IAQ 2024

The International Conference on Indoor Air Quality in Heritage and Historic Environments

November 18–20, 2024
The Metropolitan Museum of Art

Welcome to New York!

The Department of Scientific Research at the Metropolitan Museum of Art in New York City is pleased to welcome you to the 16th International Conference on Indoor Air Quality in Heritage and Historic Environments, IAQ 2024. This conference is a forum for discussions on the influence of indoor air quality on objects in museums, libraries, and archives. Over the next two and a half days, we will hear from a diverse group of conservators, curators, and researchers about topics ranging from method development in materials testing, to the impact of indoor air quality on heritage collections, to the interplay of conservation science with sustainability and climate. We look forward to the forthcoming presentations and the discussions that are sure to follow; Thank you for joining us, and we hope you enjoy the conference, the museum, and your visit to New York City!

Organizing Committee

Eric Breitung

Rose King

Julia Bakker-Arkema

Department of Scientific Research, The Metropolitan Museum of Art

Scientific Committee

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Jean Tétreault, *Ottawa, Canada*

David Thickett, *English Heritage, London, UK*

Schedule of Events

Monday, 18 November, 2024

Special Conference Tours Pre-registration Required	
14:00-15:00	*Tour Option 1* Skylights Tour of the Renovated European Paintings Galleries: Join Michael Dominick, Senior Associate Buildings Manager for Infrastructure, as he discusses the significant lighting and HVAC upgrades in the roof space above the newly renovated European Paintings galleries.
14:00-15:00	*Tour Option 2* IAQ at The Met: Get an exclusive preview of the newly renovated Michael C. Rockefeller Wing, which is not yet open to the public. Scientific Research staff will showcase the new galleries and casework design features, followed by a brief tour of the Department of Scientific Research.
17:00	Metropolitan Museum of Art closes

Tuesday, 19 November, 2024

9:00	Registration *Entrance at 81st Street and Fifth Avenue, follow signs to Bonnie J. Sacerdote Lecture Hall*
9:30	Welcome and Introduction • Welcome, *Eric Breitung* • History of Indoor Air and Preventive Conservation Science at The Met, *Elena Carrara*
Session 1: Method Development for Material Testing Chair: Jean Tetreault	
9:45	The impact of indoor air quality on the preservation of photographic archives: A case study from the Egyptian Museum, Cairo, Egypt, *Rasha Shaheen*
10:10	Benchmarking the Oddy Test: Investigations of single and mixed chemical solutions using The Metropolitan Museum's Oddy Testing Protocol, *Julia Bakker-Arkema*
10:35	Validation of the accelerated MAT-CH test for pollutant control in museums and collections (MAT-CH 3.0), *Alexandra Jeberien*
11:00	Progress on the development of a paper degradation sensor, *Eric Conte*
11:30	Flash Poster Presentations
12:00	Lunch

Session 2: Corrosion of Metals by Indoor Pollutants Chair: Eric Breitung	
13:00	Connecting Oddy and GC-MS results: Providing definition to chemical intuition, *Michael Samide*
13:25	Screening for sulfur: Methods to detect Reduced Sulfur Compounds and evaluate their corrosion risk, *Rose King*
13:50	The use of lead in ISO 11844 for determining indoor air corrosivity, *Morten Ryhl Svendsen*
14:15	Poster session
Session 3: Degradation of Collection Objects Chair: Olivier Schalm	
15:30	The key role of non-volatile organic acids in historical paper, *Irena Kralj Cigic*
15:55	Determination of acidic emissions from heritage PVC objects, *Tjaša Rijavec*
16:20	Gaseous sulfur compounds from objects: Generation of “Black spots” on bronze and emission of H2S and COS from various artefacts excavated from a marine archaeological site, *Rika Kigawa*
16:45	Organic pollutants in museums and their relationship with iron corrosion, *Ren Xiaopeng*
17:00	Metropolitan Museum of Art closes

Wednesday, 20 November, 2024

Please note that the museum is closed to the public on Wednesdays; you will not be able to access any gallery spaces during or after the conference today.

