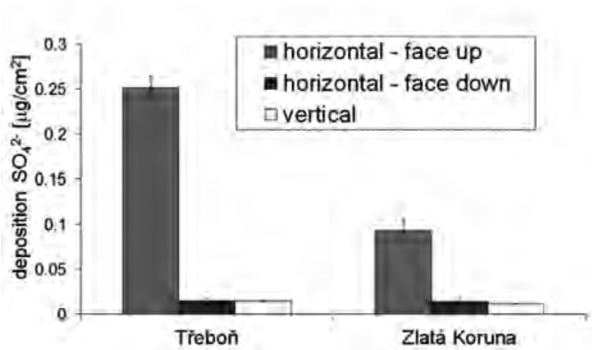

Figure 2. Concentrations of free deposited sulphate ion on horizontally (facing upwards and downwards) and vertically fixed filters at Zlatá Koruna and Třeboň.

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ASSESSMENT OF AIRBORNE BIOCONTAMINANTS

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Keywords: bioaerosols, fungal flora, CFU

Biological samples were collected from the air in the storerooms of four libraries and archives using MAS-100 aeroscope (Microbial Air Monitoring Systems). Malt extract agar plates were used as culture media. The total colony forming units (CFU) per m^3 were determinated after the incubation. The fungal species were identified from the isolated colonies.
The concentration of airborne fungal flora ranged between 27 – 623 CFU/m^3 (indoor) and 37 – 673 CFU/m^3 (outdoor). The relatively lower fungal counts were obtained at winter as a result of lower temperature and relative humidity (Fig. 1). The most frequently isolated components of the bioaerosols were Penicillium spp. and Cladosporium spp., other fungal species were present in low quantities.

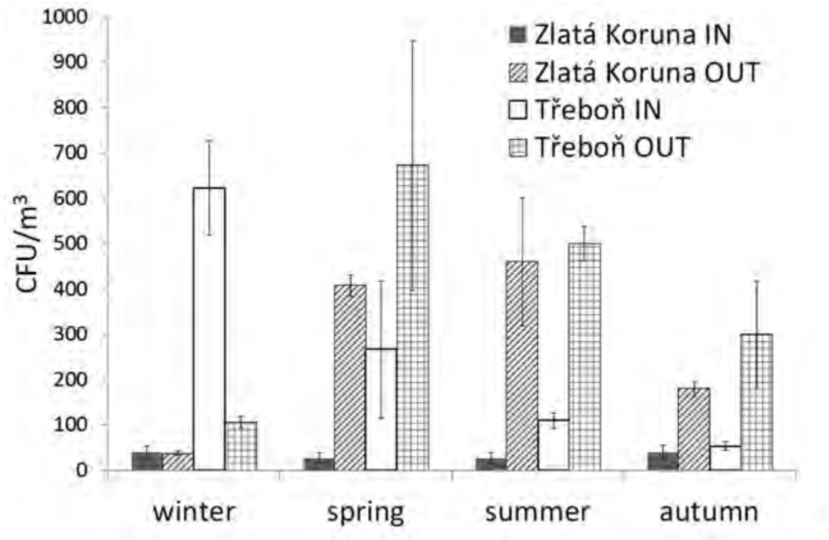

Figure 1. The concentration of airborne fungal flora measured in the indoor and outdoor environment of archives at Zlatá Koruna and Třeboň.

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ASSESSMENT OF AIR QUALITY BY DIFFUSIVE SAMPLING AT TWO CZECH ARCHIVES

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Keywords: Diffusive sampling, air pollution, archives

The measurement of gaseous and particulate pollutants in museum, galleries and archives is important to ensure acceptable conditions for the protection of artifacts displayed or stored indoors. Diffusive samplers were developed for the assessment of various gaseous pollutants [1] as a simple and less expensive alternative to traditional sampling methods and they were previously employed for surveys in such environments [2].
The present study was aimed at collecting air pollutants data at two Czech archives, Zlatá Koruna and Třeboň, located respectively in a monastery in the countryside and in a small city. The measurements were performed by means of diffusive sampling from December 2011 to November 2012 on a monthly basis.
Nitrogen dioxide, sulphur dioxide, ozone, ammonia, nitric acid and organic acids (acetic and formic) were monitored both outdoors and indoors at the two sites. The results obtained from the campaigns carried out at the two archives have been analyzed and processed. The average concentration values calculated for the different pollutants and the ratio between indoor and outdoor values are reported in table 1.

Table 1. Pollutants concentration yearly averages and I/O ratio at Zlatá Koruna and Třeboň archives.

Location	Period	Pollutant	IN (μg/m³)	OUT (μg/m³)	IN/OUT
Třeboň	Dec 11/Nov 12	NO_2	2.8	13.7	0.2
		SO_2	1.5	2.9	0.5
		O_3	1.5	32.9	0.05
		NH_3	6.7	1.6	4.2
		HNO_3	n.d.	n.d.	n.d.
		HCOOH	1.1	1.1	1.0
		CH_3COOH	1.2	1.0	1.2
Zlatá Koruna	Dec 11/Nov 12	NO_2	1.3	5.9	0.2
		SO_2	1.7	3.7	0.5
		O_3	4.0	42.6	0.09
		NH_3	10.7	1.8	5.9
		HNO_3	n.d.	n.d.	n.d.
		HCOOH	5.4	1.1	4.9
		CH_3COOH	4.4	1.0	4.4

Comparing the outdoor concentration values, the difference between the two sites is confirmed since Třeboň archive is most influenced by the small city sources of pollution showing higher values of nitrogen dioxide concentration, whereas at Zlatá Koruna higher ozone concentration values were recorded. The indoor values are quite similar at the two archives for most of the pollutants with the exception of ammonia and organic acids which show the highest concentration values at Zlatá Koruna. On the basis of the results collected and of the I/O ratios calculated it can be concluded that Zlatá Koruna is slightly less influenced from outdoor environment. The measurement of nitric acid didn't show, in most of the campaigns, detectable concentration values. The detection limit of nitric acid of 1.3 μg/m³ was only exceeded at Třeboň during three months out of the twelve under investigation.

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ANALYSIS OF AEROSOLS DEPOSITS BY ION BEAM TECHNIQUES

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Keywords: Aerosols, Elemental composition, PIXE, RBS, PIGE, PESA

The nuclear analytical techniques such as PIXE (Particle Induced X-ray Emission), RBS (Rutherford Backscattering Spectroscopy), PIGE (Particle Induced Gamma-ray Emission) or PESA (Proton Elastic Scattering Analysis) are well suited for the direct measurement of aerosols deposits on thin filters or foils. The main advantages of these methods are direct measurement of aerosol deposits on filters (no preparation of sample prior to measurement) and multi-elemental and non-destructive character of analysis. There is a possibility to simultaneously combine several related methods. In such conditions almost all important elements on filter can be analyzed including H and main matrix elements as C, O, N, and S. The important feature of these methods is also a high sensitivity and reasonable detection limits (small amount of aerosol deposit can be analysed).

The potential use of the PIXE method for aerosol analysis was already proposed in the pioneer work of Johansson [1] in early seventies. Since then the PIXE and other ion beam analytical methods (IBA) plays a significant role in atmospheric aerosol research. Many field studies focused on aerosol concentration mass size distribution, long range transport, source identification, aerosol health effects, combustion aerosol emission and indoor aerosols were conducted with significant help of PIXE and related nuclear analytical techniques during past decades [2,3,4].

In our laboratory at INP in Rez, we have a long time experience with the IBA techniques used for investigation of aerosol samples, which has started as early as at eighties [5,6,7]. Lot of aerosol research has been done on the old 3.5MV Van de Graaff accelerator before it was decommissioned and placed in National Technical Museum in Prague in 2013. Recently we have moved our activities on modern 3MV Tandetron accelerator which provides an excellent ion beam stability and variability of experimental arrangements. A new multipurpose target chamber (similar to previous one on VdG accelerator [8]) has been constructed and placed on one of the ion beam lines at Tandetron accelerator. Presently, the chamber is equipped with two PIXE detectors, PIGE HPGE planar detector and two surface barrier detectors for RBS and PESA analysis. A modern digital acquisition system from XIA company (with up to 8 digital spectroscopic lines), and a home made control program written in LabWiev software are used for automatic spectra collection and sample manipulation, The experience with different types of aerosol samples collected on different filter or foil media, efficiency calibrations, detection limits and analytical uncertainties will be presented during the proposed talk.

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BASAMATIKUM – AEROSOL SPECTROMETER FOR WIDE SIZE RANGE INDOOR/ OUTDOOR MEASUREMENTS

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Keywords: UFPM, APS, indoor/outdoor, switching valve

Many of the research studies in the field of aerosol science are focused on the measurements of indoor environment. The main reason for this is due to the fact, that people spend every day most of their time indoors [1]. The indoor aerosol particles are studied mainly because of their inverse health effects [2], but also because of the negative effects on indoor environment itself and eventually also on cultural heritage [3]. Indoor air is generally affected by both indoor and outdoor sources [4]. The outdoor aerosol concentration depends on numerous factors like source emissions, ambient weather conditions, various removal processes, etc. [5, 6]. On the other hand, the indoor aerosol concentration is affected by outdoor concentration, factors influencing the indoor-to-outdoor relationship (such as ventilation rate, penetration factor, etc.), indoor emissions and removal processes (deposition of particles on inner surfaces) [7].

Therefore, there is an increasing need to measure the aerosol concentration both indoors and outdoors at once (or at least with reasonable time gap between indoor and outdoor measurement). The other demand, especially when such an instrument is placed indoors, where the inhabitants or employees reside, is often a limitation for the instrument to not bring any additional discomfort to indoor air (alcohol odors, radioactive source, etc.). At the same time we usually need to obtain information in quite a wide range of particle sizes. All these circumstances brought us to idea to combine the two commercially available aerosol spectrometers and a switching valve to form one measurement instrument allowing easy measurements of indoor/outdoor environments.

Combined wide size range aerosol spectrometer Basamatikum allows to measure particle number size distribution in a range between 20 nm – 20 mm. The instrument separates the measured aerosol particles into 58 size bins. The instrument can automatically switch the scanning between two sampling points (e.g. indoors and outdoors). It consists basically from two aerosol spectrometers (UFPM and APS, both TSI), electrically actuated ball valve, sampling tubing with isokinetic subsampling to both of the two spectrometers and two sampling lines. The overall control, data logging and saving to file, the switching between sampling lines and the user interface is provided by the means of the LACP-made (Laboratory of Aerosol Chemistry and Physics) software in LabVIEW programming environment.

The instrument was thoroughly tested during several intensive campaigns (almost one year of continuous measurement in Zlatá koruna, 4 two-week campaigns in Teplice and 4 two-week campaigns in Prague). Detailed presentation of the obtained results can be seen for example in [8]. Small issue connected with the charging in the UFPM spectrometers can be easily neglected, when we take into account that the primary purpose of the combined instrument is to evaluate the ratio between the two measurement places. Generally, the overall performance of the instrument was satisfactory and the whole instrument is suitable for deployment for a long term unattended operation.

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BASAMATIKUM – AEROSOL SPECTROMETER TESTED BY THE END USERS IN THE TECHNICAL MUSEUM IN BRNO

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The BASAMATIKUM – aerosol spectrometer for wide size range indoor/outdoor measurements was tested by the end users during a one month campaign in the Technical Museum in Brno - in room of Historical stereovision, which is a small room equipped with the wooden slide viewing device for 25 people (climate is not controlled by the central air-condition system). Room climate is regulated by the cooler unit with dust filter to control the temperature between 19 °C and 22 °C and mobile humidity control unit to set the relative humidity from 45 % to 55 %.
Time behavior of submicron particles concentration showed that visitors did not affect the fine particle concentration and that these particles mostly came from outdoor environment. The average concentration of indoor particles was 1.5 x 10^3/cm^3, which was about 3.5 times lower then outdoors. Indoor concentration of coarse particles showed periodical rising starting at the beginning of the opening hours, with maxima achieved at the end of visiting hours and subsequent decrease to initial values (Fig. 1). Bigger maximal concentrations were recorded during the first school week and then every weekend.

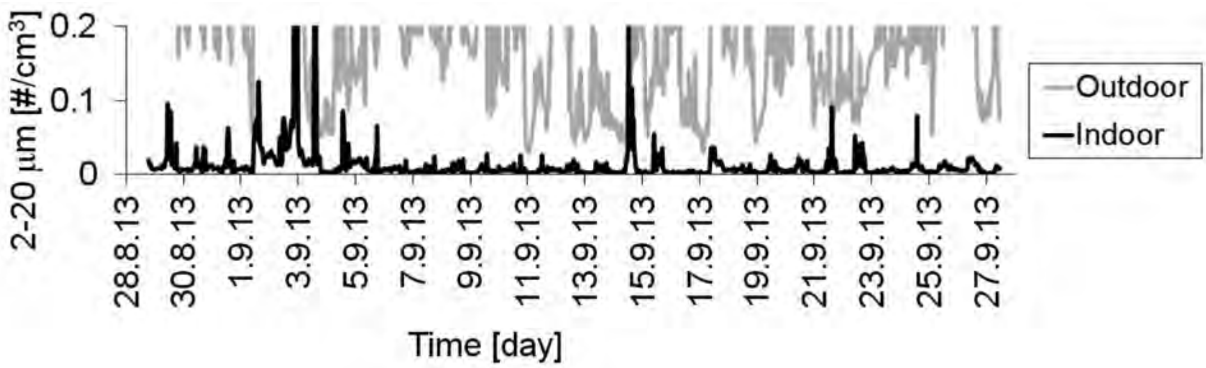

Figure 1. Time series of the indoor and outdoor number concentration of coarse particles (fraction 2-20 μm) during a one month campaign in the Technical Museum in Brno.

Correlating these experimental data with the previous not accruing measurements gave as the information about the efficiency of room technical utilities and the effect of the visitors on the air quality. Generally, evaluation of the data helped as to enhance the museum control strategy and gave as some interesting ideas for the building preventive conservation. Installation and operation of the BASAMATIKUM aerosol spectrometer was optimal, with no influence to the exposed showpieces or to the visitors comfort zone.

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MONITORING OF INDOOR AIR QUALITY IN LIBRARIES AND ARCHIVES

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Keywords: corrosion, classification, monitoring

It is essential that corrosion monitoring of indoor atmospheres be highly sensitive, especially, when corrosion rates corresponding to the lowest standard aggressiveness categories are supposed to be identified within one or a few days. The electrical resistance (ER) technique in combination with high sensitivity electrical resistance sensors enabled detection of a corrosion loss on an atomic scale. The aim of the testing was to indicate corrosive action of the outdoor and indoor conditions to corrosivity in the archive and to compare the response of the monitoring system with other techniques – quartz crystal microbalance (QCM) and coulometric reduction (CR) of corrosion products on coupons. Two case studies were performed in two historical buildings that are partially used as an archive.
The case studies follow the historical buildings of a monastery from 13th century and a chateau from 17th century that is currently used as an archive of historical documents. The conditions in the archive are not controlled and the indoor atmosphere quality is influenced by external aspects. The atmosphere aggressiveness inside the archive was monitored by three resistometric sensors – silver (50-nm), copper (100-nm) and lead (400-nm). Corrosion rates of silver and copper can be classified according to standards, while the lead aggressiveness classification is not available. And it is lead that is renowned for its significant sensitivity to organic substances that are a product of paper degradation. The loggers were placed 20 cm from a window. Both the ER and QCM techniques lead to the same corrosivity classification. The reason why the QCM does not distinguish between corrosivity towards copper and silver is probably the fact that the QCM register any increase in mass of the crystal, not just the corrosion products formation. CR provided the all-season overview of the corrosivity of the indoor as well as of the outdoor atmosphere.
Case studies have demonstrated the sensors' ability to timely inform the users about changes in the atmosphere quality. In confrontation with quartz crystal microbalance technique, resistometric sensors provided better explainable data. Case studies of indoor atmospheres of archives highlighted advantages of regular monitoring of corrosion aggressiveness. Sufficiently sensitive sensors are able to inform the user in time about the air quality impairment and may uncover unexpected influences crucial in terms of corrosion protection.

SURVENIR – THE NON-DESTRUCTIVE EVALUATION OF MATERIAL CONDITIONS IN CONSERVATION, THE ACTUAL AND THE POTENTIAL USE

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Keywords: non-destructive monitoring, paper analysis, SurveNIR, preservation

SurveNIR permits on the basis of special fast infrared technology and a user-friendly software, the computer-based, non-destructive analysis and evaluation. The developed solution for book and archive collections is so far unique in the world and revolutionized the assessment and evaluation of the aging condition of book and archival collections [1], [2].
Using Near Infrared (NIR) spectroscopy, an entirely non-destructive characterisation tool and surveying methodology was developed in the 6th Framework Programme SurveNIR collaborative project, 2005-2008. By building a large database of historic paper samples and by their detailed characterization, an incredible resource was built, now available for further studies. This database was used for chemometric calibration of a purpose-built NIR spectrometer to characterize the degradation rate of paper [3], [4].
In recent years, there has therefore been a growing market for applications. Especially NIRS is used for its advantages to control online processes. NIRS is a nearly ideal method for determining the water content in all kinds of products. The method finds application in quality analysis of agricultural products (like cereals, flour, milk, oil or fruits) and feed for the determination of moisture.
Lichtblau e.K. does use two applications for the paper measurements: a climate of approx. 18 °C/40 % RH and a climate of approx. 23 °C/50 % RH. This corresponds roughly to the climatic conditions of the North-South divide of Europe. That is the approach the climatic conditions to examine regarding their impact on collections in libraries and archives. This raises the question of how do optimally adapt the climatic conditions in libraries and archives to today's requirements with regard efficiency and effectiveness as well as to the requirements for the conservation of cultural heritage [5], [6].

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COMPARING OF IDENTICAL INCUNABULA STORED IN DEPOSITORIES WITH DIFFERENT QUALITY OF AIR

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Keywords: identical incunabula, paper, SurveNIR, quality of air

The research project of the Ministry of Culture presently being solved, "The methodology of evaluation of influence of air quality on book and archive collections" (2011-2015) should make more clear the relationship between environment quality and conditions of stored books and archive materials. The comparing of identical incunabula stored in depositories with different quality of air is a special part of this project [1].

Identical books (i.e. the books printed on the same paper and stored in various conditions) offer a unique source for research, which assists understand, how environment and manners of utilization affect condition of the books. Differences in conditions of the identical books reflect differences in a way of utilization in various libraries and differences in storage conditions.

In our experiment we start from the presumption that on printing identical incunabula, number of which was limited, identical or very similar paper was used from the same manufacturer, and that is why their conditions may reflect quality of environment, in which the incunabula were stored. A group of incunabula was selected, thus imprints published since the days of Gutenberg´s invention in the middle of 15th century as far as to the end of year 1500 and which can be found in the National Library in the Klementinum , in the Research Library of South Bohemia – Zlatá Koruna and in the Regional Museum in Teplice. Because it concerns only 6 incunabula, it was decided to include in the research also other incunabula, which can be found in the National Library and only in one of other examined libraries (in Zlatá Koruna or Teplice). With respect to difficult handling, the largest formats of these incunabula were excluded, and on the contrary, incunabula were taken into account with more identical copies, which will be possible to compare with one another. In research the identical pages are assessed.

Identical incunabula were measured with the use of SurveNIR measuring system. The method used compared measured infrared spectra (NIR) with extensive spectrum library of known samples of sheets of paper, in which pH were measured, together with degree of polymerization, and contents of lignin, proteins and rosins, tensile strength, tensile strength after folding, and presence of optical brighteners.

Conditions of bookbinding and book block may affect the damage by surrounding environment. Wooden cover and clamps prevent from penetration of surrounding environment into the book block, on the contrary, damage of cover and stitching, curled book block and bent page edges make it possible.

Incunabula of the National Library and of the Regional Museum in Teplice were deposited on a long-term basis in environment contaminated by pollutants. To that fact correspond also chemical and physical-mechanical properties of paper – lower pH, degree of polymerization, tensile strength, and tensile strength after bending – as compared to identical incunabula on deposit in the Zlatá Koruna in environment with low level of pollutants.

Physical conditions of volumes in all three libraries are comparable. No demonstrable correspondence between pH values and degree of polymerization and closeness of bindings was found.

Presented results were obtained with the support of the research project no. DF11P01OOVV020 Methodology of Evaluation of the Effect of Air Quality on Library and Archival Collections – Ministry of Culture of the Czech Republic

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APPLICATION OF DUST PARTICLES ON MODEL SAMPLES OF PAPER AND TESTING EFFICIENCY OF MECHANICAL CLEANING

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Keywords: mechanical cleaning, dust

Dust particles sticking to the surface of paper are highly hygroscopic, which is a possible cause of activation of microbiological attack. They consist of salts, soot, grease from imperfectly burnt hydrocarbon fuel, and other substances present at emissions. Pollen, spores, and other biological matters, are other integral components. Salts of acids cause acidic hydrolysis of cellulose, and transient metals have catalytic effect on all degradation processes. Effective removal of dust particle is, therefore, an integral part of restorer´s procedure. Various techniques were examined of application of dust particles on a paper, so that they mostly corresponded to real samples. Subsequently, various materials used for mechanical cleaning in conservational practice were tested, air flow and vacuuming, and mechanical cleaning by the help of a brush. For evaluation of mechanical cleaning efficiency, measurement of color changes was used in system CIE Lab, and mass difference. For comparison of extent of paper surface damages, the samples were observed under microscope, and by the help of confocal microscope, 3D scans of surfaces were evaluated.
Real dust obtained by mechanical cleaning of books in depositories of NL by the help of a vacuum cleaner was used for application. Two methods were selected for application of dust; application by frictioning, and application by a roller. As a paper pad, Whatman No. 1 chromatographic paper was used.
The materials used for mechanical cleaning were on all known bases. It concerned polyvinyl chloride, factice, rubber, and latex. It concerned solid materials, fungi, and pulverized materials. At mechanical cleaning by air flow, vacuuming and shot blasting with different amount of air and CO_2 flow are compared.

Materials used for mechanical cleaning

1. Wishab
2. Wallmaster
3. Sanford Magic Rub Vinyl Eraser
4. Able Rub Art Gum Erasers
5. Sanford Peel-Off Eraser Stick
6. Document Cleaning Powder
7. Document Cleaning Pad
8. Swish Cleaning Cloths
9. Purus Ceiba
10. Adhesive Pick Up Rubber Cement Eraser
11. Groom Stick Book Cleaner
12. Kneadable Rubber Eraser
13. Staedler Mars Plastic Eraser
14. Brush

The objectives of this project are to evaluate efficiency and, at the same time, friendliness of the most frequently used materials and aids for mechanical cleaning of paper. In light of efficiency, Sanford Magic Rub Vinyl Eraser (3), Able Rub Art Gums Erasers (4), Sanford Peel-Off Eraser Stick (5) appeared as the best ones. It concerned especially hard stripping rubbers on different chemical bases, in which the most expressive color change occurred after mechanical cleaning. At the same time, however, visible surface erosion occurred of paper mats with these materials, which can be seen on microscope. Evaluation friendliness to paper will be objectively assessed by the help of confocal microscopy.