9:00	Coffee
Session 4: Sustainability and Climate Session Chair: Morten Ryhl-Svendsen	
9:30	PM deposits on calcareous stone heritage: What are they, how they differ seasonally and are they dangerous?, *Eva Menart*
9:55	Pollution control and sustainability, *David Thickett*
10:20	Monitoring air quality at The Met Cloisters, *Jana Butman*
10:45	Coffee Break
Session 5: Risk Mitigation Session Chair: Julia Bakker-Arkema	
11:00	Time-resolved investigations on the effectiveness and capacity of air pollutant sorbers regarding the mitigation of acetic acid, *Amelie Stahlbuhk*
11:25	Advanced (multi-)methods for safe handling of biocide-contaminated objects: Findings from the MUSA pilot study, *Dr. Elise Spiegel*
11:50	Bridging cause and effect: A holistic approach to risk assessment in heritage conservation, *Olivier Schalm*
12:15	Closing Remarks

Oral Presentation Abstracts

Session 1: Method Development for Material Testing

The Impact of Indoor Air Quality on the Preservation of Photographic Archives: A Case Study from the Egyptian Museum, Cairo, Egypt

Rasha Shaheen, Youssef Elreweny

The preservation of photographic archives in museums is critically dependent on the quality of indoor air, which can significantly influence the longevity and integrity of these delicate materials. This paper presents an in-depth analysis of the impact of indoor air quality on the photographic archives at the Egyptian Museums in Cairo. The study encompasses the identification of common pollutants, their sources, and the resulting deterioration mechanisms observed in the photographic materials. By leveraging advanced analytical techniques and conservation methods, the research aims to provide comprehensive guidelines for mitigating adverse effects and enhancing the preservation conditions for photographic collections in heritage institutions. The paper will set the stage by discussing the significance of photographic archives as cultural heritage assets and the importance of preserving optimal indoor air quality to prevent their deterioration. It will provide a brief overview of the Egyptian Museum's photographic collection.
The results will present findings on the types and concentrations of pollutants identified in the museum environment. This section will discuss the observed deterioration mechanisms in photographic materials, correlating them with specific air quality parameters. Comparative analysis with international standards and previous studies will be included to contextualize the findings.

A detailed case study of the Egyptian Museum's photographic archives will be presented, illustrating the practical challenges and solutions implemented to combat the adverse effects of poor indoor air quality. This section will highlight specific examples of deterioration, conservation treatments applied, and the outcomes of these interventions.

Based on the findings, this section will propose effective conservation strategies to mitigate the impact of indoor air pollutants. It will cover recommendations for environmental monitoring, preventive measures, and advanced conservation techniques tailored for photographic materials.

The conclusion will summarize the key insights from the study and emphasize the importance of maintaining high indoor air quality standards in heritage institutions. It will also suggest directions for future research and potential collaborations to further advance the field of conservation science of the heritage photographs.

Benchmarking the Oddy Test: Investigations of Single Chemical Solutions using the Metropolitan Museum's Oddy Testing Protocol

Julia Bakker-Arkema, Rose King, Jana Butman, Eric Breitung

Many institutions around the world rely on an Oddy Test to evaluate the suitability of materials for potential use in collections care. More than 40 variants have been reported, and differences in methods and materials are known to produce inconsistent results between test variants. Examples include differences in water to vessel volume ratio, metal purity and surface polishing techniques, airtightness, and vessel type. Furthermore, the evaluation of the metal coupons at the end of the test is subjective, as a trained individual must visually assess the material as suitable for permanent (P) or temporary (T) use, or unsuitable (U) for use with collection objects.

In this work, we are developing standardized chemical mixtures to act as an Oddy test variant calibration tool, or "benchmark". The goal is to provide a mechanism for generating reliable and reproducible Oddy Test results across different testing institutions, protocols, and evaluators. Solutions prepared from a range of chemicals with varying vapor pressures and functionalities including carboxylic acids, aldehydes, amines, sulfides, and thiols were introduced directly to the Oddy Testing vessel, and subsequently tested according to the Metropolitan Museum of Art's Oddy Testing Protocol. Specific chemicals were selected from the results of DTD-GC-MS studies of conservation materials, which had been highlighted due to their prior field and Oddy Testing performances. Solution concentrations were varied to probe the boundaries between Permanent and Temporary ratings, and between Temporary and Unsuitable ratings.

In this talk, I will present single chemical Oddy Testing results and discuss our progress towards the generation of standard benchmarking solutions. Ultimately, we aim to relate the reactive components and their concentrations to the amount and type of corrosion detected on Oddy coupons, and more broadly to the performance of commercial materials in the field. The goal is to provide a system for benchmarking or normalizing Oddy (and other) material test systems to improve access to unbiased information regarding the suitability of display, transport, and storage materials. In addition, this greatly expands our knowledge of what chemical classes have the potential to react with metal artworks.

Validation of the accelerated MAT-CH test for pollutant control in museums and collections (MAT-CH 3.0)

Alexandra Jeberien, Sabrina Maric, Nivin Alktash, Bernd Szyszka

In the Material Checker (MAT-CH) project, the Berlin University of Applied Sciences (HTW) is researching pollutant control in museums and collections using the example of the well-known Oddy test. This test method is based on the corrosiveness of pure metallic silver, copper and lead coupons in the presence of gaseous compounds (ODDY 1973). The coupons - and therefore the tested materials - are evaluated by comparing them with control samples and classifying them as permanent, temporary or unsuitable for museum use. (THICKETT/LEE 1996, ROBINET/THICKETT 2003). The test offers a low-threshold option for material testing because the required equipment is available to almost every institution.

Despite its many advantages, the Oddy-test has clear deficits, including a lack of standards for the equipment and the evaluation method. Over twenty variations are used worldwide (THICKETT 2016), therefore the results generated are neither comparable nor reproducible (DIAZ/ CANO 2022). Ultimately, the test is characterized by low sustainability in terms of consumables, including silicone stoppers and metals, with the high proportion of pure lead coupons being particularly problematic.

In order to improve the relevance of the Oddy test, HTW Berlin is developing uniform and sustainable test components and researching their application. After the test tubes and silicone stoppers were replaced with an inert, holistic reaction container (HEINE / JEBERIEN 2018), thin metal-coated indicators were recently developed that are intended to replace the unsustainable metal coupons. The feasibility of these indicators has been fundamentally proven (ALKTASH et al. 2021). On the other hand, the functionality still showed inaccuracies and a need for optimization.

Therefore, in the current project phase (MAT-CH 3.0), the indicators were validated in terms of their reaction behavior and referenced with regard to the conventional Oddy test. Validation was performed on up to thirty-five products containing both solids and liquids. The test materials were selected from the British Museum and AIC Wiki databases. Accordingly, they have already been tested several times. The validation was carried out using instrumental analysis, which enabled a chemical characterization of the existing corrosion and thus a more precise assessment of the results - both in comparison to the tested material and in terms of referencing the conventional test method.

The presentation will introduce the validation and referencing results developed up to that point, including the analysis.

Figure: Validation of indicators using foams and boards as test material

Progress on the Development of a Paper Degradation Sensor

Eric Conte, Keerthana Chari, Eric Breitung

We present our work on an Oddy-like test for paper-based artwork. A strip of Whatman thin layer chromatography paper is used in place of metal coupons. Display and packing material are placed individually within this container, sealed, and accelerated aged at 80°C for two weeks in a saturated water headspace. Acid-catalyzed hydrolysis is the major contributor to the degradation of cellulose, thus weakening paper. We are measuring the resulting products of this reaction, including glucose and cellobiose, which are extracted from the strip using deionized water and measured using ion chromatography. We are concurrently measuring glucose in these samples using a modified pharmacy-bought glucometer. The results of ten display and packing materials will be presented. Also included in this talk are the degradation profiles of two known paper-destroying substances, acetic acid and hexanal.