This work was supported by the Ministry of culture ČR under the grant Methodology of evaluation of effect of atmosphere quality on library and archive funds, identification code DF11P01OVV020.

THE IMPACT OF A HISTORICAL CONSERVATION METHOD FOR THE PRESERVATION OF ENTOMOLOGICAL COLLECTIONS ON THE INDOOR AIR QUALITY OF REPOSITORIES

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Keywords: emission, naphthalene, formaldehyde, entomological collection, air purification

Background
Museums of Natural History serve community and science by paying serious attention to understanding biodiversity. Recently Dutch entomological collection from different institutes have been combined into one main collection. The collection preservation was based on moth-balls (naphthalene). Workers complained on the odor and sharp feeling of the eyes, therefore investigations were needed to know the origin of the contaminants and to improve the indoor air quality.

Aim
To establish possible risks for the occupational health of working with the entomological collection before and after moving and to improve the indoor air quality.

Methods
The indoor air quality of the old and new repositories was evaluated by analyzing air samples and measuring the ventilation rates. Tenax™ GR was used for the adsorption of VOCs and DNPH cartridges were used for the adsorption of volatile carbonyls. Analyses have been performed using GC-MSMS and LC-MS. Quantification was done using standards. Additionally the air purification system was evaluated and modified. Personal monitoring of the employees finally showed the exposure to formaldehyde.

Results
The old repository contained over 800 cabinets with 10 drawers each (filled with 5-6 moth-balls). The highest concentration observed of naphthalene and formaldehyde indoor were subsequently 9300 and 169 $\mu g/m^3$. The formaldehyde concentration exceeded the Dutch threshold limit value of 150 $\mu g/m^3$ [1]. Chamber emission tests on the wooden cabinets indicated that they emit mainly formaldehyde. All moth-balls were removed and the collection was moved. Although the repository had air purification naphthalene and formaldehyde were present at high concentrations. Formaldehyde exceeded again the Dutch threshold limit value resulting in closing the storage rooms for workers. After evaluating the current purification system it was concluded that a wrong filter medium was originally applied. Additional tests showed that a combination of chemical filters, containing sodium- or potassium permanganate, were able to reduce effectively both concentrations naphthalene and formaldehyde.

Conclusions
Old preservation methods may have a high impact on working with collections due to the emission of harmful volatiles. Air purification is able to reduce the concentration of contaminants indoors significantly, however it depend on the type of filter medium.

Acknowledgement
Naturalis Biodiversity Center is highly acknowledged for funding the work.

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HISTORIC WOODEN ARCHIVAL BOXES: TO DISCARD OR NOT TO DISCARD?

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A research network was launched for the study of the interactions between historic wooden boxes used to keep archival records, their environment and their contents. It includes the center for research on the conservation of collections (CRCC), the center for research and conservation of the museums of France (C2RMF), the scientific and technical laboratory of the National Library of France (BnF) and the research laboratory on wood material (LERMAB – ENSTIB Epinal) in collaboration with the laboratory of molecular and structural archeology (LAMS), Puratech and Xylodata companies.
The work first focused on identifying and dating 288 historic boxes from French archives using dendrochronology. Purafil coupons, Radiello and IVL sensors for aldehydes and organic acids were used to evaluate the air quality in several archives' indoor air and in a set of wooden archival boxes. The air exchange rates were measured as well. Emissions of VOCs were also measured in an emission chamber on oak samples from the XIVth to the XIXth c.
The concentrations of aldehydes and organic acids were in the range usually found in archives indoor air and were rather similar inside and outside the boxes. The impact of volatile organic compounds (VOCs) emitted by the wooden boxes on paper was evaluated by exposing model papers in the boxes for several months and measuring the viscometric degree of polymerization (DP_v) (ISO 5351 standard) and the oxidation state of cellulose (T430 cm – 99). It was found that regardless of their age, most boxes did not seem to present a major risk for the long-term preservation of cellulosic materials and metal objects.

THE EMISSION OF MERCURY FROM MERCURIC CHLORIDE TREATED HERBARIUMS

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Keywords: mercury emission, natural history, herbarium

Introduction

One of the most used biocides for disinfection of natural history collections and in special herbarium collections is mercuric chloride, $HgCl_2$ [1]. $HgCl_2$ forms solid white crystals, and once it was applied as a medicine against e.g. syphilis. However, $HgCl_2$ is extremely poisoning and has the ability to sublimate, that is why it is also called "corrosive sublimate". As it has been suggested that $HgCl_2$ decomposes into metallic mercury (Hg^o) and may emit from the collection and pollute the indoor air. This work is related to the relation of the concentration of Hg inside a herbarium box and the Hg-emission behavior of the collection once it is out the box and being consulted.

Experimental

29 herbarium boxes were selected for our work by *Naturalis Biodiversity Center* at Leiden. The mercury concentration in the box was analyzed directly by putting the inlet of the Mercury Vapor Monitor MV-3000[2] in the box and by reading at stable signal (usually < 60 s). Subsequently the content of the boxed was put into a small scale emission chamber and at different ventilation rates the concentration of mercury in the air was measured. Interpretation of the measurements were done using the theories of Hoetjer-Berge-Fujii [3-6].

Results

Direct analysis of the air in the herbarium box resulted in distribution of the concentration within a range of 10 – 60 μg/m^3. Additionally concentrations were found up to 90 μg/m^3. there is a straight line occurring once the ventilation rate divided by the emitting surface is plotted against the reciprocal Hg concentration. Subsequently a relation was established between the direct measured concentration and the calculated concentration at a ventilation rate of 1 [1/h]. Figure 1 shows an example of the result of the Hoetjer-Berge-Fujii emission line for one sample coming from a herbarium box. The calculated correlation (R^2) was 0.9693.

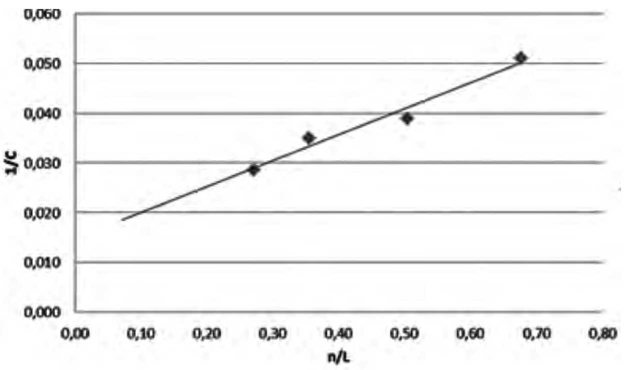

Figure 1. the emission of mercury from a herbarium box, measured at different ventilation rates

Conclusion

The emission of mercury from herbarium collections fits in the theories of Hoetjer-Berge-Fujii. Therefore calculations can be made to predict a mercury concentration in the air if one or more collections are being consulted. Also predictions can be made if large amounts of the collection are put in a digitization area. Subsequently precautions can be made for a safe work environment.

Acknowledgement

Naturalis Biodiversity Center is highly acknowledged for funding the work.

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VERMILION TURNING BLACK? BLAME MERCURY!

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Since antiquity, red mercury sulfide (α-HgS), called cinnabar in its natural form and vermilion in its synthetic form, has commonly been used as a pigment [1]. An undesirable phenomenon is the degradation of this bright red material, causing it to turn black. This degradation phenomenon has been observed on the surface of frescoes at important heritage sites such as Pompeii, and of paintings from famous Masters such as P. P. Rubens and P. Brueghel. Appropriate conservation of this valuable and irreplaceable heritage requires a profound knowledge of the degradation mechanism of the pigment.

Three factors are suspected to influence the degradation: light, humidity and chlorine. The origin of the latter can be intrinsic, but also environmental factors such as the deposition of chlorine-rich particulate matter (PM) is a far from negligible source. Several methods such as XRD, XANES and SIMS have been employed to identify the degradation products: $HgCl_2$, Hg_2Cl_2, $HgSO_4$, Hg_2SO_4 and $Hg_3S_2Cl_2$ [2-4]. Yet, none of these compounds has a dark colour that can explain the blackening of α-HgS in a convincing manner. Several hypotheses for the decomposition and discolouration circulate, some based on the formation of black α-HgS [5] or of metallic mercury as a deposit [2]. Thus far, however, none of these compounds have been detected on naturally or synthetically degraded HgS paint.

This study presents the results of electrochemical experiments that demonstrate for the first time the formation of metallic mercury as a degradation product of α-HgS in the presence of light and chlorine ions [6]. Moreover, the experimental setup provides an easy and fast method for the evaluation of the potential harmfulness of different environmental compounds/conditions on pigments such as α-HgS.

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MODELLING OF PARTICULATE MATTER INFILTRATION IN THE BAROQUE LIBRARY HALL IN PRAGUE

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Keywords: infiltration, modeling, emissions, library

Indoor air quality assessment in museums and libraries is important as indoor pollutants threat the preservation of the collections. Particulate matter (PM) can cause damage of the materials by particle soiling or chemical reaction due to deposition and absorption. Indoor pollutants either originate from indoor sources or penetrate indoors through the building envelope.
The aim of the current work was to analyze the characteristics of indoor PM and the influence of outdoor PM to the indoor PM levels in the Baroque Library Hall in Prague (Czech Republic).
Three intensive campaigns took place during spring, summer and winter 2009. The number concentration of PM was measured both indoors and outdoors with an APS (TSI, 0.5 – 20 μm) and an SMPS (TSI, 14 – 700 nm) instruments. The indoor particle number concentration was modelled using a dynamic mass balance model:

$$\frac{dC_{in}}{dt} = PaC_{out} - aC_{in} - kC_{in} + \frac{S}{V}, \quad (1) \qquad \frac{dC_{in}}{dt} = PaC_{out} - aC_{in} - kC_{in} \quad (2)$$

where, C_{in} is the indoor particle concentration, C_{out} is the outdoor particle concentration, t is the time, V is volume of the area under study, P is the penetration efficiency, a is the air exchange rate, k is the deposition rate and S is the emission rate of particles. Under the absence of primary sources (equation 2), the independent parameters are k and P.
In order to reveal the influence of outdoor PM to the indoor concentration, equation (2) was evaluated for different pairs of k and P. The results revealed a linear relationship between the two parameters with no unique solution. Table 1 presents the best-fitted values of k and P for each measurement period. Moreover, a dependence of k and P on particle size found when the model applied on the different size fractions. Higher rates of k found on nucleation (< 100 nm) and coarse (> 2.5 μm) particle modes and higher penetration efficiency on accumulation (100 nm < < d < 710 nm) and fine (d < 2.5 μm) particle modes. High correlation between the measured data and the modeled values found in most cases with average $R^2 = 0.9$, indicating that the indoor concentration is well described by equation (2). Nonetheless, in the coarse particle mode, the correlation was low and R^2 varied between 0.1 – 0.58, mostly due to inability of the model to compute the several peaks of indoor number concentration.

Table 1. Input parameters of the modeled indoor concentration.

	APS			SMPS		
Input parameter	Spring	Summer	Winter	Spring	Summer	Winter
Penetration efficiency (P)	0.45	0.35	0.62	0.51	0.34	0.55
Deposition rate (k), min^{-1}	0.0008	0.0001	0.0012	0.00026	0.00011	0.00041
Air exchange rate (a), min^{-1}	0.0022	0.001	0.0025	0.0022	0.001	0.0025

Fine particles found to dominate both the indoor and outdoor number concentration with fractions close to 0.99 and 0.98 respectively. Along with higher I/O ratio (~ 0.6) on 0.1 – 1 μm particle sizes, it is believed that the enrichment of fine particles inside the library is the result of particle penetration from outdoors. The relationship between indoor and outdoor pollutants at the same site is also reported in [1]. On the other hand, low response of the model at the coarse particle mode, especially at periods with increased PM number concentration (peaks) suggests the existence of indoor sources. It is believed, that during these periods, indoor sources correspond to human presence inside the library. Indeed, all the increased concentration periods reflect to visiting hours. Moreover, the coarse PM indoor number concentration during visiting hours (10 am – 17 pm) increased by 55 %, supporting the above assumption. In order to determine the indoor emissions, the equation (1) was used instead of equation (2). The average particle emissions inside the library calculated at 9.7×10^5 particles min^{-1}. In summary, fine particles likely originate from outdoors through the building envelope, whereas, coarse particles are generated or transported indoors by the visitors of the library.

The experimental work was supported by EEA/Norwegian Financial Mechanisms under grant A/CZ0046/2/001. The modelling work was supported by the European Union 7th framework program HEXACOMM FP7/2007-2013 under grant agreement N° 315760 and the Ministry of Culture of the Czech Republic under grant DF11P01OVV020.

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SIMULTANEOUS MEASUREMENT OF NITRIC AND NITROUS ACIDS BY MEANS OF A NOVEL MULTIPOLLUTANT DIFFUSIVE SAMPLER

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Keywords: archives, gaseous pollutants, diffusive sampling

The study of the “family” of nitrogen containing compounds, including nitrogen oxides, nitrous and nitric acid, PAN, is important to clear the relative abundance, role, of possible harmful potential and impact on indoor and outdoor air quality.
The importance of indoor monitoring in environments devoted to conservation of artifacts, in particular books and manuscripts, such as libraries and archives was emphasized in previous works [1]. Damage to paper due to the presence of acidic species was studied both in artificial [2] and in real conditions.
A well established and known technique to collect these atmospheric trace gases is represented by denuder sequence based systems employed to sample the species separately and to avoid mutual interferences, but this technique is time consuming and labor intensive. Diffusive sampling can overcome these problems since it represents an easy to use technique which exploits the spontaneous diffusion of species collected by specific absorbing media.
Recently a novel “multipollutant” diffusive sampler was designed for simultaneous sampling of three different pollutants (nitric acid, nitrous acid and nitrogen dioxide) collected at separate sampling stages.The sampler has been employed to perform measurements at two locations in the Czech Republic, National Archives in Prague and Regional Library at Teplice. Both locations represent a different outdoor environment with high traffic load in Prague and high load of industrial emissions at Teplice. The outdoor measurements in Prague have been performed on balcony of building oriented to busy street (OUT), indoor measurements have been done in room of the “Bohemian tables (BT)” and in room of “Archives of the Czech Kingdom (ACK)”. The first room contains “Bohemian tables” date since 1541 (the oldest part since 1278 was burnt during the great burning in Prague in 1541), the second room collects manuscripts of the Czech Kingdom since the twelve century. Both rooms have its own HVAC system. The Regional Library at Teplice is located in chateau in the center of city and contain Cistercian monastery library in Osek, former chateau library of Clary-Aldringens, and the collection “Goethe-Schiller”. Monitoring scheme is in Table 1.

Table 1. Monitoring Scheme.

Location	Sites	Season	Dates	Pollutants investigated
Prague	IN 1 (BT) IN2 (ACK) OUT	Spring	04/08-05/10/2013	SO_2, O_3, NH_3, NO_2, HNO_3, HONO HCOOH, CH_3COOH PM
			05/10-06/11/2013	
		Winter	ongoing	
Teplice	IN OUT	Spring	04/09-05/09/2013	
			05/09-06/10/2013	
		Winter	ongoing	

The measurements have been carried out using diffusive samplers Analyst for SO_2, O_3, NH_3, NO_2, HNO_3 and IVL samplers for formic and acetic acids. Additional measurement has been provided through the parallel exposure of the multipollutant sampler in the case of NO_2 and HNO_3.
Preliminary results collected at present indicate that NO_2 concentration values were higher, as expected, in Prague, the I/O ratios calculated both for NO_2 and HNO_3 showed a greater penetration of pollutants indoors at Teplice and can possibly indicate the effectiveness of the indoor air treatment unit installed in Prague’s archive. HONO concentration values were, as expected, lower outside at both of the sites.

This work was carried out in the framework of CNR – AVCR Agreement Joint Projects 2013-2015.

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POLLUTION SOURCES IN MUSEUM ENVIRONMENTS: INTEGRATED REAL-TIME AND OFF-LINE MEASUREMENTS TO INVESTIGATE INDOOR-OUTDOOR EXCHANGE DYNAMICS

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Keywords: indoor-outdoor exchange dynamics, portable real-time instrumentation

Good practice in preventive conservation of cultural heritage primarily requires the development of monitoring strategies of indoor air quality to limit the impact of pollution on the museum collections. To this aim, an integrated analytical methodology is necessary in order to investigate in different museum contexts the synergic interplay of contaminants and of thermo-hygrometric parameters on the degradation of art-objects.
A multi-technique approach which combines real-time measurements by portable instrumentations with off-line chemical analysis of PM and gaseous pollutants has been experimented to monitor indoor air quality in two museum painting collections characterized by very different urban environments, microclimate control systems and visitor flows.
More specifically, micro-climatic trends, aerosol size distributions, aerosol black carbon contents and ozone concentrations have been recorded simultaneously at high temporal resolution (1 min) with portable instrumentations during seasonal campaigns. Real-time measurements were performed both in a fixed and a mobile mode to investigate temporal and spatial variation of environmental parameters inside the museum and results have been compared with the outdoor background (Fig.1). Off-line chemical analysis of aerosols samples and of selected organic volatile compounds collected onto filters by several techniques, including chromatography, SEM-EDS and ICP-AES, served to put on a robust chemical ground the on-line characterization. The cross-correlated analytical data available from this integrated approach afforded us deep insight into indoor-outdoor exchange dynamics, allowing tracing indoor pollutant sources. This basic information was crucial to plan strategies to improve indoor air quality in the selected museum.

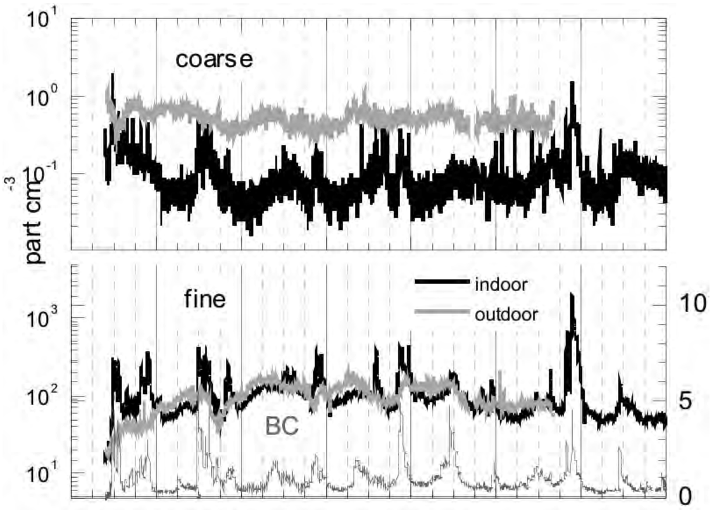

Figure 1. Example of time series of aerosol (fine and coarse fractions – black line) and black carbon (red line) concentration profiles measured inside a museum. The correlation between the intense indoor contamination episodes of fine particulate matter and the black carbon trend is clearly shown. For comparison, the outdoor background particulate matter profiles are also shown (grey line).

This work was carried out within the research activities of the project “Sviluppo delle attività di ricerca, valutazione e tutela conservative” of the Regione Umbria, “Progetto 1 del Primo atto integrativo all’APQ: Tutela e prevenzione dei beni culturali”.

OZONE MONITORING IN MUSEUM ENVIRONMENTS BY ELASTOMERIC DOSIMETER FIELD EXPERIENCES

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Keywords: latex, ozone, dosimeter, monitoring

In recent years latex has been considered as an ozone dosimeter for museum environments. Most of the studies were based on laboratory experiments, whereas the field experiences are restricted to measurements in storage places [1, 2].
In this paper, the results of field experiments related to latex-based elastomeric strips in exhibition halls and display cases in the Pergamon Museum and the Bode Museum in Berlin, as well as in the Reza Abbasi Museum and the Malek National Library and Museum Institution in Tehran are discussed.
These museums are located under different geographical and climatic environments and have to face different challenges in terms of facility design, air conditioning system, number of visitors and materials, among others.
The changes in the appearance (color and surface) of the latex strips which had been placed into various locations in the museums were documented at intervals over one year. In parallel, air exchange rate of display cases and micro-climatic conditions in the museums including temperature, humidity and light were monitored.
After period of natural aging of the strips, both changes in their appearance as chemical changes – including color, microscopic and molecular features using Colorimetry, Digital Microscopy and Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy (ATR-FTIR) – were studied. As a comparison, some artificially aged strips were studied with the same methods.

In addition to the evaluation of the elastomeric strips as an ozone dosimeter, it is the second aim of the project to estimate the ozone concentration, and to identify the internal and external sources of this pollutant in the museums.

This work is supported by the Deutscher Akademischer Austausch Dienst (DAAD).

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INDOOR/OUTDOOR PARTICULATE MATTER CONCENTRATIONS AND MICROBIAL LOAD IN MUSEUMS

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Extensive indoor/outdoor measurements of particulate matter mass/number concentrations and microbial load were performed in two museums and one library in Greece for a period of one year at selected time intervals. The aforementioned are: the Historical Museum of Crete, located in Herakleion/ Crete (costal environment), the Criminal Museum of the University of Athens (urban environment) and the *Neofytos Doukas* Library, located in Zagori/ Ioannina (mountainous environment). Their collections consist mainly of organic materials (textile, leather skin, parchment, bones, wood, paper, etc).
In conjunction with the particulate measurements (PM_{10}, $PM_{2.5}$, PM_1, PM_1 number concentration, mass size distribution) were also performed measurements of microorganisms in air (heterotrophic bacteria, actinobacteria, acid producing bacteria and mesophilic fungi), gaseous pollutants (NO_2, SO_2 and O_3) and environmental conditions (continuous measurements of temperature, relative humidity and lighting indoors/outdoors). Early warning sensors (EWOs) were also deployed to report the damage level of the organic exhibits. Air exchange rates were estimated using the exponential decay of the concentration of CO_2.
The particulate matter measurements showed a considerable variability which is related to the outdoor concentration levels, indoor environmental conditions, infiltration rates and indoor activities such as the number of visitors. Figure 1 shows the yearly average mass concentrations of particulate matter in the different museums during the measurement campaigns. The lowest particulate matter concentrations were observed at the Zagori museum which is located in a mountainous region at the north west of the Greek mainland, whereas the highest particle levels are observed in the Athens museum. In addition, the $PM_{2.5}$ fraction in the PM_{10} mass is ranging from 0.9 to 0.7 in the sampling sites indicating also that particles indoors have a significant outdoor origin. Furthermore, the average PM_{10} mass concentration indoors is higher than the outdoor levels for all three museums. This finding indicates that the presence of visitors in the museums contribute to higher concentrations through particle resuspension.