Connecting Oddy and GC-MS results: Providing definition to chemical intuition

Michael Samide, Kylie Blake

The Oddy test remains the standard approach to determine the suitability of a material for use in the display or storage of artwork. In this test, volatile pollutants emitted from a test material react with lead, silver, and copper metal coupons under conditions of elevated temperature and humidity. If corrosion is noticed after a 28-day incubation, the material is classified as unsuitable for use in a museum environment. In this test, it is not necessary to know the identity of the pollutant, but rather evaluate the extent of corrosion to assess suitability. However, it is generally accepted that the lead coupon will detect acidic pollutants, silver is used for detection of reducible sulfur compounds, and copper highlight the presence of chlorides and oxides.

Newer methods like direct thermal desorption – gas chromatography – mass spectrometry (DTD-GC-MS) have been explored as a way to establish a more objective approach to material suitability testing. Chemical information such as the identity and, with calibration, concentration of volatile organic compounds (VOCs) can be used to understand reactivity of emitted pollutants. However, these methods often rely on some inherent knowledge of chemical reactivity – what we call “chemical intuition” – to decide if a detected VOC is actually a pollutant which will cause corrosion to a metal Oddy coupon and therefore classify the material as unsuitable for use. Unfortunately, it can be difficult to fully understand reactivity and some materials could be rejected simply because a known or suspected pollutant is detected. This is especially so for semi-volatile organic acids like stearic acid, which are often detected in modern materials using DTD methods.

In this work, an attempt is made to link observed corrosion of the Oddy lead coupon and GC-MS pollutant identity to better elucidate "chemical intuition". Lead Oddy coupons are exposed to a variety of organic acid pollutants and the corrosion products are being studied to connect GCMS data and Oddy results. Raman spectroscopy is used to identify the corrosion products, and then jar conditions are modified to gain a better understanding of how volatile and semi-volatile acids cause corrosion. Preliminary data suggest two different mechanisms can occur based on the volatility of the acid. Very volatile acid compounds engage in an electrochemical reaction on the surface of the coupon to generate primarily a lead carboxylate salt. Semi-volatile acids produce primarily lead carbonate salts through a proposed multi-step reaction. The chemistry and mechanisms for these processes will be discussed.

Screening for Sulfur: methods to detect Reduced Sulfur Compounds and evaluate their corrosion risk

Rose King, Jana Butman, Julia Bakker-Arkema, Eric Breitung

Using an extensive archive of previously tested materials and their associated Oddy test results, we sought to explore the relationship between a material's volatile emissions profiles and its Oddy test behavior. A recent example with expanded PVC boards illustrated that the Oddy test can be insufficiently sensitive to sulfur-containing analytes [1]. While a 'pass' result was awarded using the Oddy test, tarnish of collection objects was observed, and GCMS proved that a reduced-sulfur compound (RSC) emitted from the same material was the cause. RSCs cause significant corrosion to silver and copper surfaces at ppb concentrations and are an important target for material emissions screening methods.

This talk will cover a holistic approach to sulfur screening with a focus on evaluating methodologies for material emissions analysis (GCMS), material analysis (microchemical, XRF), and the analysis of corroded Oddy test coupons (electrochemistry, XRD).

We explored how frequently our interpretation of DTD-GCMS screening data and Oddy test results aligned for a subset of materials that either caused silver tarnish in the Oddy test, contains an RSC by DTD-GCMS, or both. While sulfur-containing analytes were easily identified in 6/10 materials, DTD-GCMS was not able to identify sulfurous analytes in 4/10. A lack of sensitivity with the chosen GCMS method could account for the disconnect, and more general limitations of MS analysis will also be discussed.