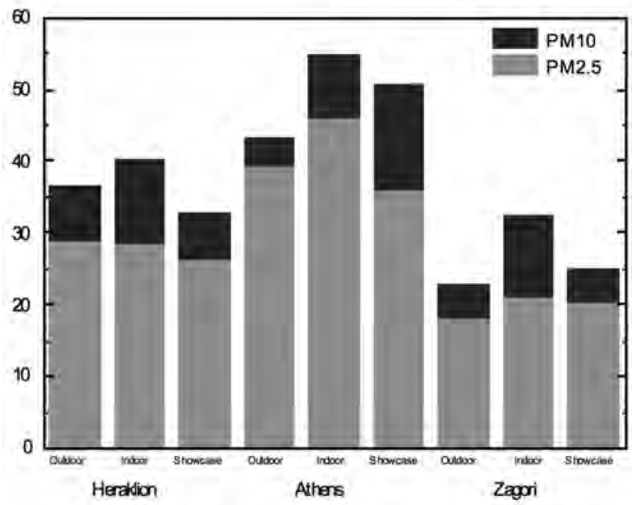

Figure 1. Yearly average values of the particulate matter concentrations in the three museums.

Measurements of airborne microorganisms at the museum sites showed that the lowest concentrations of airborne microorganisms were measured in the Historical Museum of Crete in Heraklion. In accordance, the concentrations of airborne microbes in the closed showcases of this museum were from 24 % to 58 % reduced. In contrast, the highest concentrations of airborne bacteria were measured in the library of N. Duka in Zagori, whereas the highest concentrations of airborne fungi were measured in the criminology museum in Athens. The closed showcases of these two museums could only protect the exhibits from airborne fungi, actinobacteria, and acid producing bacteria but not from heterotrophic bacteria, which were more abundant inside the closed showcases.
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POLLUTANT PREVENTION IN THE NEWLY REOPENED KUNSTKAMMER OF THE KUNSTHISTORISCHES MUSEUM, VIENNA

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Keywords: pollutant prevention, show cases, tendering process

The Kunstkammer – the most extensive and highest-quality collection of its kind worldwide – was reopened in March 2013 after undergoing a ten-year reinstallation project. The Kunstkammer arose from the former imperial collections and contains exceptional works of goldsmithing and glyptic, bronzes, ivories, clocks, automata and scientific instruments dating from the early Middle Ages to the 19th century. The heterogeneous collection consists of objects made from diverse materials, in many different production techniques and the whole range of states of preservation. Most of these objects are highly sensitive to external and internal air pollutants.
The proposed paper presents the concept of pollutant prevention for the collection, gives an overview of the measures that were conducted and describes the problems that appeared during implementation of the new permanent exhibition.
The HVAC concept for the historical premises of the Kunstkammer is based on a passive air conditioning system. The most important elements of this system are tightening of the building envelope, minimizing of external heat input, controlled fresh air supply and heating and cooling via activating of the thermal mass of the building. The re-circulated indoor air and supplied outdoor air are cleaned continuously using activated carbon filters. To further prevent the generation of air pollutants, especially low-pollutant building materials were selected for furnishing the historical interiors and pollutant-adsorbing material was used for all wall coatings.
The heterogeneity of materials and states of preservation of the collection made it necessary to present artworks in show cases with different micro climate and different pollutant filtering. Two thirds of the overall 294 show cases were equipped with an internal air circulation system with passive air conditioning and pollutant filtering for delicate objects made of enamel, glass, silver, gilded silver, organic materials and material combinations. Due to economic reasons one third of the show cases for artworks of bronze, terracotta or stone, was built without air circulation and pollutant filtering.
To assure functionality of the air circulation system, the showcases were designed as air- tight enclosures with an air exchange rate of 0.1 per day. Simulation calculations were performed to assure the functionality of the air-circulation system.
It was essential for pollutant prevention inside of the show cases to introduce conservational specifications into the tendering process for these cases and to stipulate contractually the conservational requirements in the product specification.
The requirements for selection of show case materials were defined mainly based on the now published BEMMA scheme of BAM (Federal Institute for Materials Research and Testing, Germany) [1]. For monitoring emissions in the show cases, a set of key pollutants was defined. Their concentrations analyzed by standardized analytical procedures were not to be exceeding the given threshold values. In a multi-phase tendering process the building of test show cases was commissioned, emissions within them were analyzed and the results of these analyses were used as one of the key criteria for awarding the building of the show cases.
The contractor building the show cases was asked to test all constructing materials by emission chamber measurements and submit the results and product specifications. In addition Oddy tests were conducted for all materials used for the show cases like textiles, object mounts, etc. [2, 3]
After completing the show cases, exemplary emission measurements were performed in cases with and without an air circulation system and pollutant filtering. After eight months in operation, these measurements were repeated. The partly unexpected results will be presented and discussed in detail in the proposed paper.
In all rooms of the Kunstkammer and exemplarily in some selected show cases a continuous VOC monitoring with a handheld measuring unit (ppbRAE 3000) was implemented. Besides a continuous surveillance of the environmental conditions, this also offers the possibility of observing and evaluating the emission potential of more special operations, like e.g. floor cleaning and maintenance.

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NOVEL SENSORS FOR DETECTION OF SELECTED PESTICIDES ON MUSEUM OBJECTS

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Keywords: pesticides, sensors, colourimetry

Mercury compounds, particularly mercuric chloride ($HgCl_2$), have been used in past treatments to protect objects from attack by various insects and their larvae.[1-7] The persistence of mercury-containing residues on the surface of objects presents potential toxicity problems to those handling, accessing or studying collections. Before mitigation measures are taken to decontaminate objects methods of analyses are required that permit rapid on-site methods of determination to identify objects previously treated with mercury-containing salts. Handheld X-ray fluorescence (XRF) instruments have been used to successfully detect mercury salts on the surface of objects, however the instruments are relatively expensive, require specialist training and shipping conditions due to the presence of a radioactive source, and only measure discrete points on an object; contaminated sections may be missed. Dussubieux *et al.* described the capability of XRF as "semi-quantitative at best" and noted that the instrument does not take matrix or surface variation into account.[8] In 2000, Odegaard, Carroll and Zimmt published a collection of tests for museum objects, including the use of diphenylcarbazone (DPC) for mercury salts.[9] The DPC reagent was prepared as a 1 % ethanolic solution and applied to swabs collected from the contaminated object. This colourimetric test is extremely useful however the reagents have to be prepared fresh prior to use.
This paper will discuss the use of sensors that colour in the presence of mercury-containing salts. In this work the DPC reagent was loaded into an agar gel permitting ease of transport, storage and application. On contact with a swab containing $HgCl_2$ the sensor immediately developed a strong indigo colour. Moreover the doped agar gel is robust; 2 months after preparation a dried gel coloured on immediate contact with a contaminated swab. To simulate a contaminated museum object, a 250 mg piece of fur cloth was spiked with 50 mg of $HgCl_2$ and swabbed with a cotton bud wetted with distilled water. The swab was then applied to the doped agar gel and an instant positive result was obtained. The doped agar sensor is also selectively sensitive to chromium (VI) salts after pH modification of the swab. The developed sensors have been shown to be robust, easy to use, fast and cheap to manufacture representing a new useful tool in the heritage sector.

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BIOAEROSOL IN INDOOR ENVIRONMENTS FOR CONSERVATION OF CULTURAL HERITAGE: POTENTIAL RISKS FOR HISTORICAL-ARTISTIC MANIFACTS AND HUMAN HEALTH

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Keywords: biological particles, preventive conservation, biodeterioration, healthcare.

An integrated approach was applied for the characterization of the biological airborne particulate in four Sicilian sites with peculiar structure, thermo-hygrometric and lighting parameters. We focalized the attention on: *i*) *Crypt* in the *Cathedral Treasury Museum* (Palermo), an underground environment (lithic and stone artifact), daily visited by tourist and characterized by a reduced indoor-outdoor exchange; *ii*) the *Saints Cave* in Licodia Eubea (Catania), a semi-confined environment (fresco), strongly influenced by the surrounding countryside and by a continuous airflow; *iii*) the *Diocesan Historic Archive* in Palermo, (documentary funds, IX-XX sec.), characterized by low air change rate and reduced frequency of fruitors; *iv*) the *Sibilla Antrum* (Trapani) a hypogeal environment (frescoes), where biological particulate can be vehicle by visitors and sometimes related to the presence of rodent pest.
Non-invasive sampling was carried out on surfaces by Nylon membrane or by sterile swab. A portable sampler equipped with gelatin filters was utilized for aerosol.
Microbial consortia colonizing both the works of art surfaces and the aerosol of conservation/exposure environments, were revealed and characterized by optical and electron microscopy (OM, SEM, CLSM), *in vitro* culture and molecular analysis [1-3].

a) b) c)

Fig. 1: (a) SEM micrograph showing microbial colonization of rodent pest metabolic products; (b) In vitro culture on Nutrient agar of bacteria and fungi sampled by Nylon membrane fragment; (c) PCR products, corresponding to 16S rDNA portion of Cyanobium sp., resolved by (2%) agarose gel electrophoresis.

Combining biological results (Fig.1) with environment parameters data, acquired by HOBO U12 (temperature / relative humidity/ lighting) data-loggers (equipped with EEPROM memory), we define a protocol to prevent artifacts biodeterioration and to evaluate the potential health risk for visitors and operators, according to a preventive conservation strategy [4].

This work was developed in the *Research Project It@cha – Italian Technologies for Advanced application in Cultural Heritage Assets*, under grant *PON "Ricerca e Competitività" 2007-2013*.

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EVALUATION OF THE MICROBIAL QUALITY AND AIR DISINFECTION EFFECTIVENESS IN MUSEUMS AND LIBRARIES

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Keywords: microorganisms, bioaerosol, workplaces, disinfection

In libraries and museums, technical materials e.g., paper, fabrics, wood, and leather can induce microorganisms growth. Many microbes contribute to degradation of historical objects and archival materials. Examples of biodeterioration include weakening or loosening of paper, books overgrown with fungi and foxing, mostly appearing in the form of loss of structure, discoloration on the surface and the presence of filamentous fungi and slimy substances [1]. Work with materials, contaminated by microorganisms may affect the health of the personnel. Indeed, the occupational diseases of this group of workers include allergies, upper respiratory tract infections, dermatoses, and other disorders linked to the presence of fungi in buildings, such as SBS (Sick Building Syndrome) and mycoses [2,3]. Therefore, it is essential to provide personal protection for employees and maintain hygiene of the storage areas. In practice, such areas are not cleaned and disinfected.
The aim of this study was the assessment of air quantitative and qualitative microbial contamination and determination of the effectiveness of disinfection methods: photocatalytic ionization, UV irradiation and chemical misting with quaternary ammonium salts (QACs) in library and museum storage areas.
Disinfection was carried out using FreshAir purifiers, MEDIVENT flow lamps, Mgła-E TURBO electrical sprayer with QACs. The air was sampled with a MAS-100 Eco Air Sampler. The microorganisms number was determined by culture method. The identification was performed by microscopy method (molds) and biochemical tests (bacteria, yeast).
The number of microorganisms in the library air, prior to the process of disinfection was 3.0×10^2–6.9×10^2 CFU/m^3, with the fungi as a prevalent group (1.7×10^2–5.0×10^2 CFU/m^3). The number of microbes in the museum air was much higher, the total microbial count was 5.4×10^2–4.0×10^4 CFU/m^3, with fungi amounting to 6.3×10^2–3.9×10^4 CFU/m^3. In museums, the most commonly isolated were microorganisms from the genera: *Bacillus, Chryseobacterium, Kocuria, Micrococcus*, *Paenibacillus, Pseudomonas, Staphylococcus, Aspergillus, Mucor, Rhizopus*. Among the microorganisms present in the libraries' air, with the highest frequency were isolated genera: *Bacillus, Staphylococcus, Micrococcus, Cladosporium.*
Photocatalytic ionization and UV irradiation were found to be highly effective in reducing the microorganisms number in the air (reduction R=73–99 %). Chemical disinfection showed lower efficiency (R=0–84 %), but it was found to be superior in terms of moulds elimination, especially those resistant to other methods. Longer disinfection time of photocatalytic ionization and UV irradiation increases the process effectiveness (minimum duration of 2 or 3 days at continuous process), while the microorganisms elimination due to QAC disinfection is short-termed (up to 1 day). The tested disinfection methods efficiently eliminate pathogenic or potentially pathogenic microorganisms from storage areas.

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TAXA OF MICROORGANISMS ISOLATED IN THE INDOOR AND OUTDOOR AIR OF THE NATIONAL LIBRARY OF POLAND.

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Keywords: microbiology, indoor, library, mould

In 2012 on the Indoor Air Quality Conference in London the methods of the microbiological control of the indoor and outdoor air at the National Library of Poland were presented. The presented system is working. Since 2012 we have managed to obtain indoor data supported with two years (working) day-by-day background sampling.
The paper presents not only quantitative values but for the first time (since the introduction of daily background sampling) also qualitative results. As expected, the *Cladosporium* sp., *Penicillium* sp., *Aspergillus* sp. and unidentified hyphaceus fungi are dominating. However, there are significant differences in ratio of appearance of these fungi in the indoor and outdoor air. Furthermore, there are differences between buildings and rooms, depending on the air exchange and climate control (heating, ventilation, filtration) types. Some typical as well as extraordinary cases of microbiological air control results are analysed. The presented data are basis for climate control decisions that apply for about 10 millions of units preserved by the National Library of Poland. They are also important and used in the fields of: labour safety, infrastructure investment, preventive conservation, risk management, emergency preparedness. The material is used to work on with students of Faculty of Conservation and Restoration of Works of Arts of the Academy of Fine Arts in Warsaw. The reference for the analysis of the results are usually the guidelines of the Umweltbundesamt (Federal Environment Agency), Berlin, Germany [1], [2] as well as Polish publications on preservation of the works of arts [3].

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THE EFFECT OF DUST PARTICLES ON CELLULOSE DEGRADATION

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Keywords: cellulose, dust particles, degradation, ammonium sulphate

This study was focused on changes of properties of cellulose filters Whatman 41 which took place as a consequence of contamination by dust particles and artificial ageing.
The dust particles fractions PM1 and PM10 from repositories of the State Regional Archives in Třeboň and the Research Library of South Bohemia at Zlatá Koruna (Czech Republic) were collected on cellulose filters. The Whatman 41 was selected as a representative of cellulose-based paper. In parallel the same size fractions were collected on polytetrafluorethylene and quartz filters. These samples were analysed gravimetrically, by Ion Chromatography, PIXE and thermal-optical method, giving mass, ionic, elemental and organic and elemental carbon concentrations. The sampling was carried out in the spring, the summer and the autumn of 2012. The mass of the dust particles deposited on the cellulose filter fluctuated between 6.6 and 61.1 $\mu g \cdot cm^{-2}$. The samples were aged at 80 °C and a relative humidity of 65 % for 28 days. Reference samples of pure Whatman 41 filters were aged in the same way. Monitored properties of the filter paper were the total color difference, the pH value of an aqueous extract and the viscosity-average degree of polymerization of cellulose.
On the basis of the results, a defined mass of pure ammonium sulphate was deposited on Whatman 41 filters under laboratory conditions and the samples were artificially aged. In this way a relative contribution of this ubiquitous compound to the total degradative effect of the dust particles could be estimated.
It was confirmed that Whatman 41 filters can undergo substantial changes when contaminated by dust particles and artificially aged. The degree of degradation showed a positive correlation with the content of sulphate ions in the dust particles. These changes could be monitored by the decrease of DP of cellulose (Fig. 1)

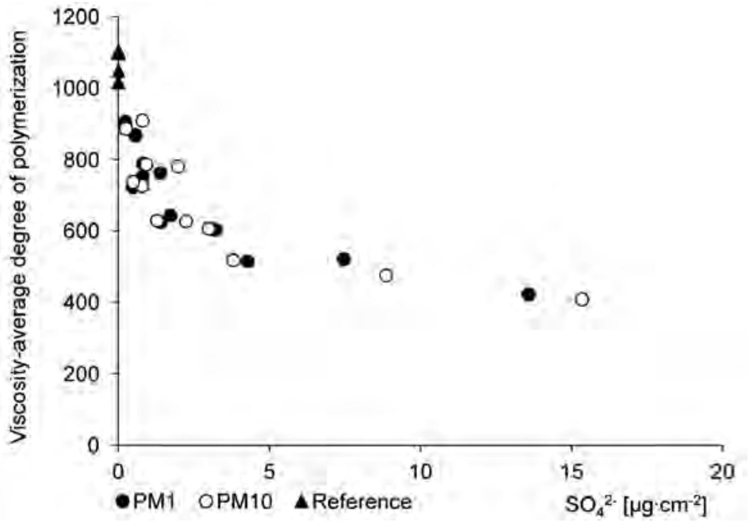

Fig. 1. Decrease of DP of cellulose in dependence on sulphate concentration for PM1 and PM10 particles.

The results of the measurement of the total color difference and the pH value of the aqueous extracts were in agreement with the results of DP measurements, although the sensitivity of those methods was lower. Considering the particle size fraction, the results obtained for PM1 and PM10 samples did not differ significantly, suggesting the decisive importance of the fine particles.
The degradative effect of the fine sulphate particles was also confirmed with the samples with the deposite of pure ammonium sulphate which showed a significant decrease of DP after artificial ageing. The question to what extent this compound can be degradative to paper under real conditions is studied at present.

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THE EFFECT OF PARTICULATE MATTER ON PAPER DEGRADATION

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Keywords: paper, PM, indoors, exposure

In this work we explore the chemical and visual effects of particulate matter (PM) on paper. While PM deposition is monitored frequently in heritage institutions, its effects on materials such as paper are not well understood [1]. We exposed Whatman paper samples to the environment in different locations in central London, outdoors (in sheltered conditions) and indoors, for a period of 6 months (20/2/2013 to 20/7/2013), during which PM deposition was monitored. We exposed 5 sample racks in 5 different locations. Four of these racks were in Apsley House, located near a busy roundabout in Hyde Park Corner, while one was in the Wellcome Collection building, in Euston Road. These are two of the most polluted roads in London, where the average concentration of $PM_{2.5}$ during the monitoring period was around 16.7 ± 11.5 $\mu g/m^3$, with a maximum of 80 μg/m.

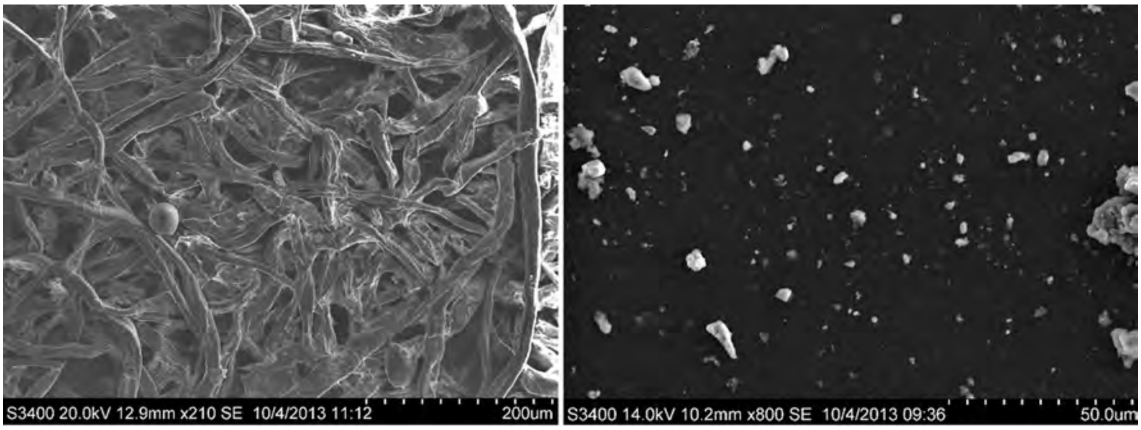

Figure 1: SEM micrograph of particulates embedded in an exposed paper sample (left) and on a carbon stickers used for particle counting (right).

We monitored particulate matter deposition by counting the particles deposited every month with an SEM microscope. We sampled particles on conductive carbon stickers and took several micrographs of each surface, from which size-resolved particle counts were obtained using image processing software (Fig. 1). This method can count particles with diameters above 0.1 μm, and based on this data, deposition rates were calculated, using the time of exposure and the dimensions of the analysed area. In two of the locations (outdoors and indoors in Apsley house), we also monitored the concentration of suspended particulate matter in different size modes (0.5 – – 1 μm, 1 – 2.5 μm, 2.5 – 5 μm and 5 – 20 μm) every minute using several laser particle counters (Dylos DC1100) connected to a computer.

In order to isolate the effects of particulate matter and gaseous pollutants, we covered part of the samples using a permeable polymer membrane (Clopay MicroPro). This membrane protected the sample from particulate matter and light, but allowed gases to penetrate. We used an UV Logger (Hanwell) to ensure that it blocked 99.1 % ± ± 0.2 % of the incident UV light, and we used diffusion tubes (Gradko) to ascertain that the membrane allowed 77 % of the O_3 and 94 % of the NO_2 present in the environment to reach paper samples. On the other hand, SEM analysis of the protected paper samples did not reveal the presence of a measurable amount of particulate matter larger than 0.1 μm.

In order to accelerate the effects of the deposited particles on the paper substrate, we aged the samples for 2 and 3 weeks at 80 °C and 65 % RH. We then used viscometry to measure the change in the degree of polymerisation, which is proportional to the decrease in the average molecular weight of cellulose. We also measured colour change and analysed elemental composition of the deposited particles using inductively coupled plasma mass spectrometry (ICP-MS). The experimental results relate PM deposition rates and elemental composition with colour change of paper and acceleration of paper degradation due to particulate matter.

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DEGRADATION OF PAPER UNDER VARIOUS ADVERSE ENVIRONMENTAL CONDITIONS: A MODELLING APPROACH

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Keywords: cellulose, prediction, pollutants, ageing

Research on the impact of the environment on the degradation of paper using accelerating ageing tests has been available since several decades. Attempts to correlate the information with the prediction of the level of deterioration of paper in natural ageing conditions are scarcer. The purpose of the present research is to explore these correlations in various environment conditions included in the presence of outdoor and indoor airborne pollutants. Using the model for the degradation of linear polymers usually applied to cellulose and based on the first order reaction kinetic proposed by Ekamstam [1] (eq. 1), Zou developed a model for determining the degradation reaction rate constant k [2]. This model was adapted in the present work to simulate the impact of different pollutants, relative humidity levels and temperature on paper stability (eq. 2).

$DP_{nt} = DP_{nt0}\, e^{-kt}$ (eq. 1)

where
DP_{nt} is the number average degree of polymerization at time t
DP_{nt0} is the initial number average degree of polymerization
k is the reaction rate constant (yr^{-1}), t is the time (years)

$k = [(A_W + A_{P1}[P_1] + A_{P2}[P_2] + \ldots + A_{PZ}[P_Z]) \text{ x } MC] \times e^{-Ea/RT}$ (eq. 2)

where
A_W is the frequency factor for reactions associated with water (yr^{-1})
A_{P1}, A_{P2}… A_{PZ} are the frequency factors for reactions associated with pollutants P_1, P_2,…, P_Z (yr^{-1} ppb^{-1})
$[P_1]$, $[P_2]$…, $[P_Z]$ are the concentrations of pollutants P_1, P_2,…, P_Z (ppb)
MC is the moisture content of the paper (fraction), E_a is the activation energy (kJ $mole^{-1}$), R is the universal gas constant (kJ $mole^{-1}$ K^{-1}), T is the temperature (K).

Data produced in our previous work [3] served to determine the parameters in the model and allowed predicting the decay over time of DP_n of cellulose in pure cellulose papers exposed to NO_X and to volatile organic compounds such as low molar mass aldehydes and organic acids. Correlations with other chemical and physical properties of paper allowed the prediction of the changes over time in the values of zero-span breaking length, yellowing and degree of chain oxidation. Data published by other authors have also been used to extend further the application of the model by including other pollutants and other types of papers than pure cellulose. The impact of deacidification treatments and alkaline reserve in paper was assessed as well.

The model permits quantifying the impact of pollutants, relative humidity and temperature on papers under different scenari ranging from typical climates in libraries and archives to worst case situations such as old buildings in polluted urban environments. The proposed application of the model is intended to assist stake holders in decision making towards optimizing the preservation of paper based heritage. It provides a tool that enables to evaluate the impact of the environment and thus the choice of the best cost benefit mitigation strategies adapted in each particular context and situation.

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PHOTODEGRADATION OF SOME COLOURED ARTIFICIAL ARCHAEOLOGICAL MIMIC SILK SAMPLES IN RELATION TO INDOOR AIR QUALITY PARAMETERS

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Abstract

The present work dealt with studying the photodegradation of some coloured artificial mimic archeological silk samples in relation to the Indoor Air Quality (IAQ) parameters represented by the pollutant gasses: NOx, SOx, O_2, O_3, SO_2 gasses and artificial daylight (ADL). Thus, examined samples were exposed in Giza city as historical location to ADL at different time intervals and at constant temperature and relative humidity. It was concluded that IAQ parameters contribute greatly to the photodegradation of those examined samples and remarkable decrease in their colour parameters was observed.

Keywords: Pollutant gasses, Artificial day light, Mimic archaeological textile, Photodegradation, Colour parameters.

ARE SHORT EXPOSURES AT HIGH CONCENTRATIONS EQUIVALENT TO LONG EXPOSURES AT LOW CONCENTRATIONS?

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Keywords: artificial ageing, reciprocity failure, acetic acid, paper

The fact that air pollutants can damage paper materials has been convincingly demonstrated in numerous laboratory experiments. However, to achieve significant yellowing or embrittlement within experimentally reasonable time frames, artificially high concentrations of pollutants are required. Pollution chamber experiments therefore typically operate at parts-per-million concentrations, while actual concentration levels found inside buildings are thousandfold smaller at parts-per-billion concentrations. Although naturally occurring pollutant concentrations appear rather dilute, preservation guidelines and standards typically suggest that these levels are not safe. Heritage institutions who want best for their collections, are encouraged to take measures to actively reduce pollutant concentrations within their repositories. It is important to understand that many of the stated maximum allowable concentration levels are derived from high concentration artificial aging studies, and calculated by mere extrapolation to low concentration levels across several orders of magnitude.

In contrast to numerous artificial high concentration exposure experiments, rather few comparative field studies have been published [1]. None of these studies, comparing pairs of identical books stored for longer times in both clean and polluted environments, report significant damage differences attributable to differences in pollutant exposure. Lacking direct evidence, it is necessary now to look very carefully at the extrapolation models that have been used.

All pollutant concentration extrapolation calculations in conservation science literature follow a similar scheme. A description is given by Tétreault [2] under the heading Lowest-Observable-Adverse-Effect-Dose (LOAED). The LOAED concept is based on the assumption that the amount of „damage“ (thickness of corrosion layer, color change, depolymerization, number of cracks, etc) is proportional to the amount of pollutant absorbed by the material, also called dose, and assumed to be proportional to the product between concentration and time. The idea of damage as proportional to the product of concentration and time comes from the field of radiation physics and it relies on a fast reaction with a material never saturated by the reactive pollutant or radiation. This proportionality allows to equate short term exposure at high concentration levels to long term exposure at low concentration levels. This is the reciprocity principle applied to pollutants. From the reciprocity principle it follows that no concentration level, however low, can be safe. Given enough time even exposure to extreme dilute concentrations will eventually accumulate in a critical dose. For highly reactive pollutants the reciprocity principle appears to be correct. However, for less reactive pollutants it is understood that sooner or later equilibration will occur, and reciprocity breaks down. An extreme example is water vapor which is not absorbed unlimited by a hygroscopic material. But also pollutants like acetic acid can be understood to equilibrate between the solid phase and vapor phase in a simultaneous fashion [3].

Because acetic acid is a prime suspect, moderately reactive, indoor generated pollutant, and because both the paper-air equilibrium [3] and the chemical kinetics of acid catalyzed hydrolysis [4] are well understood, modeling air borne acetic acid damage of paper provides a clear counter example, which clarifies reciprocity failure and provides an alternative approach to estimate parts-per-billion level pollutant damage.

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PERFORMANCE OF ADSORBENT MEDIA FOR SUSTAINABLE MITIGATION OF ORGANIC POLLUTANTS

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Keywords: air quality, museum enclosures, adsorbent media, mitigation

The impact of organic pollutants in museum interiors and especially in museum showcases is still of great concern for museum conservators. In the context of the European MEMORI project, which was funded under the seventh framework programme [1], both laboratory trials and investigations on-site in museums have been performed in order to evaluate the applicability of absorbent media inside of enclosures for improving microclimates within preventive conservation strategies.
The experiments included adsorbing materials which are already used within environments and those which are especially designed for museum purposes, namely charcoal granulates, foams and cloths as well as zeolites. Formaldehyde, formic acid, acetic acid, toluene and alpha-pinene have been selected as target substances due to their known corrosive impact on cultural assets as well as due to their frequent occurrence in museum environments [2, 3].
The experimental set-ups have been designed in such a way as to answer open questions concerning the chemical and adsorbing properties of the selected adsorbent media for the target substances. It was also of interest if undesired reaction products might be generated by contaminant-adsorber interactions and if used adsorbent media might act as potential secondary emission sources after adsorbing gaseous volatiles which might be desorbed again at a later stage.
The results revealed clear differences between the adsorption performance of the media tested, also concerning the filtration of specific target substances. Activated charcoal materials were evaluated as the best performing adsorbent materials for the selected target substances. Both pure activated charcoals and alkaline impregnated charcoals showed a good or very good adsorption efficiency. For this reason, the application of impregnated charcoal types, which are mostly more expensive, seems not to be necessary in order to mitigate pollution levels. Although zeolites performed well, no additional advantage was observed over activated charcoal media. Products which are especially designed for museum purposes had also no additional advantage according to the test results. Subsequently performed emission analysis of used adsorbent media gave strong indications that most of the materials off-gas toluene and alpha-pinene in a changed atmosphere. As some new substances occurred which could not be detected before performing exposure tests under active and passive conditions, it might be assumed that secondary or degradation products were generated.
Furthermore, the performance of adsorbent media on-site within museum enclosures will be affected by different parameters. For example, the surface to volume ratio of the adsorbent material is very important, in general the granulate materials had a low ratio, where charcoal cloth and foams had a high surface to volume ratio. In addition, practical considerations have to be discussed, as this is often an important factor when working with collection materials. Typically it is easier to install a charcoal cloth, compared to granulate material, as facility trays or similar are required. Moreover, the filtration of target substances seems to be more effective within showcases than within microclimate-frames, perhaps due to the limited air space and air flow.
The talk will present the outcome of all performed adsorbent tests within the MEMORI project including an evaluation of adsorbent media and recommendations for their utilization in museum enclosures.

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THE "MEMORI TECHNOLOGY": MEASUREMENTS, EFFECT ASSESSMENT AND MITIGATION OF POLLUTANT IMPACT ON MOVABLE CULTURAL ASSETS, INNOVATIVE RESEARCH FOR MARKET TRANSFER.

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In the EU project MEMORI (EU FP7-Supported Collaborative Project: 265132) a user friendly tool was developed for the evaluation of air quality risk to cultural heritage materials indoor. "The tool" includes a dosimeter which is sensitive to the indoor air quality, a small portable instrument to read the dosimeter results and web pages (http://memori.nilu.no/) where the results can be uploaded to accounts exclusive to the users. Besides information about the MEMORI technology, the MEMORI web pages include information about sources for indoor pollution, the sensitivity of a range of heritage materials to the gaseous pollution and general tables for more than 50 heritage materials' sensitivity to air pollution and climate factors also arranged according to the priority. From the tables and accompanying information the most likely risk factors for selected indoor heritage can be determined. The web pages explain how MEMORI measurements can be used to assess the risk to objects and also include information about other measurement methods that can be used.
The two MEMORI dosimeter glasses respond to air pollution components that can usually be distinguished as external (NO_2 and O_3) and internal (Organic acids), in addition to temperature, RH, and UV light. On uploading of the result and choosing the heritage material of interest on the MEMORI web pages a "traffic light response" of green, yellow or red, is obtained, indicating low, medium or high risk for damage to the object within ~ 30 years in that environment. Diagnosis of the source contribution can be performed by viewing the results in a two dimensional traffic light tri-colour diagram (Figure 1).

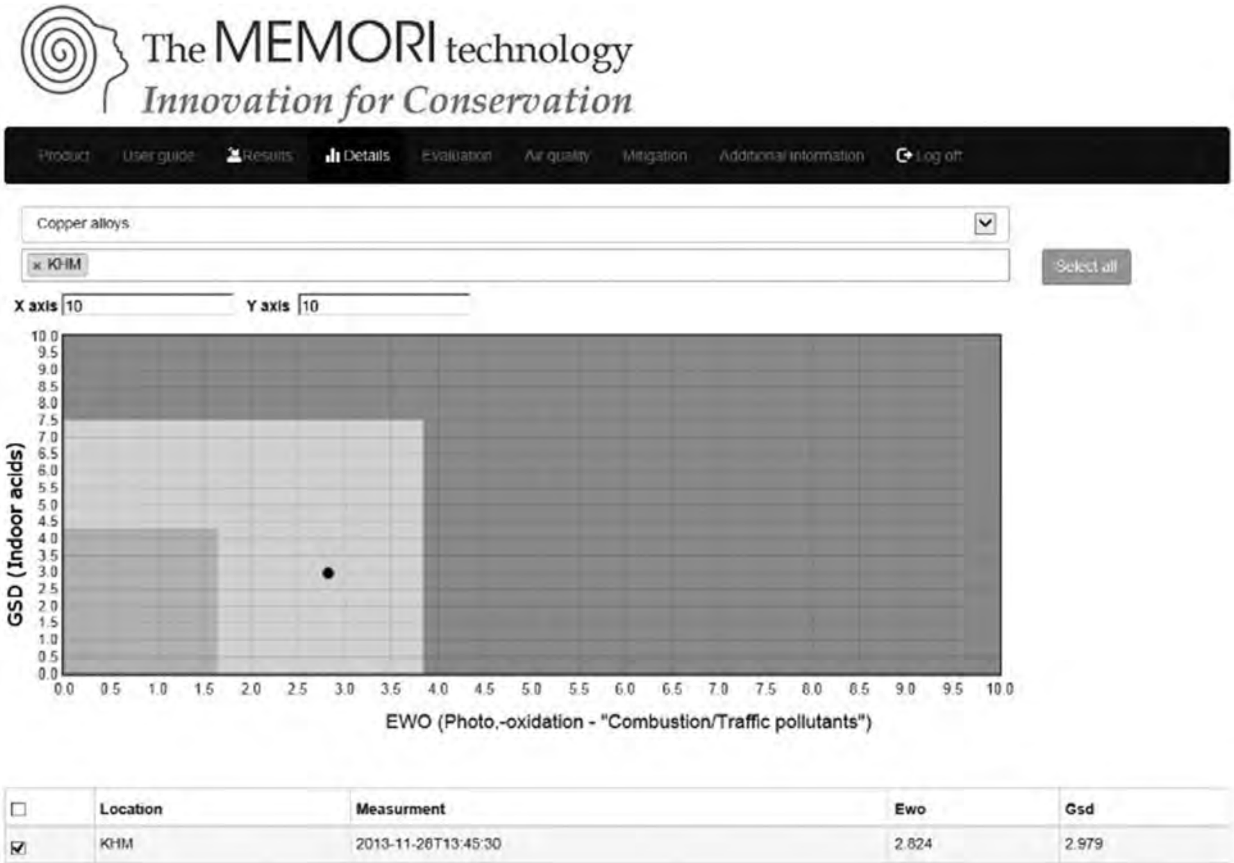

Figure 1: The MEMORI "traffic light evaluation diagram"

The web pages supply a decision making model to guide users from evaluation of measurement results to most cost effective mitigation methods, exemplified with case studies. The MEMORI web-pages give product information and guidelines for performing MEMORI dosimeter measurements.

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(See: http://memori.nilu.no/). We thank the EU commission FP7 for the support to the research.

THE MEMORI POLLUTANT MEASUREMENT, EFFECT ASSESSMENT AND MITIGATION DECISION SUPPORT MODEL

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Keywords: Risk assessment, Mitigation, Preventive conservation

There are a number of environmental parameters that can cause damage to historic collections, pollution is one important example [1]. Each material has a different sensitivity to pollution and also to the other environmental parameters. It is important to consider the risk of damage from pollution within context of the environmental risk. A pollution focused decision support model has been developed in the EU MEMORI project. Where resources are limited they can be targeted to the greatest risk.

Results of a survey, carried out within the MEMORI project, identified that a significant number of heritage professionals did not measure pollutants, or check display and storage materials. They reported this was because they felt they lacked the necessary knowledge or experience [2]. The decision support model presented here aims to provide the necessary information to allow for effective pollutant measurement, effect assessment and mitigation by end users.

In addition to identifying materials at risk from pollution, information is provided on scenarios where risk may be increased. Further information on other important factors is provided, such as the effect of temperature on pollutant emission. Initial development of the model was reported (climate for collections [3]); the refined features of the model will be reported in this work.

The MEMORI project included research into the effect of organic acids on materials, where insufficient previous research was reported. The materials investigated were pigments, varnishes, leather, parchment, textiles and paper. New LOAEL's and NOAEL's have been defined for some materials [4].

The model provides an assessment of the effect of pollutants on many heritage materials. These new research results from the project are combined with a literature review to identify if measured pollutants pose a risk to collections. For each material, the damage caused by pollution is detailed, with concentrations specified and the method of measuring damage described. These results are interpreted to determine the MEMORI dosimeter response category [4]. Observed degradation is described, to help users identify pollutant related damage, and other factors that can affect deterioration are discussed.

Finally the model considers pollutant mitigation. A number of questions are posed to the user to help them decide which mitigation options are available for their specific scenario. A number of other tools are presented to allow users to effectively answer these questions. These include a calculator to determine the effect of temperature and RH on the measurement and when measurements are likely to be at a maximum, a silica gel lifetime calculator [5], and a model that predicts the effect of air exchange rate effect on pollutant concentration. For each mitigation strategy, its likely effect, cost (both initial and ongoing), and energy usage is estimated. A number of cases studies are presented to illustrate the decision process. The decision support model for pollutant measurement, effect assessment and mitigation will be available on the MEMORI website (http://memori.nilu.no).

This work enables non expert end users to reduce the risk of damage to their collections. They can identify enclosures of high risk, assess measurement results, decide where mitigation is required, and implement the most effective strategy within their budget.

The MEMORI project (Grant Agreement no. 265132) was funded by the 7th Framework Program of the European Commission. The authors would like to thank all project partners, the collaboration has guided much of the work presented here.

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QUANTITATION OF TARGET COMPOUNDS IN ODDY TEST VESSELS WITH SPME-GCMS

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The Oddy test is a widely accepted screening test method in museums for the evaluation of materials for their safe usage in display and storage of artworks. Sample material is enclosed in a test vessel with metal coupons under elevated temperature and humidity condition and the test evaluates the effect of off-gassing from the material on the metal coupons. Different test set-ups have been published [1, 2], and refinement to overcome disadvantages of the test, such as relatively long test period and intrinsic subjectivity of the result evaluation, have been proposed [3-6], but the nature and extent of off-gassing that affects the metal coupons is not well studied. In order to explore this aspect, air from test vessels was analyzed with SPME-GCMS. In previous presentations, qualitative analysis of compounds emitted from tested materials in Oddy test vessels was discussed, and these results were compared with the analysis of the same materials by evolved gas analysis and thermal desorption-GCMS using a temperature programmable pyrolyzer attached to the gas chromatograph.

In this presentation, quantitative analysis of target compounds will be discussed. For a temporary exhibition of photographs, the use of a base board made of walnuts wood, coated with clear polyamide epoxy, was proposed for the esthetic preference. In our past Oddy test experiences, no clear coatings have improved the test results, and indeed, also in this case both the bare walnuts wood piece and the coated one badly corroded the lead coupons. By qualitative analysis of the air in these test vessels with SPME-GCMS, series of linear carboxylic acids and aldehydes were detected, together with other compounds from polyamide epoxy coating in the test vessel of the coated sample, such as dipropylene glycol and 1-phenoxypropan-2-ol. In both tests, as formic and acetic acids showed particularly large peaks, the amount of these two compounds was quantitatively compared in new tests with walnuts wood pieces of 1x1x2 cm. Deuterated acetic acid was used as an internal standard and the calibration curves were prepared in the range between 100 and 2500 ug/m^3 for both acids. After two weeks of the test period, formic acid was detected about 1500 and 2000 ug/m^3 in test vessels for uncoated and coated samples, respectively, but acetic acid was exceeded the upper calibration limit. Its response was about five times more than 2500 ug/m^3 calibration standard. Both acids were detected more in the coated sample than uncoated sample. Since in the qualitative analysis of polyamide epoxy dried on Mylar sheet these acids were not detected, this difference could be due to the difference of the amount emitted from wood pieces, but the amount of acetic acid emitted from walnuts wood pieces was extremely high in both cases.

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PREVENTIVE STRATEGY AND CONTROL MEASUREMENT PROCEDURE IN TWO RECENTLY OPENED EXHIBITIONS AT THE GERMANISCHES NATIONALMUSEUM IN NUREMBERG

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Keywords: air-exchange-rate, AGÖF-Guidance-Values, control-measurement, preventive-strategy

At the Germanisches Nationalmuseum (GNM), which is the largest museum of cultural history in the German-speaking region, the Institute for Art Technology and Conservation (IKK) has developed an internal profile of requirements for showcases and display materials as a preventive strategy to reduce airborne pollutants. As a part of the specifications for tenders, the profile defines conservative requirements such as low-emitting construction materials, climatic conditions and air-tightness. Accordingly, the testing procedure for the preselection of display materials is also described as the control measurement procedure of the accomplished showcases.
The proceedings of the GNM's preventive strategy can be shown by the example of new showcases which were introduced at the exhibition of "Mittelalterbilder" at the Lapidarium in 2013 [1]. Additionally, the 20th century objects collection was opened in March 2014.
As a matter of fact, many parameters can influence the measurement results of VOC's in indoor air. The concentration of VOC's in a showcase depends on the air-exchange rate, the measurement procedure itself (active versus passive air sampling) and the sampling media.
In this paper, we will discuss the challenge to determine the adequate concentration of VOC's as well as the difficulties arising with their evaluation.
Firstly, a mathematical model shows the impact of the air-exchange rate on steady state conditions. Using this model, a time-difference between showcase preparation and air sampling can be predicted. Assuming an air-exchange rate of 0,1 per day, the concentration of VOC reaches 95 % of steady state concentration within 30 days (99 % within 46 days). Secondly, the discussion about limitations of passive air sampling, such as a minimum of air speed or the impossibility of air sampling during steady state conditions, shows the necessity of active air sampling. Active air sampling implicates a wide selection of sampling media and thus defines the spectrum of detectable substances. Determining the sampling volume, you have to keep in mind that the air streaming in dilutes the air inside the showcase, which contradicts the objective of a minimal quantification limit.
Since there are no specific, official limit values for VOC's in showcases, the GNM uses the AGÖF Guidance Values for Volatile Organic Compounds in Indoor Air (AGÖF Orientierungswerte) [2]. The reference values are based on a statistically derived assessment concept and were established by two research projects financed by the German Federal Environmental Agency. Statistically derived reference values are a very reliable instrument to decide whether there is a background level (normal) or an unusual exposure, which indicates a source of any substance.
On the one hand, these results show the necessity of a ventilation and examination concept after finishing the construction of the showcases because the pre-examination of construction materials does not guarantee low emission showcases. On the other hand, the developed concept resembles a useful instrument to improve the quality standard of showcases. Furthermore, the two projects point out that high requirements of specifications concerning the air-exchange rate in showcases are very difficult to be met.