Both microchemical tests and XRF were assessed for their ability to screen for sulfur within a material and offer a relatively quick way of pre-screening materials while awaiting Oddy results.

Ultimately the research presented in this talk aims to further our understanding of silver's reactivity with volatile and semi-volatile sulfur-containing compounds and evaluate what analytical methods are suitable for accurate assessment of a conservation material's risk toward silver corrosion.

[1] Samide, M. J. and Smith, G. D. (2020) 'Assessing the Suitability of Unplasticized Poly(Vinyl Chloride) for Museum Showcase Construction', Journal of the American Institute for Conservation, 61(1), pp. 1–13. doi: 10.1080/01971360.2020.1765122.

The use of lead in ISO 11844 for determining indoor air corrosivity

Morten Ryhl-Svendsen

Lead has been included in ISO 11844 since 2020, as a standard test with high sensitivity to gaseous organic acids. However, means of classifying corrosivity with lead are only given by mass loss determination (by acid pickling) of the metal coupons, and not by the easier method of weight measurement (mass increase) as for the other metals included in the standard. Furthermore, the non-linear corrosion rate of lead makes it difficult to compare different measurements if they are not exposed for exactly the same amount of time, which is specified in the standard as one year. In my presentation I will present several examples of lead coupon exposures in museum environments for various periods of time (some for several years), as well as examples of laboratory exposures of lead coupons to elevated levels of organic acids, relative humidity, hydrogen sulphide; either as single factors or in combinations. The observed corrosion rates will be compared against simultaneous measurements of climate and pollutant levels, and corrosion measurements by other means (by AirCorr loggers with lead sensors). I will in the presentation argue that determination of indoor corrosivity can be done by mass increase measurements also for lead, as the method is sufficiently accurate, is easy, and the same coupons can be reused and their corrosion rate development monitored over time. Levels of mass increase of lead for the classification of indoor atmosphere corrosivity will be proposed.

Reference: ISO 11844-2020, Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres (3 parts).

The key role of non-volatile organic acids in historical paper

Irena Kralj Cigić[1], Ida Kraševec[1], Aleksander Kravos[1], Klara Retko[2], Hend Mahgoub[1], Matija Strlič[1]

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[2] Institute for the Protection of Cultural Heritage of Slovenia, Poljanska cesta 40, 1000 Ljubljana, Slovenia

A collection of 89 samples of European paper from the period between 1844 and 1990 [1] was analysed for the content of organic acids and other properties of interest for conservation. The content of acetic, formic, lactic, glycolic, glyoxylic, succinic, maleic, and oxalic acid was determined. Oxalic acid was the acid determined in the highest concentrations and clearly correlating with the pH of acidic paper, and can thus be considered as the driver of acid-catalysed hydrolysis, a key process of paper degradation [2]. The multivariate data analysis revealed correlations between the lignin content and the contents of oxalic and formic acid, illustrating the dominant influence of lignin on acid production. The results also indicate that the content of oxalic acid in paper increases by about 0.01 mmol/g per year, resulting in a decrease in pH of 0.008 per year (assuming other variables remain constant).

Importantly, the effect of this acid on paper degradation can be greatly reduced by deacidification conservation processes that include Ca^{2+} and Mg^{2+} ions forming insoluble oxalates. The low volatility of oxalic acid and its low pKa means that it cannot be found as a pollutant in the archival air and that it likely contributes to the protonation of acetic and formic acid, and thus to their observed emission from historical paper. The contribution of acetic and formic acid to the degradation of historic paper, which has been a major concern in paper conservation literature during the past two decades, can therefore be considered less important [3].

The observed outcomes are significant as they demonstrate the dominant impact of oxalic acid on acidic paper conservation.