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DECISION SUPPORT TOOL FOR MITIGATION, ADAPTATION AND PRESERVATION STRATEGIES OF INDOOR-CLIMATE IN HISTORIC BUILDINGS

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One of the key objectives of cultural heritage preservation is to keep indoor-climate conditions in historic buildings safe for the building interiors as well as for valuable collections deposited and preserved there. Particularly, concerning the relative humidity and temperature of the interior air, there exist various standards and recommendations [1, 2]. Their application naturally depends on the character of the building, vulnerability of the collections (see e.g. various classes defined by ASHRAE [3]), regular number of visitors (concerning their comfort on the one hand and their negative impact on increasing relative humidity on the other hand), opening hours, etc. As regards the indoor-climate mitigation measures and control methods, next to the passive approaches (for example enhancing the air-tightness of windows and doors, use windows shading) a number of active mitigation measures exist, for example humidity control, conservation heating, humidistat heating, friendly heating, wall heating, controlled air exchange, etc. (see e.g. [4] for comparison of selected methods using building simulation software). An enhanced level of expertise is needed to select and design most suitable method for a given building type and the actual purpose. Even though the above information and knowledge is widely available and accessible for experts, it is not edited for easy understanding for the decision makers on-site.
In the presentation, a user friendly decision support tool for mitigation, adaptation and preservation strategies of indoor-climate in historic buildings will be presented, which was designed within the EU project Climate for Culture (http://www.climateforculture.eu/). The web based tool utilizes an open source software exDSS, which was developed and implemented for the given purpose by the authors. Using the software exDSS, the know-how provided by the experts for example in form of logic decision trees or tables has been implemented.
In the web based decision support tool, through an interactive questionnaire, the end-user gradually provides the information on the building type (dimension characteristics, envelope type), its use (archive, collection hall, museum), on the identified risks (e.g. mould growth), etc. An answer to a given question can be provided as a number or a string to be filled in a text box. The answer can also be provided by ticking radio-buttons or check-boxes corresponding to the most appropriate option(s) offered by the tool. After passing all the questions available for the given subject (selected by the user in the beginning of the questionnaire), the tool provides a list of recommendations, comments and links to the documents or web pages, which can be useful to the end-user for decision making.
The exDSS based tool has primarily been designed to present results and provide expertise gathered within the Climate for Culture project. However, it can openly be used to include expertise from different subjects of cultural heritage field, which have not been covered by the project. The presentation will include the overview of all the steps needed for implementing specific decision support module, including the decision process classification, representation and implementation. The tool will also be briefly introduced and offered for testing.
The presented research has been supported by the European Commission under the project of the 7th Framework Program Climate for Culture, No. 226973

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ENERGY EFFICIENT CLIMATE CONTROL IN HISTORIC BUILDINGS

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Keywords: microclimate control, adaptive ventilation, equal-sorption, energy efficient

The heavier demands that society now places on the efficient management of finite resources in general and energy in particular is bound to have consequences for our ability to preserve the cultural heritage in buildings by means of preventive climate control. A sustainable use and preservation of historic buildings requires broad and long term compromises between social, economic and environmental aspects. Solutions must not only provide a good indoor climate with respect to preservation, they must also be economically and ecologically sustainable.
The first part of the presentation aims to evaluate different approaches to microclimate control in historic buildings in relation to the requirements for indoor climate and energy consumption [1]. Conventional methods are examined: passive microclimate control, humidity control and humidstatic heating; and compared with two novel control strategies: equal-sorption humidity control and natural climate fluctuations control. Starting from a general overview of the methods based on the state of the art and experience from selected case studies, the methods are evaluated using building simulation software.
For the equal-sorption humidity control method, next to the simulation based analysis, new results of its implementation in Třeboň archives are presented, extending the former application presented in [2]. Utilizing mathematical models of moisture sorption phenomenon in organic materials (particularly wood and paper), the estimated moisture content variability is kept within safe ranges just by adjusting relative humidity of the indoor climate air.
Adaptive ventilation is presented in a case study from a Swedish medieval stone church where a novel integration of solar heating and adaptive ventilation has been implemented [3]. Solar energy is collected in the day and stored. In the night, when the outside air generally is drier (in absolute terms), outside air is preheated using the energy stored in the daytime and added to the building.
The results show that

- Adaptive ventilation can be a low-cost and low-energy option as compared to conventional humidity control.
- The average relative humidity and mould risk has decreased significantly.
- Auxiliary measures, such as dehumidification, would be needed, mainly in the summer.
- The energy from the photovoltaic elements has mitigated the cooling effect of the outside air.

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REAL-WORLD LABORATORY TESTING OF MOLECULAR FILTERS

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Keywords: filter, molecular, pollutant, performance

After temperature, relative humidity and light; control of airborne molecular (chemical) pollutants is the next important element of a preventative conservation strategy. Some of the latest guidance [1][2] on control of molecular pollutants provides conservators and those responsible for indoor environmental conditions with greater flexibility in terms of the ventilation regimes used to determine and achieve acceptable indoor air quality (IAQ). It is advised that as part of a conservation strategy; steps should be taken to understand the sensitivities of the collection, the extent and severity of the pollution and how effective any control measure should be. These views were echoed by several presenters at the 2012 conference in London [3]. Perhaps most importantly, conservators and those with budgetary responsibility want to be certain that investments in molecular filtration will deliver proven performance, value for money and they want to understand in advance long-term lifecycle (replacement) costs. At-site determination of chemical pollutants in the external ambient air and in enclosed spaces provides useful information and may be indicative of filter performance. However such protocols may have drawbacks including; high cost, requirement for dedicated and skilled human resources and in some cases considerable delays to receipt of results. However it must be recognized that data is only generated after investment and installation of filters.
Surely, a more logical approach would be to validate filter performance in a laboratory environment, under application real conditions before commitment to investment was made. For this purpose Camfil have built a unique laboratory to evaluate the performance of molecular filters and the adsorbent materials which are the functional agents used in their manufacture. The filtration industry uses two types of adsorbents; activated carbon and activated alumina. In some cases, these adsorbents may be impregnated with chemicals to enhance their capacity towards specific molecular contaminants. In this test facility, filters and adsorbents may be challenged with those gases of greatest concern to conservators, including sulphur dioxide, nitrogen dioxide, ozone and acetic acid. Very sensitive gas detectors positioned up and downstream of the test filter allow efficiency curves to be produced in real time. Since temperature and relative humidity can significantly affect the behaviour of an adsorbent, the test rig allows both these parameters to be set to values that mimic the customer's application. Another factor that influences the performance of an adsorbent is the concentration of the challenge gas. It is counter intuitive, but low concentrations of gases, as are typical for cultural heritage buildings are more difficult to control with high efficiency than high concentrations which might be prevalent in industrial air cleaning applications. In this laboratory, adsorbent performance can be assessed over a range of application-real challenge concentrations. The Camfil laboratory and test protocols adhere to the procedures and guidelines of the recent international standards for testing molecular media, ISO 10121-1 [4] and full filter testing, ISO 10121-2 [5]. Testing according to the ANSI/ASHRAE standard 145.1 [6] and ANSI/ASHRAE 145.2 [7] can also be performed.
The performance of several adsorbents that are known to be widely used in cultural heritage buildings around the world have been assessed against sulphur dioxide, nitrogen dioxide, ozone and toluene (as a representative of all VOCs). A wide range in performance has been observed for different adsorbents, from very high efficiency to low efficiency. In particular, for challenges with sulphur dioxide, nitrogen dioxide, ozone or toluene it was observed that activated carbon based adsorbents always gave vastly superior performance in terms of efficiency and capacity (lifetime) compared to activated alumina that had been impregnated with potassium permanganate ($KMnO_4$). This observation held true for adsorbent materials from Camfil and those offered by other vendors. Filters based on the use of activated alumina impregnated with $KMnO_4$ are in widespread use throughout the global cultural heritage industry. In light of the observed laboratory results, this situation is somewhat surprising. The recent observations confirm the findings of the groundbreaking study published by the Department of the Environment, UK government in 1981[8] that concluded that two different grades of commercial activated carbon performed significantly better than an activated alumina impregnated with potassium permanganate in respect of control of atmospheric sulphur dioxide.
Detailed test protocols and full results will be presented.

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POSTERS

P001 – INDOOR AIR QUALITY IN THE NEW DEPOT OF THE SWISS NATIONAL MUSEUM

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Keywords: silver tarnishing, monitoring, charcoal filters, corrosion logger

The Collection Centre of the Swiss National Museum is a state-of-the-art facility which contains the laboratories for conservation and conservation research and the museum's storage facility Completed in 2007, it houses the more than 850'000 objects of the overall five museums.
Storage equipment, building and packing materials were chosen carefully and tested before use as far as possible. Temperature and relative humidity is controlled by air conditioning and the incoming air is filtered. However, silver objects which are stored beside painted sculptures in an extra room, started to tarnish faster than acceptable.
In order to take appropriate measures first the source and the kind of pollution had to be identified. It was necessary to identify whether the pollution had an indoor or outdoor source. A research project named "Chemical interactions between selected cultural metallic artefacts and indoor environment in the new Collections Centre of the Swiss National Museum" was started in the framework of the COST Action D42 [1]. For this purpose silver coupons were placed in the middle of the room, in the closed compactus shelves containing silver objects on one side of the room and on the other side where wooden painted sculptures are located. At the same time, passive samplers (Radiello® and from IVL, Sweden) were placed in the middle of the room in order to identify the kind of pollution. By these measures it could be confirmed that the pollutants, identified mainly as H_2S and NO_x, came from the outside.
So far the incoming air was only cleaned by fine dust filters. Fortunately, extra space in the air conditioning construction was reserved for additional filters, if necessary. Charcoal filters were tested by real time corrosion monitoring by an AirCorr logger which was developed in the EU project Musecorr [2, 3]. Anyway, normal charcoal filters are not effective in the case of acidic gases like hydrogen sulphide. Therefore, special impregnated charcoal filters were built in. Their effectiveness is monitored directly in the air conditioning system by a corrosion logger in order to decide when the filters have to be changed.
As a conclusion, the air conditioning system is now on a satisfying state which keeps the storage conditions as good as possible. The silver tarnishing was reduced to the best achievable level.
Parts of this work were supported by the European Union under the COST framework, by the Swiss State Secretariat for Education and Research (SER) and the European Commission under the 7th framework.

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P002 – SEALING SYSTEM FOR EXHIBITION FRAMES: THE EVALUATION OF SAFE DISPLAY AND TRAVEL OF PHOTOGRAPHIC MATERIALS USING A DESIGN OF EXPERIMENT APPROACH

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Keywords: microclimate, frames, photographs, experimental design

Photographs are sensitive objects that required a tight control of the environmental conditions for safe and responsible display, storage and transit. Current guidelines include a range of acceptable materials and sealing systems to achieve buffering and shielding especially from fluctuations in relative humidity which are the most harmful to photographs. Choosing effective frame sealing must take into consideration the object, the context of its display and anticipated environmental conditions. Institutions with active exhibition programs must consider availability and cost of the materials and labor.

In a continued effort to evaluate the best practice measures for preservation and safe display, storage and travel of collections in The Museum of Modern Art (MoMA), the Department of Conservation and Department of Photography have embarked on a yearlong survey to evaluate and optimize sealing protocols of exhibition frames. A Design of Experiment (DoE) approach was employed to lay out the experimental plan and evaluate the influence of the different design variables on the conditions experienced by the photograph inside the framing package.

The design variables are based on the current practice of frame components and sealing systems for photographs which are carried out in the in the museum frame shop: high quality rag-board window mat, relative humidity buffering material (Artsorb),sealing film (Marvelseal 470) Permacel J-LAR Polypropylene Clear-To-The-Core pressure sensitive tape and Lineco Framers Sealing Tape.

In order to measure the impact of the design and the choice of materials on the microclimate experienced by the artworks, the environmental conditions inside the frame package were monitored using a HOBO U23 Pro v2 datalogger with an external temperature/relative humidity probe with fast sensor response and suited for deployment in tight spaces. Based on a full factorial design, a total of 16 frames were assembled. The frames will be hanging in a location in the museum with no environmental control for a period of at least one year. The monitoring of this location started a year earlier in preparation for the project and registered relative humidity values between 15 to 80 % RH and temperatures between 5 to 30 °C.

Different metrics can be derived from the temperature and relative humidity data to describe the conditions inside the frames and to compare them with the conditions in the room: temperature and relative humidity average and standard deviation, daily or seasonal amplitude of fluctuation, time weighted preservation index (TWPI), moisture and temperature equilibration rates, etc... These response measures can then be used in the statistical evaluation and quantification of the impact and benefits of the different frame designs and materials.

The analysis of the first month of data (December 2014, 12 °C and 40 % RH average conditions in the room) indicates that the best protection from humidity fluctuations (a 80 % reduction of the % RH std) is provided by the combined use Marvelseal sheet (highest impact) and buffering with Artsorb, in particular if the photograph is not housed in a mat (the presence of Artsorb will compensate for the absence of a mat). The analysis also shows that there is a benefit in taping the edges of the frame package but only if Artsorb is included, and that JLar and Lineco Frame tapes are equally suited for that purpose.

Data from the loggers will be downloaded and evaluated on a monthly basis. We will report on the progress of this ongoing project and update our conclusions, and we will discuss how the results may influence the framing policies in the museum.

P003 – DECREASING OF RELATIVE HUMIDITY WITH THE GRANULAR SILICA GEL ADSORBTION

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Keywords:climate, RH, silica gel

Keeping relative humidity of air in narrow limits is a mandatory condition for prevention of microorganism's growth on museum artifacts and deceleration of corrosion of metal objects.
Unfortunately certain museums don't have cutting edge ventilation and conditioning systems for regular climate control. In absence of such climate control systems in exhibition halls and archives severe alteration of temperature and relative humidity can occur. It leads to moisturizing of objects due to condensed water and hygroscopic property of materials. In those museums artifacts made of leather, paper, wood and textile remain in conditions of constant microorganism attacks and require antimicrobial treatment.
There are several methods of prevention of materials from excessive moistening which do not require special sophisticated equipment: storage in multilayer wrappings, in special sealed containers and local dehumidification by using adsorbing agents. In our lab we examined granulated silica gel and we actively recommend it to be used for decrease of relative humidity of air in show-cases, lockers, boxes with hygroscopic objects and metal items subjected to corrosion.
In village-museum of Russian writer of 19th century A. Ostrovsky from April to October (central heating is switched off) climate in exhibition halls and storage rooms fully depends on weather conditions. There for relative humidity of air (RH) is getting higher than 66 % with temperature levels at 20 – 24 ^{0}C for about six months. And in sealed lockers and boxes storage conditions are much worse. Excessive humidity and absence of proper ventilation can create favorable conditions for microorganism development. Twice a year curators had to dry and ventilate objects and to remove mold coating. Using silica gel (SiO_2) in circular granules of 3 – 8 mm width we decreased RH levels for 15 %. Textile packages with silica gel (500 g) were placed in the bottom of closed suitcases with clothes made of leather and different types of fabric. After 2 hours RH fell from 69 % to 62 %. After 24 hours RH decreased to 56 %. Thus in conditions of high RH (69 %) in archive building we managed to decrease RH in boxes with objects till 56 %.
Alterations of temperature and humidity were measured by thermo hygrometer IVTM-7K (Russia) with memory module stick and ability to graphically display the process of air drying. Using this method of humidity reduction in certain boxes and show-cases we were able to stop excessive moisturizing and molding of works of art.
Property of silica gel to adsorb moisture can be used not only to prevent contamination of museum objects with mold but also to inhibit metal corrosion.
In State Research Institute for Restoration the department of conservation of metal items, metal works of art and cold weapon are stored in metallic cases. They need to be stored at RH level ≤ 50 % to prevent corrosion. In summer and autumn time in Russian climate conditions it is hard to keep such RH levels without special instruments. Experience has shown that 500 g of silica gel can keep necessary RH level in 0,7M3 box for 1 week. Property of silica gel to adsorb moisture and to return it after heating/drying allows using it repeatedly. After saturation of silica gel granules with water vapor it must be replaced with moisture-free portion. Wet portion must be simple dried in ventilated thermostat. It is recommended to dry the silica gel by spreading it in shallow pans and heating it at 120 °C for a minimum of 12 hours [1].
Thomson states that a well-sealed case can be expected to have an air leakage rate of one air change per day. Using Eq.1 Thomson calculates that 20 kg/m3 of silica gel with an M-value of 2 g/kg would be needed to achieve a hygrometric half-time of 150 days for a display case having a leakage rate of 1 air change per day (ACD). This recommendation has become the standard guideline for using silica gel as a passive RH control method inside display cases [2]. According this standard it is obviously that we can easily maintain RH inside museum display cases, storage boxes and lockers in certain museums with not comfortable indoor air conditions and limited funding.
This simple and low cost method of RH reduction in air using silica gel had been described as early as in 70s of last century. But examples of silica gel using for maintenance of necessary RH levels in closed boxes and show-cases are not frequent at all. Polling of curators from different cities and regions has shown that the main cause of such uncommon usage lies in insufficient information about this method. The same polling has shown the actuality of this method for local RH control.

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P004 – THROUGH A GLASS DARKLY, PART 2: AN INVESTIGATION OF PROBLEMS OBSERVED WITH DISPLAY CASE GLASS

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Keywords: glass, hazing, display-case, cleaning

Museums around the world have reported smearing and residues on the inside of display case glass made by a number of different manufacturers. This has occurred in cases with a wide variety of contents and conditions. These residues, referred to in this poster as hazing, are unsightly and can detract from the displays.
Initial investigations on this were reported at the ICOM-CC conference in Lisbon, 2011 [1]. The type of hazing was described and initial analytical work was reported; a vast range of contaminants was detected including sodium formate salts, hydrocarbon and silicon-carbon containing species [2]. Similar analytical work at the Metropolitan Museum of Art (New York) also showed sodium chloride, sulphate and nitrate compounds [3]. The Royal Ontario Museum has observed extensive hazing and is carrying out similar investigations [4].
The exact nature and cause of the hazing however has yet to be determined. To progress the work, conservators at the Museum of London carried out a survey of cases to determine patterns and common factors. This showed that hazing occurred in almost all recent display cases irrespective of manufacturer, type of case, contents, environmental conditions or location. The hazing occurs in well-sealed as well as in leaky cases, and in cases with climate control and positive pressure. A database of reports of hazing in other museums was collated.
The presence of hazing is made more evident when the case lighting is external and raking. Display cases constructed over the last 15 years have tended to have all glass sides and tops and are often lit externally from lights on ceiling tracks.
This poster is presented at the IAQ conference to communicate progress to date and to solicit further examples of observations of hazing. It is hoped that analysis planned over the next year will help to explain the cause of the hazing.
Cleaning methods will also be described; damp microfiber cloths have been successful generally. These have an added advantage that no solvents are required substantially reducing the use of chemicals within museum display and storage areas. However over the last year, it has been observed that microfiber cloths are not effective for some hazing and other cleaning products are being investigated.
Currently, routine cleaning is considered the only effective solution to remedy the problem. However, this is resource heavy and ultimately far from an ideal solution. As such this problem is in the interest of museums and case manufacturers to resolve.

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POSTERS

P005 – INFLUENCE OF AIR-CLEANER WORK ON THE CONTENT OF MICROMYCETES IN BOOK-REPOSITORY AIR

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Keywords: indoor and outdoor air, micromycetes, air-cleaners

High content of harmful contaminations and microorganisms is one of the problems of library repository air. Use of the local means of regulation of climatic condition of rooms where documents are held is of interest for small rooms which are not equipped with special systems of air conditioning and cleaning. Variations in the quantity of microorganisms in air of two repositories of the National Library of Russia – in the Division of rare books and in the Division of music publications and sound records – after the work of two air-cleaners during three months from April to June were studied in this work.

Photocatalytic cleaner MC704VM made by Daikin (Japan) was used in the repository of rare books with the volume of 292 m^3. The action of the cleaner is based on photocatalytic technique and saturation of air with airoions. Photocatalytic filter destructs particles with the size up to 0.001 µm. Light from the sources of ultraviolet radiation falls on surfaces covered with titanium oxide with the formation of H_2O_2 and hydroxide radicals. These compounds have strong oxidizing properties and can decompose aroma compounds into CO_2 and H_2O.

Recirculating medical air sterilizer OM-22 (Russia) was used for air cleaning in the repository of the Division of music publications and sound records with the volume of 514 m^3. The sterilizer is intended to ensure air clearness in working area according to the Russian standard GOST 14644–1. Purification of air flow is realized with filter made of ecologically clean material of synthetic crashproof fibres allowing the filtration of particles larger than 0.3 µm.

Air samples for the content of microorganisms were taken simultaneously by two methods – method of aspiration (using sampler MAS-100 Eco® according to the International standard ISO 14689-2-2005 and method of sedimentation (exposure for an hour). Air consumption when using the sampler was 1000 liter. Petri dishes of 90 mm with agarized Czapek-Dox medium were used in the both methods.

The quantity of fungi was reduced 2-15 times as a result of the work of air-cleaner MC704VM, and after the sterilizer it went down on average 1.5-3.5 times; however, in the middle of April, at the minimum content of fungi in outdoor air, there was practically no difference in micromycete` quantity before and after the work of sterilizer. In comparison with outdoor air, the quantity of micromycetes was 7-8 times less in the Division of music publications and sound records and 2-2.5 times less in the repository of rare books. The quantity of fungi before the work of photocatalytic cleaner was from 30 to 140 CFU/m^3 indoors; and it was 70-250 CFU/m^3 outdoors, depending on climatic conditions. The quantity of fungi before the work of recirculating medical air sterilizer indoor was from 40-50 CFU/m^3 on the first tier and 20-30 CFU/m^3 on the second tier. The quantity of fungi was 70-170 CFU/m^3 outdoors, depending on climatic conditions, too.

Efficiency of the work of both cleaners was much higher at the closed windows. Naturally, the concentration of micromycetes rose after ventilation and the power of cleaners was insufficient to eliminate fungi constantly once again incoming from air at the open windows.

Twenty-six species of micromycetes belonging to 14 genera were isolated outdoors; some of them were not found in the repository: *Aspergillus candidus*, *Geotrichum candidum*, *Penicillium godlewskii*, *Torula lucifuga*, and others. Twenty-one species of fungi belonging to 12 genera were found in the Division of music publications before air cleaning; 23 species belonging to eight genera were found in the repository of rare books. Some species of fungi which were absent in outdoor air: *Acremonium strictum*, *Aspergillus flavipes, A. sydowi, Cladosporium sphaerospermum, Penicillium camemberti, P. granulatum, P. raistrickii, P. raciborskii*, *P. variabile, P. viridicatum, Ulocladium consortiale* were isolated from indoor air. The following fungi with high frequency of occurrence: *Aspergillus niger*, *A. ochraceus, A. repens, A. versicolor, Penicillium aurantiogriseum, P. brevicompactum, P. commune, P. simplicissimum, P. terrestre* were isolated from all the repositories and outdoor air. Eight and nine species were not found after air-cleaner work in the repositories of music publications and rare books, respectively, including three species in both repositories: *Aspergillus flavipes, Penicillium raciborskii* and *Penicillium variabile*. Thus, in the absence of air-conditioning systems in the small library depository the concentration of microorganisms may be decreased by different ways, for example, by using the air-cleaners.

P006 – COMPARATIVE ANALYSIS OF INDOOR AIR MYCOBIOTA ON VARIOUS NUTRIENT MEDIA

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At present, there are no unified standards regulating the use of nutrient media for determining indoor air contamination and the selection of medium is a personal preference of mycologist carrying out the testing. Consequently, the comparison of air analysis results presented by various authors is not possible as the use of various nutrient media influence to the obtained results both in quantitative and qualitative composition of mycobiota, which is connected with the features of composition of the media used.

Comparative analysis of the qualitative and quantitative composition of air mycobiota by the example of one room – the repository of the Division of music publications and sound records of the National Library of Russia was carried out. Eight nutrient media with various sources of carbon: Czapek-Dox medium and two its modifications containing filter paper and starch as the only source of carbon, Sabouraud's medium, nutrient agar, malt extract agar, DG-18 and wort agar were used to estimate air condition. Air samples were taken using sampler Mas 100 Eco (Switzerland). Two series of testing were carried out with month interval. Double blind randomization technique was used to even out the effect of the order of use media on the data obtained.

The air contamination of examined repository by micromycetes on various nutrient media varied from 0 to 260 CFU/m^3. The data obtained was statistically processed: «outliers» were excluded, following which the average and median values were calculated for each medium. The analysis of results showed that the values of air contamination with micromycetes obtained on media with starch and paper were understated in comparison with the others: average level mold contamination was about 10 CFU/m^3, viable micromycetes were not found in a third of the samples. When taking samples on standard Czapek-Dox medium, nutrient agar and Sabouraud's medium, the average values of air contamination varied from 30 to 70 CFU/m^3, and on malt extract agar, DG-18, and wort agar, from 90 to 140 CFU/m^3.

Thirty-five species of micromycetes belonging to 11 genera: *Acremonium, Alternaria, Aspergillus*, *Botrytis*, *Cladosporium*, *Fusarium*, *Paecilomyces*, *Penicillium*, *Scopulariopsis*, *Trichoderma* and *Tritirachium* were isolated from inspected room air. Most quantity of species was isolated on DG-18, nutrient agar and malt extract agar – 20, 19 and 18 species, respectively. Values of Jaccard coefficient varied from 10 % to 52 %, which indicated the significant specific difference of mycobiota isolated on various media and to a certain extent it was stipulated by the abundance of infrequent or occasional species, especially on rich media. Most similarity of species composition (above 30 %) was registered between rich media, the least one (below 20 %), when compared those media with media containing paper and starch as the only source of carbon. Only *Penicillium brevicompactum* was isolated on all the eight media, this species was dominant or abundant on all the media except medium with starch. *Mycelia sterilia* and *Aspergillus versicolor* were often found on agarized malt extract and DG-18 (in 40 % and 30 % of samples, respectively). Besides, *Penicillium commune* was often found on all the media besides Sabouraud's medium and medium with starch; *Penicillium aurantiogriseum* was often found on the following media: Czapek-Dox medium, nutrient agar, wort agar, and medium with starch. It should be noted that micromycete *Trichoderma viride* – active biodestructor of documents which was isolated in significant amounts on others media – was not found at the use of media of DG-18 and malt extract agar. Therefore, DG-18 and malt extract agar media are not optimal for the estimation of air condition of book-repositories.

Thus, the selection of nutrient medium for the estimation of air contamination should be done on the basis of the specific tasks and climatic features of examined environments, especially relative air humidity. It is necessary to take into consideration indoor air mycobiota and stored objects, and also the ability of potentially dangerous micromycetes to grow on that medium. Normative value of air contamination should be specified for each used medium.

P007 – BIOLOGICAL AND MICROCLIMATIC DIAGNOSIS IN CULTURAL HERITAGE CONSERVATION

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This work presents the application of a methodological model based on an integrated system for biological and microclimatic monitoring to assess and prevent biodegradation risks. The integrated system [1] was implemented inside the Derossiana room of the Palatina historic library in Parma, Italy. Biological and microclimate monitoring were performed during summer and winter 2012. Samples were collected at a height of 1 m, 2 m and 4 m. The concentration of microorganisms in the air was measured by active sampling (DUO-SAS 360) and expressed as CFU/m^3. The number of airborne microorganisms settling on surfaces was measured by passive sampling (Petri dishes) to determine the Index of Microbial Air contamination (IMA). Airborne particles 0.3, 0.5, 1.0 and 5.0 µm in diameter were counted with a laser particle counter (Climet 754). The surface contamination of ancient manuscripts and shelves was measured using nitrocellulose membranes to determine the Microbial Buildup (MB, total number of microorganisms accumulated on a surface prior to the sampling) and the Hourly Microbial Fallout (HMF, number of microorganisms that settle on a surface during 1 hour). A spore trap sampler (VPPS 1000) was used for direct microscope detection of fungal spores, both viable and nonviable, and to measure the temporal distribution of the particulate. Microbiological contaminants were analysed by means of cultural and molecular biology techniques. A wide variability of air microbial and particle contamination was observed. A significantly higher concentration was observed in summer for particles 0.5 µm ($p=0.004$) and 1.0 µm ($p=0.004$) in diameter, while a significantly higher concentration was observed in winter for particles 5.0 µm in diameter ($p<0.001$). Air microbial contamination expressed in CFU/m^3 was significantly higher in summer ($p<0.001$), while no significant differences in IMA values were observed between the two seasons. The comparison between 1 metre and 2 metres showed a significantly higher concentration at 1 metre for particles measuring 0.5 µm ($p=0.003$) and 1.0 µm ($p=0.007$). Air bacterial contamination expressed in IMA was significantly higher at 1 metre ($p=0.034$). The most frequently isolated microfungi genera were *Cladosporium, Alternaria* and *Aspergillus.* Bacteria genera such as *Streptomyces, Bacillus, Sphingomonas, Pseudoclavibacter* as well as unculturable bacteria were identified by polymerase chain reaction (PCR). Microclimatic parameters (air temperature, relative humidity, air velocity and mean radiant temperature) were recorded. The Computational Fluid Dynamics (CFD) simulations based on a multi-physics approach were used to study the tracing and diffusion of particles inside the room [2]. Based on the particle concentrations measured at the various defined levels of the room, a particle-tracing post-processing was carried out after solving the air velocity fields. These were combined with infrared temperature measurements of several surfaces. Results from the thermal analysis simulation show that the room appears to be well insulated from external conditions, maintaining a constant temperature throughout the air domain. This finding agrees with experimental evidence. The latent heat power due to a person standing near a bookcase does not significantly modify the distribution of vapour concentration in the inside air volume, even when the total vapour flux reaches its maximum values in the air volume around her. Changes in the airflow patterns and air velocity distribution inside the room clearly occur when the person is moving. This finding underlines the fact that, in the absence of imposed pressure gradients (forced indoor ventilation), the effect of a person moving in the buoyancy-driven flow may have a considerable impact, especially with respect to any small particle transport. This interdisciplinary research represents a contribution towards the definition of standardized methods for assessing the biological and climate quality of indoor heritage environments, preserving cultural property and safeguarding the health of operators and visitors.

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P008 – AIR FUNGAL STUDY FOR PREVENTION TO BIODETERIORATION IN PAPER COLLECTIONS

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Keywords: biodeterioration, archives, fungal

The Directorate of Libraries, Archives and Museums is the institution that oversees the conservation of national heritage in public Chilean institutions. One of the risks that face their collections is biodeterioration that may affect objects and stakeholders

Among their collections are historic and modern archives, stored under the tuition of the National Archive, most of them paper documents from the XVI to XXI centuries, which are not exempt of being attacked by microorganisms.

Several studies have demonstrated the presence of microorganism in libraries and archives, whose damages can go from stains to a complete paper disintegration depending of attack extension [1-4] The air microbiological load in enclosed areas could be a contamination risk not only for the objects but also for the health of the workers of these places, causing allergies and infections [5-7]

Based on above background, it was studied the environment fungal load in six storage areas in National Archive with different conditions using it as an additional parameter to be measure as well as relative humidity and temperature that are routinely registered. The method of microbiological study included the use of two culture media, one for the general biota and other for organisms able to metabolize cellulose.

The results showed a high concentration of air fungus in some areas, which increased in spring in relation to winter. It was identified fungal genus usually documented in museums, storage areas and exhibitions [4], these organisms have been described to be harmful to human health [8].

This experience was the first step to generate a methodology to be use along with other parameters registered routinely for the prevention of biodeterioration like a tool available for others institutions.

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P009 – AIRBORNE FUNGI IN THE REPOSITORIES OF THE NATIONAL LIBRARY OF RUSSIA

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Microbiological air quality in the repositories of the National Library of Russia (NLR) is one of the most important parameters influencing the preservation of its collections.
Mycobiota of air environment have been investigated in the repositories of NLR located in St.-Petersburg city centre on Fontanka river embankment since 2002. Data in this paper are the result of the investigation has been carrying out for one year. Air samples were taken in three repositories (the volume were 50 m^3, 515 m^3 and 680 m^3) and outdoors.
Air temperature in repositories was 19-27 ˚C, relative air humidity in July-to-September period was 45-50 %; and during heating season – 20-40 %. Changing of indoor micromycete quantity in the repositories of NLR had the seasonal nature: their values amounted to its maximum (130-210 CFU/m^3) in summer and in autumn, and its were minimum in winter period (from 0 to 30 CFU/m^3), with the exception of a sampling point at the 2nd tier, where its were up to 90 CFU/m^3. The CFU/m^3 level of outdoor air in most cases considerably exceeded indoors level. The first tier of repository contained more quantity of micromycetes than the second one.
Micromycetes formed from 60 to 90 % of the total values of microorganisms, the rest were represented mainly by bacteria.
A total of 68 species of micromycetes (including 61 ones from repositories) were isolated from indoor and outdoor air. Its belonged to 25 genera (of the divisions *Zygomycota*, *Ascomycota* and anamorphic fungi). It should be noted that most of isolated species belonged to the anamorphic fungi, mainly of class *Hyphomycetes*, families *Moniliaceae* (15 genera) and *Dematiacea* (8 genera). Genus *Penicillium* was represented by maximum number of species (23), 11 species belonged to genus *Aspergillius*, genera *Acremonium* and *Cladosporium* had four species in each; the rest genera were represented by one-to-three species.
Genera *Penicillium* (30 %), *Aspergillus* (27 %), and *Cladosporium* (10 %) were most numerous in amount of species in outdoor air. Relative abundance of genus *Penicillium* fluctuated in repositories from 32 to 47 %, *Aspergillus* – from 19 to 35 %, *Acremonium*, *Cladosporium*, *Paecilomyces* and *Scopulariopsis* were less.
The highest frequency of occurrence in outdoor air was recorded for *Penicillium aurantiogriseum* (68.2 %). This species was the only dominating one. It should be noted that this species was belonged to the category of "frequently encountered" in indoor air of library repositories. The following species of genus *Penicillium* were also often to be found in outdoor air: *P. brevicompactum*, *P. chrysogenum, P. commune*, *P. frequentans* and *P. variabile*, and the rest species were infrequent or occasional. *A. flavus*, *A. fumigatus*, *A. sydowii* and *A. versicolor* had the highest frequency of occurrence of genus *Aspergillus* in outdoor air.
Biological diversity of *Aspergillus* was larger in library air (11 species) than in outdoor air (8 species), i.e. fungi of genus *Aspergillus* seems to be more typical for close space of book-repositories than for outdoor air. *A. niger* was a occasional species outdoors, however it often occurred in air of some repositories and on documents' paper. Fungus species quantity in library air was greater mainly at the expense of infrequent or occasional species which were considerably less outdoors where more active species dominate.
Using the index of frequency occurrence enabled us to reveal complexes composed of 14 species of micromycetes typical for street and repositories air. Ten of them were indicator species for outdoors. Nine species of micromycetes: *Aspergillus flavus*, *A. niger*, *A. versicolor*, *Cladosporium cladosporioides*, *Paecilomyces variotii*, *Penicillium aurantiogriseum*, *P. commune*, *P. Chrysogenum* and *Scopulariopsis brevicaulis* were the indicators of air environment typical for the examined repositories. Five of this species were typical for one repository which located at the first floor and six – for others repositories which located at the second floor. Wide range of tolerance regardless of the condition of their habitation was found for five species of micromycetes: *Penicillium aurantiogriseum*, *P. commune*, *Aspergillus flavus*, *A. versicolor*, *Cladosporium cladosporioides*.
Most specific similarity was observed between micromycetes isolated from air of repositories with intensive air exchange and outdoor' micromycetes (Sörensen quotient of similarity $_s$ = 0.55). Smaller values of Sörensen quotients (0.42 and 0.36) indicated the reliable differences between mycobiota of air in the second floor repositories as compared with outdoor air and air of repository with intensive air exchange.
Many of found micromycetes are not only active destructors of library materials but also can cause various allergic reactions. In spite of the relatively high frequency of occurrence of opportunistic fungus species, in whole the conditions in repositories can be considered as satisfactory, as the values of micromycetes in air is 2.5 times less than the maximum permissible value recommended by the World Health Organization – 500 CFU/m^3.

P010 – FUNGAL INFECTIONS AND CULTURAL HERITAGE: AN ALTERNATIVE APPROACH FOR VOCS ANALYSIS APPLIED IN INDOOR ENVIRONMENTS

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Keywords: Indoor air, VOCs, Fungi, Cultural Heritage

Fungal infections inside libraries and archives are frequent and complex problems to manage, often with severe economic and health implications. Even if indoor environments are climate controlled (18-20 °C, 50-60 % relative humidity), some fungal species are still able to grow on materials, preferentially in air-stagnation microenvironments [1, 2].
It is well known that Fungi during their development, even in the early stages, produce several volatile organic compounds (VOCs) that are then suspended in the air or adsorbed on dust particles [3]. The assessment of their nature is needed for a proper assessment of the indoor air quality.
A rapid tool to understand fungal contaminations in indoor environments could be air sampling followed by gas chromatography-mass spectrometry (GC-MS) analysis. For the broad speciation of unknown trace of VOCs we tested evacuated stainless steel canisters (3 Liters of volume) to sample within a few seconds the indoor air [4].
The composition of the indoor air in a deposit of Ca' Foscari University Library affected by an active molds infection was analyzed with the aim of detecting a specific chemical fingerprints of Fungi. Seven canisters were adopted in different areas of the deposit to collect VOCs and subsequent analyzed by GC-MS. Moreover, laboratory experiments were developed to collect VOC production directly from infected books and from the two dominant fungal species isolated from the library by previous sampling (*Eurotium halophilicum* and *Aspergillus penicillioides*). In addition, dedicated sample chambers were realized for the analyses of VOCs emitted by infected books, while specie-specific fungal colonies were grown in culture bottles with proper media and temperature. All the samples were monitored for a period of 1-2 months by weekly analysis of the emitted VOCs. For all the analysis, microscale purge & trap Entech 7100 was adopted as sampling and pre-concentration system directly connected with corresponding sampling devices (canisters, sample chambers, culture bottles) and GC-MS.
Several volatile organic compounds that were detected in the indoor air (i.e. 1,4-pentadiene and 2-butanone) were also found in the emission of the dominant fungal species isolated from materials and in the volatiles released from the infected books. The results suggest a close relationship between the fungal infections and the indoor air quality.

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P011 – FUNGICIDAL PROPERTIES OF SATURATED AND DILUTED VAPOURS OF ESSENTIAL OILS

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Keywords: essential oils, vapours, microbicidal properties, gas chromatography/mass spectrometry detection

Essential oils (EOs) are volatile, natural compounds characterized by a strong aroma. They are formed by plants [1] and isolated from plants mostly by hydro- or steam distillation, by pressing [2] or by fermentation [3]. The EOs are used for example in food and beverage industry or as fragrances in perfumes and cosmetics. The EOs play an important role in the protection of the plants [1].

The study presented in this poster was performed in the frame of project "Saving of culture heritage on paper". The poster describes chemical composition and fungicidal properties of saturated and diluted vapours of *Lavandula angustifolia*, *Citrus aurantifolia*, *Cinnamomum zeylanicum*, *Citrus Bergamia* and *Myrtus communis*. Fungicidal activity was tested against *Aspergillus brasiliensis, Penicillium aurantiogriseum* and *Cladosporium cladosporioides.* Experiments were performed in desiccators both for saturated and diluted (5 times) vapours of EOs.

The fungicidal activity was determined by the modified vapour-agar contact method by Czech version of the European Standard ČSN EN 14562. The determination of volatile components in gas phase in the desiccator within antimicrobial study was performed by using a cylindrical wet effluent diffusion denuder when the components of EOs in gas phase were absorbed into a thin film of n-heptane (used as an absorption liquid) and the analyses were performed by gas chromatography coupled with mass spectrometry.

The concentrations (ppm (v/v)) of the saturated vapours of the most volatile components were: *Lavandula angustifolia* (linalool – 99.9, eucalyptol – 44.9), *Citrus aurantifolia* (limonene – 405), *Cinnamomum zeylanicum* (α-phelandrene – 69.2, eucalyptol – 58.1, α-pinen – 56.9, limonene – 55.0), *Citrus Bergamia* (limonene – 75.3, β-pinen – 43.6), *Myrtus communis* (α-pinen – 531, eucalyptol – 334, limonene – 160).

The saturated vapours of volatile components *Lavandula angustifolia* showed the most effective fungicidal properties from studied EOs. Volatiles of *Lavandula angustifolia* completely inhibited tested fungi within 2 days (*Penicillium aurantiogriseum*), 3 days (*Cladosporium cladosporioides*) and 1 week (*Aspergillus brasiliensis*), respectively. The volatile components of *Citrus aurantifolia* manifested very good antifungal properties against *Penicillium aurantiogriseum* (3 days), *Citrus bergamia* and *Myrtus communis* against *Cladosporium cladosporioides* (3 days). The saturated vapours of volatile components of other studied EOs were also sufficiently effective (1 or 2 weeks). Fungicidal effect of the diluted vapours (5 times) of the studied EOs was not manifested in process of 6 weeks.

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P012 – ESTIMATION OF ACETIC ACID AND AMMONIA GASES CONCENTRATION IN MUSEUM DISPLAY CASES USING EMISSION RATE OF CONSTRUCTION MATERIALS

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Keywords: emission rate, construction material, display case, gas concentration

Recently, many construction materials are used in museum. Some of them emit gases that cause adverse effects on artifacts. Choosing low emissive materials is essential. The most important thing is that gas concentration in display cases, exhibition rooms and storages should be lower than guideline values. Especially, in display cases, gas concentration is required to be careful because that is easily increased due to airtightness of these cases. This study addressed gas concentration in display cases was estimated using emission rate of construction materials.
Emission test of plywood, adhesive for plywood with cloth and sealant materials were conducted. It was assumed that they were emissive materials in construction materials widely-used for display cases in museum at present. Target gases were acetic acid and ammonia that cause adverse effects on artifacts. Emission test was carried out when no seasoning and after 7 and 21 days of seasoning of materials in order to investigate the relation of emission rate with days of seasoning. Because it is known emission gas from materials was decreased by seasoning of materials [1]. (We have recommended material seasoning before set up display cases and stuff of museum.) Concentration in display cases was estimated using emission rate of materials after 21 days of seasoning.
As result, estimated concentration of one model display case was above our guideline values. This suggests that there is possibility to become a high concentration in display cases by air change rate of display cases and surface area of materials even if low emission materials. It is possible to estimate gas concentration in a space in museum using emission rate. We hope that estimation of gas concentration helps improve museum air quality.

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P013 – EFFECTS OF AEROSOL PARTICLES ON LIBRARY AND ARCHIVE MATERIALS

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Keywords: library and archive materials, dust particles

Samples of archive and library materials – paper, cardboard, binding leather and parchment, pigments and binding agents, and photographic materials, were deposited in depositories, in which measurements were carried out of gaseous pollutants and dust particles. The selected depositories are situated in areas in the Czech Republic, which basically differ in air quality: State Regional Archives Třeboň – a tourist region, Research Library of South Bohemia in Zlatá Koruna – an agricultural region, Regional Museum in Teplice – an industrial region, National Archives in Prague –urban locality with high traffic load.
Originally planned one year´s exposure time of samples in depositories was extended to two years after visual estimation of extent of sample dustiness. After this time, characteristic optical, chemical and physical properties – will be evaluated in samples and compared with those of control samples.
This work was supported by the Ministry of Culture of the Czech Republic under grant no. DF11P01OOVV020 Methodology of Evaluation of the Effect of Air Quality on Library and Archival Collections.

P014 – RESEARCH OF IDENTICAL INCUNABULA ON A LONG-TERM BASIS DEPOSIT IN DIFFERENT ENVIRONMENTAL CONDITIONS

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Keywords: identical incunabula, ISTC identifier, SurveNIR, dust particles

Interdisciplinary cooperation of a chemist-technologist, a conservator, and a historian was effectively applied in a specific research of identical incunabula. The objectives of which were to find out to what degree the different quality of ambient air was reflected on properties and degree of paper degradation at long-term deposition. Selection of identical incunabula from collections of the National Library CR in Prague, the South Bohemian Scientific Library in Ceske Budejovice, and the library of the Regional Museum in Teplice, was performed according to the Incunabula Short Title Catalogue database, where each of the publications was assigned an unambiguous numeral identifier of the bibliographical record ISTC, which made interconnection possible of all preserved copies.
SurveNIR measuring system [1] was used for comparison of naturally aged paper, volumes were demonstrably on deposit for a period of at least 200 years in one locality. SurveNIR system utilized non-destructive analytical spectrometric method in near infra-red wavelengths of spectrum (NIR), and chemometry, which applied statistical and mathematical methods for calibration and validation of measured values and for inference of maximum quantity of chemical data. The measurements were carried out always on the same pages of different copies, in which we can assume that they were printed on the same paper. In view of investigation of effects of dust and gaseous pollutants on historical paper, attention was paid also to protective elements and damage of bookbinding [2].
Identical copies of the National Library CR and the Regional Museum in Teplice were deposited on a long-term basis in environment more polluted with gaseous and solid pollutants, to which correspond also lower pH values of cold leach, average degree of polymerization, tensile strength, and tensile strength after bending. Research is aimed to development of advanced monitoring and methods of evaluation of effects of gaseous pollutants, dust particles, and microbial contamination on library collections [3].

This work was supported by Ministry of Culture Czech Republic under the project Methodology of Evaluation of Air Quality Effect on Library and Archival Collections (DF11P01OVV020, 2011-2015, MK0/DF).

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P015 – TEMPERATURE DEPENDENT EMISSION OF ACETIC AND FORMIC ACID FROM PAPER, AND ITS CONSEQUENCES FOR THE AIR QUALITY IN ARCHIVES

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Keywords: emission chamber test, ion chromatography, indoor climate, passive samplers

ABSTRACT SUBMISSION FOR POSTER

Introduction:
Paper records affect the indoor environment in archives, because the paper may give off acid compounds to the air. These emission products origins from the decay of cellulose and lignin in the paper. As the off-gassing origins from chemical processes within the material (e.g., acid hydrolysis) the reaction rate is therefore, among other things, depending on temperature. Some of the emission products from paper, e.g., acetic and formic acid, are problematic from a conservation point of view, because they will re-react with the paper and other archival materials and cause further deterioration.
The problem is amplified by an often very large loading (mass of material vs. volume) of paper in archival rooms. Furthermore, many archives have only little ventilation, so the exchange of polluted air with ambient air is low.
The general trend; higher temperature accelerates material's emission, and a high loading increases the level of internally generated pollutants in a confined room, is well recognized. However, the decisive factors are only sparingly quantified, and in the poster we will place these in a conservation context.

Method:
In a series of laboratory tests, we have determined the emission rate of acetic and formic acid for four historic and two standardized paper types, at 10, 22 and 38 °C. All tests have been conducted at a moderate relative humidity (45-55 % RH), which is representative for an archival climate. Air samples were taken from a dynamic air-flow emission chamber, in which the paper sample was conditioned to constant temperature and relative humidity. The samples were collected by bubbling the air through 0.1M NaOH for 24 hours, and analysed by ion chromatography (ongoing, until February 2014).
In four archival rooms we measured the concentration of acetic and formic acid in the room's air at different seasons (different room temperatures). The temperature of these archival facilities typically varies between 26 °C in summer and 10°C in winter. Sampling was conducted by the use of passive (diffusive) samplers, each time for a period of one month. Based on the results the mass-budget of the emission products from paper in the archives will be calculated (ongoing, until February 2014).

Results and discussion:
This project is ongoing and results are preliminary. All results will, however, be available before April 2014.
Preliminary; we observe a decrease in emission rate on the order of 60 – 90 %, depending of paper type, when temperature is lowered from 22 to 10 °C. This temperature span reflects the indoor climate in a typical unheated storage building in Northern Europe. However, when temperature increases above normal room temperature (from 22 to 38 °C) the effect on the emission rate is less straightforward, with a change in emission rates between none and 500 % increase. This behavior will be discussed in the poster, and compared with the field concentration measurements in archives at different temperature levels.

Author contributions:
This work is the subject of a master thesis by S. Smedemark, supervised by I. Nielsen (ongoing project: 2012-2014).
Laboratory work at the National Museum is conducted by S. Smedemark under supervision of M. Ryhl-Svendsen.
Field measurements at the Royal Library are conducted by S. Smedemark under supervision of B. Vinther Hansen.

POSTERS

P016 – CORROSION OF HISTORIC TIMBER

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Keywords: maceration, climate measurements, timber

Wood corrosion or maceration is a surface damage of timber. These damages can be seen at construction materials protected by fire protection agents [1]. In the Church of Peace in Jawor, (Poland) Ammonium salts (-phosphates or – sulfates) were used in the 19th century to protect the wood. The church is a World Heritage Site, completely made of wood and an example of timber frame construction of the 17th century.
In a research project climate measurements were performed at the top floor as well as measurements of wood moisture of historic and new timber. Climate measurements were made during one year using an ALMEMO® 2590-4S system with temperature and humidity sensor FHAD 462. Wood moisture determination was done by using a wood moisture sensor for long term measurements FHA636 MF10. There are strong fluctuations of temperature (T) and relative humidity (RH) during the year (T_{max}=38 °C; T_{min}= 0 °C; RH_{max}= 92 %, RH_{min}= 31 %) at the top floor. Significant differences in the wood moisture of historic and new timber could be observed. The variation of wood moisture (Δ RH) in the historic timber is more than 20 % in comparison to about 4 % in the new timber. Caused by the treatment of the wood with fire protection agents hygroscopic salts are located in the near surface region which are absorbing and desorbing water (Fig. 1).

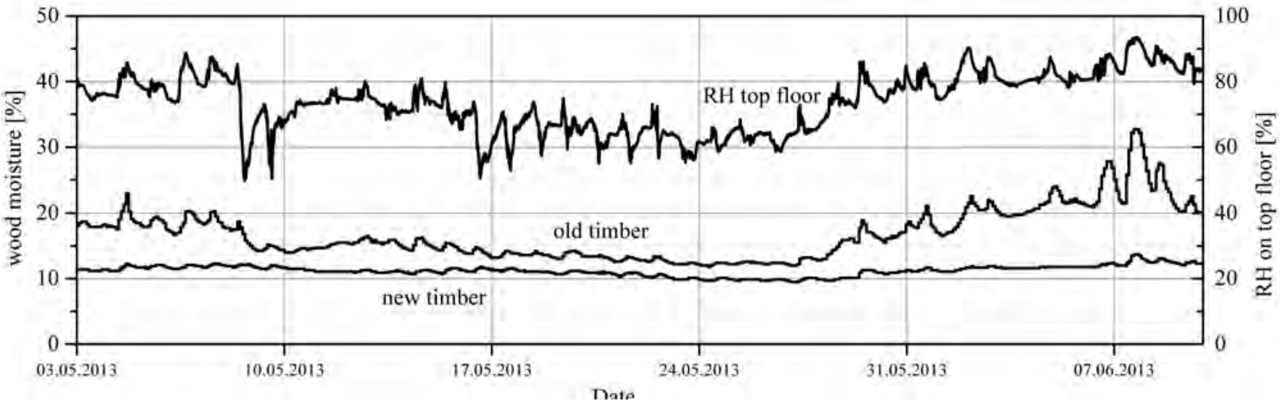

Fig. 1: Climate and wood moisture measurements, Church of Peace, Jawor (Poland) 03.05.-10.06.2013

The humidity absorption of salts takes place in a surface near region up to 5 mm depth only. Layers underneath behave like new timber. The absorption of water of fire protection salts takes place more intensive by strong variations in relative humidity (> 76...100 %). The dissolved salts can migrate into the deeper wood cells. If the environmental conditions are dry (relative humidity below 63 %) desorption of water and crystallisation of salts take place [1]. Damages of the wood structure are caused by local pressure as a consequence of the crystallisation of salts. Chemical analysis of wood samples was performed with SEM/EDX (FEI ESEM-XL30, EDX-EDAX). High concentration of sulphur and chlorine were determined in the wood surface. A high concentration of sulphur can indicate the danger of wood corrosion or maceration of timber. The chlorine containing particles in the wood are particles of timber treated by wood protection agents. Pentachlorophenol (PCP) was the most used fungicide for wood protection in the last century [2].

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P017 – INVESTIGATION OF THE ENVIRONMENTAL FACTORS EFFECTS ON ORGANIC MATERIALS CONSTITUTING THE NATURAL AND CULTURAL HERITAGE: THE INVENVORG PROJECT

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Keywords: museum, organic materials, preservation

Problems resulted by the climatic changes all over the world are affecting the state of preservation of the museum collections' objects and especially those of organic origin.
The research project entitled "Investigation of the environmental factors effects on organic materials constituting the natural and cultural heritage" (INVENVORG) focuses on organic materials, of animal as well as of plant origin, that are prone to decay due to biotic and abiotic factors. This research project has been based on the COST D42 "EnviArt" outcomes and meets the objectives of this action, focusing in organic materials http://www.cost.eu/ /domains_actions/cmst/Actions/Chemical_Interactions.
In the framework of this project, artificial ageing of organic materials under individual environmental factors, [such as temperature (T), relative humidity (RH), ultraviolet (UV) and visible radiation, sulfur dioxide (SO2), ozone (O3) and nitrogen oxides (NOx)], is implemented. At the same time it is attempted a behavior study of these materials, in real museum environments in which the air gases, the climatic factors, the particulate matter and the bioaerosol are measured. Afterwards, the evaluation of the mechanical, thermal, optical and morphological properties as well as the analysis of the composition and the determination of the chemical stability of the non-aged, artificially and naturally aged (in the museum environments) organic materials will take place.
With the completion of the above stages, the factors that correlate positively or negatively with each other will be determined by use of univariate and multivariate factor analysis techniques. The determination of the degree of dependence of the measured properties on the changes of the environmental variables and the identification of the pollution sources in the museum environment will also be accomplished by use of confirmatory factor analysis.
The modeling of the ageing, based on the correlation of the ageing parameters and the mechanical and chemical degradation observed will support the prediction of the ageing of the organic materials under various environmental conditions.
In conclusion the expected outcome of this project will:
- provide a better knowledge of the chemical interactions between the indoor environment and Museum and Libraries' organic materials;
- create possibilities for exchange of knowledge between chemists, materials scientists and conservators working in the field of preventive conservation with museum staff and decision makers;
- provide arguments necessary for the discussion with governmental organisations and the object owners to set higher priorities on funding of preventive conservation;
- contribute to establishing guidelines for indoor air quality in museums, archives and libraries;
- help to set priorities for investments in collections on display and for the concept of risk assessment in general.

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek National funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) – Research Funding Program: THALES.

P018
CANCELLED

P019 – STONE LEPROSY – A CURSE TO THE CULTURAL HERITAGE

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Key words – Acid Rain, Stone leprosy, Monuments.

At the height of industrial revolution during 1730's, originated the enormous problem of acid rain. In this era of global warming, acid rains are like adding fuel to fire and the sleeping giant of acid rain of the past is now the awakened dreaded giant. The devastating effects of acid rain on our mother earth are a matter of great concern for the entire mankind. Currently, Asian continent is the main target of acid rain but in particular, industrial acid rain is a substantial problem in China, Eastern Europe, Russia & areas downwind from them; as all of the regions burn sulphur containing coal[1]. Acid rain is directly linked to air pollution and a serious health hazard. It is any form of precipitation, unusually acidic (pH 5.6) mainly due to elevated levels of hydrogen ion concentration[2]. At present, there are a myriad of highly destructive effects of acid rain posing threat to the aquatic ecosystem, terrestrial biota as well as public health[3]. The worst significant devastation by the acid rain is the scenario of ruined cultural heritage-causing stone leprosy to the monuments, sculptures, statues, rock-carvings etc; which is a curse to the mankind. Since, marble & limestone are most vulnerable to acid rain as rocks contain $CaCO_3$ in large amounts which reacts with acids present in rain, turning it into gypsum and then it flakes-off ultimately-thus ruining the detailed effects. The dreaded giant of acid rain has engulfed some of the India's historical monuments as Taj Mahal in Agra (Uttar Pradesh)-which is one of the seven wonders of the world, made of white marble and the prestigious Victoria Memorial in Kolkata (West Bengal), made of makrana marble which are showing signs of stone leprosy after falling prey to acid rain. Thus, India's cultural heritage is at a great risk due to the destruction of these monuments and sculptures, which are the nation's pride.

Globally also, the scenario is not fine. Magnificent monuments as well as stone statues in European continents as The Parthenon, Athens, Greece has been destroyed. The British environment also experiences acidic snowfall. In Bristol, U.K., St.Paul's Cathedral has been corroded due to acid rain. Moreover, the American continent has even not been spared by deadly acid rain as Statue of Liberty, New York & Marble Balustrade, Washington D.C. are showing signs of disgrace. However, the list is countless and endless worldwide; but to name a few are-Cologne Cathedral, Notre Dame, The Colosseum, West Minster Abby etc. This is not the end as in future the scene will be worst as some of the ancient historical monuments and buildings being endangered to acid rain as: statue of Leshan Giant Buddha, Mount Emei & Long Men Grottoes, China, Acropolis of Athens, Greece, Dampier Art Rock Complex, Australia.

To overcome the menace of marble leprosy, several national as well as international organizations put forth their policies/resolutions at individual level; as use of acid resistant materials as granite in the buildings as well as corrosion resistant/acid resistant coatings & resins should be promoted to protect the penetration of acid rain. Drastic measures are being taken by covering the statues with Tarpaulins when the downpour of acid rain is expected to be maximum. Further, Flue Gas Desulphurization (FGD) should be encouraged in coal burning power plants. In fact, modern techniques have kept the buildings and monuments protected to some extent. The devastating effects of acid rain leading to stone-leprosy can be curbed and remedied by awareness and education laying emphasis on the trigger factors of acid rain.

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P020 – ENVIRONMENTAL IMPACT ON STONES & MORTARS FROM DOBROGEA MONUMENT BUILDINGS

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Keywords: Dobrogea, chalk stones, contamination

The effects of the environment on monuments weathering can be evaluated by mineralogical, petrographical and physical-chemical analyses of the samples prelevated from the buildings. Exposed stones and mortars suffer a time-degradation, due to anthropogenic pollution and/or sea-salt contamination. Synergistic effects of pollutants and microenvironmental parameters on materials are responsible for monuments weathering.
Studies carried out on stone samples from monuments of Basarabi Churches, correlated with similar buildings from Dobrogea area: St. Andrei Cave, Niculițel martyrion, Dervent Monastery. For all of them, our studies reveal decay products of deposition and interactions between atmospheric gases and wall-stone of the buildings. Sulphates and nitrates are responsible for the transformation of calcium carbonate through reactions with atmospheric gases. Sulphur, iron, titanium and carbon are the main elements attributed to the atmospheric pollution. Na^+ and Cl^- found in the damaged stones indicated marine influences in the decay process [1].
In urban locations (significant levels of SO_2), dry acid deposition is the most important factor contributing to carbonate stone dissolution, whereas in rural locations (negligible dry acid deposition), karst dissolution dominates over acid rain neutralisation, in most cases. Dissolved SO_2 in bulk water, can migrates in the capillaries or can be absorbed by hygroscopic salts, the karst effect being the major contributor to the weathering of limestone.
The decay of the stone is due to the variations in volume (gypsum has a greater volume than the calcite it replaces and its generation in cracks and pores at the surface is accompanied by expansive stresses), the difference in thermal expansion of the gypsum and the calcite (this difference is further emphasised by the black top layer, caused by fumes and carbonaceous particles, which tend to absorb a larger amount of radiation than white surfaces), and to the reduction of permeability, which will increase water retention and all the corresponding adverse effects [2].
The difficulty in finding calcium nitrate crystals on exposed stone surfaces is probably due to its very high solubility (2660 g/L for $Ca(NO_3)_2.4H_2O$) in water and its hygroscopic nature. NO_2 drastically increases the corrosion rate (indicated by weight gain) of calcareous stones in SO_2-containing atmospheres at high (e.g. 90 %), but not at low (e.g. 50 %) relative humidities [3].
Based on laboratory exposure of calcite powders, it has been proven that NO_2 acts as a catalyst for oxidation of S(IV) to S(VI) at a pure calcite surface, in the presence of molecular oxygen at humid conditions (RH: 90 %). Because of their high solubility, nitrate salts are transported into the inner part of the stone, where they undergo phase transformations such as crystallisation and hydration, depending on the ambient conditions (e.g. temperature and relative humidity), and may cause micro cracks in the stone structure and hence, accelerating deterioration. Dissolution of $CaCO_3$ from carbonate stones is generally expressed as a sum of three factors: dry acid (SO_2, HNO_3) deposition + acid rain neutralisation + karst dissolution (pH = 5.6).
Some detailed petrographic and physico-chemical (X-ray fluorescence energy dispersive (EDXRF), thermal analysis, X-ray diffraction (XRD), Dynamic Light Scattering (DLS), Atomic force microscopy (AFM), relative kinetic stability parameter) of some real samples prelevated from the above-mentioned buildings (boulders detached from the Church's wall, without any value for this church), are presented.

Acknowledgements: *This work was supported by the Romanian National Authority for Scientific Research, CNDI-UEFISCDI, under project number 222/2012.*

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P021 – PRODUCTION AND CHARACTERIZATION OF ACTIVATED CARBON- EMBEDDED FILTER PAPER FOR SIMULTANEOUS CONTROL OF PARTICULAR AND GASEOUS CONTAMINANTS

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Keywords: cellulose filter, activated-carbon, dust removal, indoor air

Concerns for indoor air quality of public spaces become intense in recent years, regarding fine dust, traffic fumes and volatile compounds emitted from construction materials. Indoor air quality is specially controlled in heritage museums, as they are located mostly in big cities where air qualities are often in bad condition. National museum of Korea, for example, was reopened in a new building at 2005, in Yongsan, Seoul. As more than seven thousands objects owned and exhibited in the museum, the building is specially designed and constructed as a "green" building, with high-tech air quality monitoring system that measures the concentration of yellow dust and other pollutants in the air, and regulates the air coming through the air conditioner to maintain excellent quality throughout the museum[1]. Many small-scale museums, however are not supported such advanced facilities and may suffer from the damages caused by contaminants in environment.

Commonly used tools for dust removal include fiber filter and electrostatic precipitator, which have been developed and applied mainly for heavy dust control in industrial purposes[2]. Most fiber filters are made of non-woven material that uses chemical binding agents during the process. Electrostatic precipitator allows high dust removal efficiency but requires high electric power for corona electrification and generates ozone gas during the operation, which requires additional treatment[3]. Therefore, it needs to develop a new tool for air quality control, especially for small-scale indoor use.

"Han-ji" is Korean-traditional paper made of pulp from paper mulberry, best known for the durability that stands for more than 10 centuries. It can be an excellent alternative to conventional fiber filter as it is made of environmental-friendly material that is almost uniform in the thickness of fiber, abundant, and durable when it is used for dust-filtering purposes.

In this study, paper mulberry pulp was used in the production of paper filter and the characteristics regarding filtering capacity were evaluated. The pulp cellulose was purchased in a form of slurry (90 % moisture content), and blended in water several times. The pulp-blending solution was then poured into a specially designed acryl funnel, which consist of support filter, acryl frame (200x200mm) and frame supporter, all connected to a vacuum pump. After vacuum-dehydration, the cellulose filter surface was sprayed with ethyl alcohol, to replace water content between cellulose fibril, so that it helps the filter surface having higher porosity after drying. Three different drying methods were applied; air dry, heat dry(50°C) and freezing dry, and each cellulose filter was evaluated for its filtering capacity through pressure-loss test, and measurement of bulk density and porosity. Series of porosity tests revealed that freezing dry method was most efficient to produce porous paper of expected quality.

Activated carbon (AC) is well known porous material that has excellent capacity to adsorb various contaminants and commonly used for treatment purposes. AC-embedded filter paper was produced by addition of powdered AC (100 mesh) at the blending step of pulp with water. In this case, freezing-dry method was applied and followed same procedure as mentioned before.

Preliminary test for dust and BTEX gas removal was carried out using AC-embedded filter paper installed in a cone-shaped chamber connected with dust and BTEX gas blower, and ports for air quality monitoring. Dust removal efficiencies were varied according to coming dust concentration and the thickness of filter paper made. Under low dust concentration, thin paper was efficient, whereas at heavy dust load, thickness of the filter became critical. AC-embedded filter was excellent in BTEX gas removal, compared to the filters without AC. More than 95 % removal was observed for all BTEX gas at a 90 L/min loading rate and equal 5 ug/m^3 loading concentrations. The production and test of AC-embedded cellulose filter paper revealed that it is capable to remove dust and BTEX simultaneously, therefore can be used in variety of indoor air quality control systems in highly effective and environmental-friendly way.

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P022 – STAINED GLASS LIKE UV FILTERS FOR PAINTED ICONS FROM OLD CHURCHES

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Keywords: UV filter, stained glass, painted icons

The painted artworks are subject to changes induced by light, that include discoloration of pigments, degradation of the binding medium, etc. Rates of chemical and physical changes in paintings depend on the temperature, relative humidity, concentration of air pollutants and ligh intensity and wavelength distribution. Stained glass is known as one of the most beautiful forms of architectural decoration; however, it is also one of the most vulnerable [1]. The medieval stained glass constitute a part of our cultural heritage that has been exposed to environmental damage over centuries. Suspended nanoparticles in stained glass block the UV light [2]. Medieval stained-glass was created by trapping gold nanoparticles in the ‚glass matrix' to create a red colour, or silver nanoparticles, giving a deep yellow colour. Stained glass, like all glass, blocks or more accurately absorbs, UV radiation.
The main purpose of this paper is to provide new insights into the composition and deterioration of stained glass, and their effect as UV filter for different paints churches indoor, too. To analyse the ancient glass, have been used small pieces of broken stained glass without any possibility to be included in other pieces. Different small pieces of stained glass were quantitatively analysed by EDXRF and ICP-AES, it order to determine a number of elements which are present bellow the detection limit of EDXRF and to evaluate the homogeneity of investigated materials. Also, to identify the processes a broad range of techniques has been used: spectroscopic techniques, such as UV-Vis spectroscopy, Fourier transform infrared (FTIR), and analytical mass spectrometric techniques, as laser desorption time-of flight (LD-TOF) mass spectrometry. The aging process and the influence of light on the triterpenoid varnishes, will be evaluated, too. An investigation of the natural aged paints of some nineteenth century Byzantine icons was carried out.
The radical chain reactions that initiates oxidation and alterations in the network polymer formation of the film catalyzed by the absorption of UV light, will be quantified by oxidation rate and degradation products. An aged triterpenoid varnish can exhibit brittleness, change in plasticity due to higher molecular weight fractions, opacity and yellowing as a secondary effect of UV light absorption. The deterioration of the icon paints conclude that the yellowing process and the density of cracks gradually decreased from the UV dose. This work presents ultraviolet radiation effects (that could cross through the stained glasses) on the painted icons. There is a gradient in oxidation and network polymer formation across the paint and varnish, which is directly related with the exponential absorption of ultraviolet radiation, resulting an equivalent gradient in the physical deteriorations, in the formation of organic compounds across the paint thickness.
The main conclusions of the study can be summarized as follows:
a) Effect of different stained glass on deterioration rate of some paints.
b) The combined use of several spectroscopic and analytical techniques is necessary to understand the chemical and physical changes induced by UV irradiation of paints.
c) Prolonged exposure to UV light results in oxidative irreversible changes of stained glass and paints, too.

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P023 – MONITORING HISTORICAL COLLECTIONS BY WIRELESS DEVICES

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Keywords: preventive conservation, monitoring, collection's parameters, wireless devices

Monitoring and controlling environmental parameters within collections – especially temperature and relative humidity- re-presents a highly discussed topic in conservation sciences again. Since the preservation of cultural collections requires very precise climate conditions, with daily and seasonal fluctuations to be kept as low as possible, monitoring devices, like hygrographs, hand-helds, and data loggers have become inevitable tools for conservators. Though, most data logger types were originally developed for industrial purposes. Therefore they often don't meet museum's (aesthetic) standards – demands in terms of precision or range of measurement – nor the need for handling them on display and practicability. The HTW Berlin project investigates the technique of wireless data transfer, which has been implemented and combined with climate and emission [1] data loggers. Hereby it focuses on the device's applicability for preventive conservation and conservation research requirements.
The interdisciplinary HTW Berlin project *Wireless Climate Monitoring Devices for Museums* investigates and evaluates novel radio telemetric measurement devices by the supplier *Virtenio GmbH*. A much higher frequency pulse contributing to a better precision by the transmitted data is one of the fundamental characteristics of the *Virtenio* instruments. Another novelty is displayed by the live data transmission technique. It enables the direct detection of object damaging conditions also from greater distances. Due to an automatic analysis function the parameters are constantly monitored and evaluated, which allows the direct intervention in case of inadequate collection conditions.
Not only the small size of the devices, also their flexibility in terms of extensibility towards various measurement variables [1] in combination with a self-sustaining, low-energy operation modus top off their application within the museum's context. Due to *Virtenio's* likewise industrial background the devices also need to be modified and evaluated before use in cultural heritage collections. Therefore the specific sensor technology has been adapted and tested within laboratory environments and will be followed by a twelve month test-run in different museums exhibitions. Here, a range of climatic regions in combination with naturally conditioned historic buildings have been considered for corresponding investigation. Recommendations for the use of the wireless *Virtenio* devices in museum´s and exhibition´s contexts can be given after the test period. First results refer to promising results, though final conclusions will be drawn after a subsequent comparison with other evaluated devices.

[1] The project includes a CO_2 measuring device for now – further emission loggers will be considered for examination in the second project phase.

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P024 – SENSORS FOR MONITORING CORROSIVITY OF INDOOR ENVIRONMENT OF MUSEUM EXPOSITION

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Keywords: corrosivity, indoor climate, monitoring, museum

The main point of this paper is presentation of indoor climate monitoring corrosivity sensors developed as an integral component of "Unified modular system of remote on-line monitoring of environmental parameters of depositories and expositions" [1].
Priceless objects kept in collections in museums have to be continually monitored in order to prevent damage accumulation or destruction due to operating degradation processes. The degradation processes often reflect the metastable nature of material and conservation care is an attempt to stop or at least postpone inevitable decay. One of the most important factor determining stability of objects in collection is a quality of indoor climate inside exposition or depository in museum. Also museum surroundings influences the indoor environment parameters, as well as microclimate inside showcase itself. In addition to this external sources of potential corrosive agents, displayed objects next to the one in question can release reactive compounds, or even unfortunate composition of materials in the object itself can be cause for its self-destructive tendencies.
First step in mitigation of interaction between objects and indoor environment is to assess correctly what compounds are dangerous for the studied object. The second step is monitoring of the compound concentration in the environment if it cannot be eliminated directly. Monitoring has to be carried continuously and the acquired data records should be remotely accessible for periodical detection of unwanted changes. These requirements can be fulfilled by corrosivity sensors developed in project supported by Ministry of Culture of the Czech Republic. Two complementary corrosivity sensors are being designed and tested. Both are based on known and well established technologies. The first one is based on continuous monitoring of Eigenfrequency of vibrating resonant piezoelectric crystal, covered by selected reactive layer. The second one utilizes precise measurement of conductivity change of a thin layer of selected type of metallic material. The advantage of the first one is relative simplicity, cost effectiveness and very high sensitivity, but it can be used only for one material type at once and the variation of the sensor's performance by the influence of other environmental characteristics is very significant (e.g. humidity variation, influence of other reagents and synergic effects of them). The second type of sensor can simultaneously measure state of degradation of several selected materials, its performance and calibration is very robust and stable, but it depends on relatively expensive device for the precious resistivity measurement. It was decided to prefer development of a parallel to the commercially available solution [2], because of the necessity to integrate the sensors in the developed monitoring system. The "black box" of commercial product is often not open for application specific modifications or communication protocol is not open. But the most important reason is a research requirement to evaluate wide spectrum of materials as corrosivity indicators.
As the nature of the both types of sensors implies, they indicate changes of the selected material only indirectly. Therefore inseparable research part of the project is to determine dose-response functions for the selected materials and reactive environment agents and use it for calibration purposes [3]. Once connected to the system and calibrated by previous testing in the laboratory, the sensor can periodically check the intensity of corrosive process and, eventually, send to museum workers data and warnings when accumulated dose reaches predetermined level.
The work is still in progress, but was demonstrated that it is possible to design and construct inexpensive sensor fully integrated into the monitoring system and to extend set of materials used as indicators of climate corrosivity to those omitted by commercial products.

The project "Unified modular system of remote on-line monitoring of environmental parameters of depositories and expositions" is supported by the Ministry of Culture of the Czech Republic – grant No. DF12P01OVV27.

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P025 – FINE DUST PARTICLE REMOVAL USING ELECTRODYNAMIC DUST SHIELD DEVICE BASED ON DIELECTROPHORETIC AND ELECTROSTATIC FORCE USING ALTERNATING CURRENT POWER SUPPLY

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Keywords: fine dust removal, indoor air purification, dielectrophoretic and electrostatic force, voltage

The environmental pollutions by industrial and economic activities in the earth have been the urgent issue to be solved immediately, which influence to the whole human life. Most of them were emphasized to main subjects to be minimized in the contamination of outer surroundings such as water, soil, and waste compared to the indoor air quality problem, which relatively has been the minor concerns in the urban life as multiple-use facilities.
It is reported that urban people spent most time(over 90% in a day) in the multiple-use facilities take a breath as 10 times much as eating food for capita, which means the indoor air quality and human life amenity have been strongly correlated. Because main sources of indoor air pollution were not only caused from the diverse human activities in house and office but also inner pollutants come from HVAC systems for indoor life amenity, the social requirement for IAQ improvement has been progressively increased for healthy and comfort human life. The IAQ pollution is connected to various complicated production mechanism and has serious influences on physical, chemical, and biological cycles. The main source of IAQ pollution included fine dusts comes from the burning process for house warming or cooking, interior smoking and contaminated air inflow from the exterior, and they are reported to influence on human respiratory system and also contain the cancer-causing affects. Because the PM10 which has below 10 μm aerodynamic radius can be infiltrated to the body through airways with absorption of toxic heavy metal and gas phase contaminants, it has to be monitored and controlled in real time.
Recently developed technologies for controlling and removing the indoor air pollutants include; filter application such as HEPA and ULPA, sorbent/adsorbent application in order to eliminate the smelling airborne chemical by activated carbon and alumina, hydroxyl radical and ozone application resulted in sterilization based on the powerful oxidation, and electrostatic precipitator which can make the indoor air pollutants charged positively to remove.
Alternative method and device of indoor air purifying has been designed based on the electrodynamic system which based on dielectrophoretic and electrostatic force in order to remove the fine dust using electrode(flexible printed circuit board) and three phased alternating current power generator which can regulate voltage and frequency respectively in this study. Various panelization and patterns were applied to investigate the removal rate of fine dust particles. Based on the observation, flexible printed circuit board-based dust shields is feasible to remove dust particles with various voltage supply from dust shields, and the removal rate is a complex function of voltage levels, types of wave signals, panelization and patterns of flexible printed circuit board.

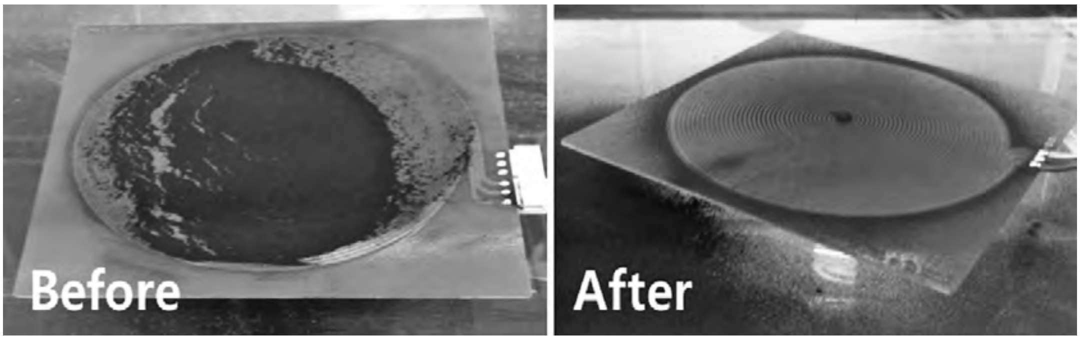

Figure 1. The experiment results of test for fine dust particles removal from electrode using activated carbon powder (below 100 μm) with supplied three phased alternating current power(over 140 V): before power supply(left), and after power supply(right)

This work is financially supported by the KICT internal project named ‘Development of ad-hoc fusion technology for indoor air purification (No. 20140073)’ in Republic of Korea.

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P026 – CONTENT OF HARMFUL CONTAMINATIONS IN BOOK-REPOSITORY AIR

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Keywords: air, contamination, gases, microclimate

The control of the indoor air condition, namely harmful contaminations, necessary carry out for providing the preservation and durability of documents. In the newspaper repository of the National Library of Russia the indoor air condition are estimated according to the Russian Standard GOST 7.50-2002. The content of microorganisms (CFU/m^3) was determined using aspiration sampler PU-1B (Russia) on Czapek-Dox medium. The content of nine harmful contaminations was determined with gas-analyzer GANK-4 (Russia), temperature (t °C) and relative air humidity (RH, %) were determined by using thermo-hygrometer Rotronic (Switzerland). All the measurements were carried out during one year five times a day with the interval of two hours in two tiers simultaneously in five points according to the principle the envelope at a height of 1.4 m above floor level. All the results are statistically processed.

The content of microorganisms indoors depended on their concentration outdoors, though the maxima of that index for outdoor and indoor air were shifted on average for two hours. Quantity of micromycetes in repository air was on average 2-5 times less than outdoors.

The quantity of micromycetes in air at the same temperature depended on relative air humidity: at the relative air humidity outdoors 60-70 % the concentrations of fungus spores was high (100-120 CFU/m^3), and it was of 40-60 CFU/m^3 indoors in the same days. At the relative air humidity of 40 % (in sunny days) outdoors the content of microorganisms came down to 14-15 CFU/m^3, indoors it came to 2-20 CFU/m^3. In cold days (at 10˚C and below) concentration of micromycetes came down fivefold: outdoors to 2-15 CFU/m^3, indoors to 0-5 CFU/m^3. At the temperature close to zero at the relative air humidity of 80-90 % the concentration of micromycetes outdoors did not exceed 7 CFU/m^3. At the relative humidity in repository during the long period (not less than a month) of 20-26 % the concentration fungi did not exceed 5 CFU/m^3, at the humidity of 30-40 % it was 2-24 CFU/m^3, and at 50 % and more the concentration of micromycetes increased up to 50-70 CFU/m^3.

Seven contaminating gases (CO_2, NO_2, SO_2, O_3, Cl_2, amyl alcohol, formaldehyde), soot and dust were estimated. Formaldehyde and ozone were not found in repositories in the course of year. In summer, in cloudy weather, most air contaminations both outdoors and indoors were registered on the level of background concentrations and did not exceed 0.005 %. Excess of maximum allowable concentrations (MAC) of the following contaminations: CO_2, SO_2, soot and dust were observed in repository most of all.

Amyl alcohol was not found in the samples of outdoor air, however amyl alcohol was found in noticeable amounts in seven samples in the second tier of repository and its concentration exceeded MAC in three samples. Quantity of nitrogen dioxide outdoors on average exceeded MAC, and indoors it was less than background concentration. Concentration of microorganisms in the first tier was higher than in the second tier, and on the contrary, concentration of contaminating gases in the period of carried out measurements was often higher in the second tier than in the first tier and higher than in outdoor air. Especially this difference was noticeable in the case of SO_2: its concentration indoors exceeded MAC 4-10 times whereas outdoors it was less than background concentrations. Multiple excess of MAC of SO_2 was registered in repository in summer, and in winter indoor concentration of sulfur dioxide was low. Sulfur dioxide and amyl alcohol that were founded in air are typical gas contaminants for book-repositories and the quantity of carbon oxide, chlorine, soot and dust depends on their quantity in outdoor air. Quantity of nitrogen dioxide increased in the newspaper repository air during a day, which can be caused by the increase of air flows connected with people activity, maximum quantity of both microorganisms and gaseous pollutants in air was from 12 to 14 hours.

Maximum concentration of soot and dust was observed in autumn; concentrations of these substances exceeded MAC in several samples. Chlorine, dust and soot were found in repository air only when they were observed in outdoor air. Their concentration in newspaper repository was always less than outdoors. In summer, in days with high humidity, the indoor concentration of microorganisms, gases and dust also increased, the concentration of microorganisms being always higher in the first tier, and dust and soot being uniformly distributed in both levels of repositories.

Thus, microclimate which is characterized by the presence of definite contaminations in air increases in seldom-aired room. Outdoor air is a source of contaminations into repository, therefore the concentration of fungus spores and harmful contaminations depends on the season, however, it seems that SO_2 is a product gradually evolving from the library materials as its concentration indoors was always greater than outdoors.

P027
CANCELLED

P028 – ASSESSING VOC'S BY SPME/GC-MS

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Keywords: SPME, voc's, Archive's indoor air quality

Whenever the subject of assessing volatile organic compounds (voc's) in a museum environment is raised, conservators and curators turn for scientific support. However defining the voc's optimal levels is not an easy task. Depending on the kind of collection and climate, the optimal range can change significantly.
A microclimate is an environment that can be clearly defined (both by measurements of the environment, and by location) [1]. Due to economic constraints and room for storage, collections are not always kept in the best possible storage conditions. The Archive of the University of Coimbra is located in a building from the late 1940's, built for the purpose of housing the University's documentation. They hold a vast collection of parchments, some of which present pending lead and wax seals. Since medieval times there has been an hospital associated with the Faculty of Medicine. Therefore the Archive holds records of institutions like hospitals and religious orders, combined in close spaces. The degradation of paper and other components of books create specific climates in contiguous rooms. The need to protect and care for these collections in a place where controlling the temperature and relative humidity is difficult is indispensable.
The documents with lead and wax seals have been kept in wood cabinets, in paper folders. These conditions are known to generate an atmosphere „saturated" with voc's. These storage conditions create microclimates inside the drawers which promote, for example, the corrosion of the lead seals. This metal is highly susceptible to the presence of corrosive organic acids, such as acetic and formic acids [2]. The comparison of a lead seal bought by the Archive in the early 50's with its present appearance, is an indicator that monitoring voc's is an important tool in preventive conservation.

Figure 1. Lead seal from 1386 (picture taken in 1950).

Figure 2. Lead seal from 1386 (picture taken today).

The solid-phase microextraction coupled with gas chromatography-mass spectrometry (SPME/GC-MS) has established itself as a reliable, fast and economical method for sampling voc's. The purpose of this work is to establish a sampling procedure with an SPME fiber and optimize a method of analysis by GC-MS, with the intent to relate continuous monitoring with real-time changes for preventive conservation. We aim to establish a correlation between levels of volatile degradation products and the degradation of heritage objects [3].

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POSTERS

P029 – FANTASTIC PLASTICS AND AIRBORNE POLLUTANTS – A DEGRADING COMBINATION?

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Keywords: polymers, acetic acid, contemporary art, collection care

Air pollution has been a troubling issue for the conservation of heritage artefacts. From direct deposit onto building surface to causing acid rain, the role of air pollutants such as nitrogen dioxide and sulfur dioxide have been extensively studied; literature on the danger these pollutants pose to indoor artefacts are plenty, but those specifically dealing with synthetic polymers in collections, on the other hand, are scarce. Studies have shown that both nitrogen dioxide and sulfur dioxide, which are both traffic-generated pollutants, contribute to polymer degradation and/or color change. [1,2]

Many indoor sources of air pollutants exist as well, and one that is of particular concern to heritage institutions is acetic acid, which can be emitted by materials such as wooden display cases, and at the same time accumulate to a high concentration in an enclosed environment; [3] the degradation of cellulose acetate produces acetic acid gas, [4] and cellulose nitrate produces NOx species that includes nitrogen dioxide, [5] which are of special interest since these polymers essentially facilitate their own degradation processes.

The mechanisms of polymer degradation are numerous and complex, including processes such as chain scission and cross-linking. [6] The way a pollutant interacts with a polymer is unique and differences will always be present simply due to the fact that most polymers are produced with additives, resulting in an end product that is essentially a mixture of different compounds. Hence this study is designed with the cultural heritage community in mind, with results that would ideally be applicable and relatable to actual practice.

Studying samples that are aged naturally in actual museum settings would be ideal, but these experiments can be time consuming and costly. An accelerated aging experiment will be done with pollution chambers, which will expose the samples to nitrogen dioxide, acetic acid, and formic acid gases, and characterization of samples will done before, during, and after the period of exposure to compare and measure changes, which entails Fourier Transform Infrared (FTIR) spectroscopy (to understand the changes at a molecular level) and colorimetric measurements (with color change on the L*a*b* scale), and will be complemented with Scanning Electron Microscopy (SEM) imaging for surface characterization;

Plastic samples include the following polymers: polyurethane, polyester, nylon, polyethylene, cellulose acetate, cellulose nitrate, and polyvinyl chloride. The samples will be exposed to 80 ppm of nitrogen dioxide and formic acid for six weeks, and 80 ppm of acetic acid for twelve weeks.

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POSTERS

P030 – MONITORING AND EVALUATION OF POLLUTANTS LEVEL IN TECHNICAL MUSEUM IN BRNO

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Keywords: preventive conservation, air quality

Specific project of Technical museum in Brno – Methodical conservation centre involved research, monitoring, evaluation and strategy definition about the current pollution level. As the mission of Methodical conservation centre is to provide consulting, informational and educational service, our considerations and motivations for the research were various. At first, complex evaluation of air quality in our institution was performed to protect existing technical collections, secondary we worked on the practical methodical guidelines (cost-effective and simplified methods for pollution control) and on practical educational courses. For this different targets, many types of analytical technique were used – active and passive sampling for recognition of specific pollutants concentration level and Ultrafine Particle Counter for detection of aerosols particles. Many campaigns were carried out simultaneously, during the spring at specific locations. Sites for the measurements were selected on the basis of a careful survey of the museum according to specific parameters (expected pollutants, environmental stress, objects degradation, climatic parameters).

Different dangerous pollutants were measured as NO_2, O_3, SO_2, HNO_3, HCOOH, CH_3COOH, NH_3, HCl, aldehydes, VOC, heavy metals and PM10 particles. Used monitoring techniques were both type passive and active – Radiello and IVL dosimeters, Gradko tubes, photometry, chemiluminiscence, gas chromatography, high-performance liquid chromatography, gravimetry and inductively coupled plasma mass spectrometry1,2. Ultrafine particular counter was used to detect particulate levels, to help to eliminate indoor air quality problems. This portable instrument detects and counts ultrafine particles (smaller than 1 micrometer) that often accompany or signal the presence of a pollutant that is the root cause of complaints. Measurements were carried out on many sites through first and second floor of the main museum building. Results of the measurement were evaluated considering many parameters. At first, we had to take into account the different climatic parameters, which were detected on the sampling's sites. Then we correlated all the data to get a feedback about the suitability, quality and accuracy of all used analytical techniques. Secondary, we analysed the data comparing the level of pollutants on sampling's sites, with the aim to understand the difference between the environmental stress at different location. Last, but not least we evaluated detected particular chemical compounds, with the aim to find and specify their sources. Results, presented in data-tables confirmed our expectations about the difference between conditions that are museum objects exposed. Correlating the data form passive and active measurements showed that the using of passive dosimeters for quantification of pollutant concentration is rather difficult. There should be a significant problem with sorption coefficient or assessment of steady state between sorption matrix and pollutant. Generally, evaluation of the experimental results gave us the data for the museum control strategy and some interesting ideas for enhancement of methodical guidelines and practical educational courses of preventive conservation.

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P031 – DEPOSITORIES OF THE NATIONAL TECHNICAL MUSEUM

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Keywords: depository, climate

All the care that is put into creating collections, including their conservation and restoration, would be lost, if the items were stored in unsuitable spaces and deteriorated there due to adverse conditions. The strict requirements on storing collection items are best met by modern functionally designed and operated depositories with complex regulation of interior environment.
The new NTM depository halls belong among top notch work spaces. The location of the building, its construction and mobiliary and technical equipment ensure suitable safety and climatic conditions for storing collection items including minimising the dustiness of the interior environment.
The three multipurpose depository halls, built in the NTM´s complex outside of Prague (Čelákovice), are such an edifice. Their construction begun in 2003, the first building (Figure 1) was erected on an area of 1800 m^2 and was awarded the price Gloria Musaealis in the category Museum achievement of year 2006. The second hall (completed in 2009) with a depositary area of 2040 m^2 was erected on an area of 1640 m^2. The building is designated for storing three-dimensional collection items, especially from the areas of transportation and engineering technology, electro technology, photography and film and exact sciences. The third newest hall with the special sprinkler system was built in 2011 and was designated for storing of the vast and very valuable archive funds – archive of technical history and architecture archive.
The structuring of these buildings with a monolithic reinforced concrete construction and sandwich cladding, practically without windows is unique; it comprises a number of specific operation areas with their own regimes (setting of required temperatures and relative humidity in individual depositories). Protection against the spreading of microorganisms requires the detachment of the receiving area and depository area. The premise for depositing exhibit items in their treatment and decontamination, which is why the hall is equipped with its own conservation workshop, a depot for contaminated collection items, areas for the mechanical and chemical cleaning and a restoration workshop. Collection items are deposited in places designated by alphanumeric codes and they are also marked with labels with an alphanumeric code of the collection item and photograph.

Figure 1. Depository of the National Technical Museum in Prague – hall I (area Čelákovice).

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P032 – NEW DEVELOPMENT OF INDOOR CORROSIVITY CLASSIFICATION

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Keywords: indoor corrosivity, classification system, standard

Metals, alloys and metallic coatings may suffer atmospheric corrosion when their surfaces are wetted. There are some technical standards define the type of environment in respect to corrosion stress. Low corrosivity indoor atmospheres are classified according to EN ISO 11844 *Corrosion of metals and alloys – Classification of low corrosivity of indoor atmospheres,* which consists of the 3 parts:

- *Part 1: Determination and estimation of indoor corrosivity*
- *Part 2: determination of corrosion attack in indoor atmospheres*
- *Part 3: measurement of environmental parameters affecting indoor corrosivity*

The aim of this standard is to characterise indoor atmospheric environments from metal corrosion attack point of view. The corrosivity of an indoor atmosphere increases with higher humidity and depends on the type and level of pollution. Frequency of *RH* and *T* in intervals and frequency and time of condensations are important characteristics. Indoor atmospheres are polluted by the components from external and internal sources. Typical pollutants are SO_2, NO_2, O_3, H_2S, Cl_2, NH_3, HCl, HNO_3, Cl^-, NH_4^+, organic acids, aldehydes and particles. To determine corrosivity of indoor environments, corrosion rates or rates of increase of mass of four reference metals after an exposure for one year are applied. The reference metals are carbon steel, zinc, copper, and silver. Due to variations of outdoor humidity and temperature, uncontrolled indoor microclimate initiates corrosion. E.g. in 2008-11 the climatic parameters were measured in three localities of mining open air museums – Pribram, Kladno and Ostrava, the Czech Republic – indoor (uncontrolled) spaces where the large steam engines and other machines are placed (Table 1). Each metal is sensitive to other type of parameters so the same corrosivity category may be found for metal even at very different indoor environments when the dominant corrosion stimulator affects its corrosion behaviour (Table 2). The average temperature at National Museum was 21,7 °C and RH 38,1 %., but the H_2S level was relative high to cause significant copper corrosion mass loss.

Table 1. Environmental yearly average values and carbon steel coupon corrosion loss in indoor of mining museums

locality	temperature (°C)	relative humidity (%)	TOW (hrs.a^{-1})	SO_2 (µg.m^{-3})	corrosion loss (g.m^{-2})	corrosivity category
Kladno	8,6	72,8	1851	2,7	0,5	IC2
Pribram	10,6	72,2	3224	2,6	1,5	IC3
Ostrava	10,0	72,0	1848	3,1	15,1	IC4

Table 2. Yearly corrosion loss and corrosivity at indoor atmospheres

locality	mass corrosion loss (g.m^{-2}a^{-1})				corrosivity category			
	Fe	Zn	Cu	Ag	Fe	Zn	Cu	Ag
Pribram museum, 1st floor	1,32	1,93	0,26	–	IC3	IC4	IC3	–
Pribram museum, basement	2,46	2,33	0,26	–	IC3	IC5	IC3	–
National Museum, depository	–	–	0,14	0,08	–	–	IC3	IC1

The standard had been published in 2006 and Working group ISO/TC 156/WG 4 starts to revise this standard since year. The proposed changes are:

- better characteristics for temperature-humidity complex,
- including lead as metal specifically sensitive to volatile organic pollution (formic acid, acetic acid, etc.)
- possibility to use a month period of measurement or exposure coupons for indoor environments with stable conditions,
- addition of quartz crystal microbalance (QCM) as monitoring method of indoor corrosivity – in some environments, the QCM technique allows measurement of the gain of the mass of copper and silver specimens directly (Table 3).

Table 3. The comparison of the corrosion rate of the copper thin film and the copper plate r_{corr} (mg/m^2.a)

Cu plate – Electrolytic cathodic reduction method	Sputter deposited Cu thin film – QCM method
371	345

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	Workshop
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