[1] Strlič, M.; Liu, Y.; Lichtblau, D.A.; De Bruin, G.; Knight, B.; Winther, T.; Kralj Cigić, I.; Brereton, R.G. (2020). Development and Mining of a Database of Historic European Paper Properties. *Cellulose*, *27*, 8287–8299, https://doi.org/10.1007/s10570-020-03344-x

[2] Strlič, M., & Kolar, J. (Eds.). (2005). Ageing and stabilisation of paper. *National and University Library.*

[3] Menart, E., de Bruin, G., & Strlič, M. (2014). Effects of NO_2 and acetic acid on the stability of historic paper. *Cellulose*, *21*(5), 3701–3713. https://doi.org/10.1007/s10570-014-0374-4

Determination of acidic emissions from heritage PVC objects

Tjaša Rijavec, Špela Pok, Irena Kralj Cigić, Matija Strlič

Poly(vinyl chloride) (PVC) is a modern synthetic polymer found in heritage collections, serving as a main component in artworks, industrial artefacts, composites, or as a temporary storage and display material in collections. Notably, PVC is prevalent in inflatable objects, furniture, costumes, clothing, and toys. It is particularly susceptible to degradation through dehydrochlorination, a process that results in yellowing, and the migration of plasticizers, which can lead to sticky surface exudates or embrittlement.[1,2] Dehydrochlorination of PVC proceeds as elimination of hydrogen chloride (HCl), forming polyene sequences along the polymer backbone, which cause yellowing.[3] Although we understand the general mechanism of dehydrochlorination and production of free HCl in PVC, there is remarkably little available research into the dynamics of these processes at room temperature.

This study aimed to establish a method for characterizing gaseous HCl emissions from PVC and to investigate its temperature-dependency to assess potential harm to nearby objects at room temperature. Using a Markes Micro-Chamber/Thermal Extractor μCTE120, the surface emission rate of HCl from a contemporary unplasticized PVC was evaluated across temperatures ranging from 80 °C to 120 °C. The results indicate that HCl emissions from PVC at room temperature are negligible, supported by the determined emission rates and the calculated activation energy. Interestingly, at 110 °C a 30-year-old yellowed PVC sample exhibited emission rates four times lower compared to the contemporary sample. In contrast, a modified Oddy test with Whatman filter cellulose demonstrated a significant decrease in the degree of polymerization of cellulose with both PVC materials, but more so for the historical sample. These preliminary findings suggest the presence of other acidic emissions beyond HCl. This research emphasizes the need for further investigation into the degradation products of PVC, particularly under room conditions, to better understand and mitigate potential risks to heritage collections.

Acknowledgements

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References

1. Rijavec T, Strlič M, Kralj Cigić I. Plastics in Heritage Collections: Poly(vinyl chloride) Degradation and Characterization. Acta Chim Slov. 2020;67:993–1013.
2. King R, Grau-Bové J, Curran K. Plasticiser loss in heritage collections: its prevalence, cause, effect, and methods for analysis. Herit Sci. 2020;8:123.
3. Rijavec T, Strlič M, Kralj Cigić I. Damage function for poly(vinyl chloride) in heritage collections. Polym Degrad Stab. 2023;211:110329.

Gaseous sulfur compounds from objects: Generation of "Black spots" on bronze and emission of H_2S and COS from various artefacts excavated from a marine archaeological site

Rika Kigawa, Ayako Izumita, Megumi Shimada, Hiroki Watanabe, Yumi Yasuki, Yoshinori Sato, Akinobu Yanagida, Soichiro Wakiya, Tadashi Uchino, Satoshi Shiga, Yoshihide Koizumi, Yohsei Kohdzuma

It is well known that gases of sulfur compounds such as hydrogen sulfide (H2S) and carbonyl sulfide (COS) can cause corrosion on metals, especially on silver and copper. The gases can come from outside environments, volcanos, marshes etc. and occasionally from materials used in exhibition cases. We report here a case study of emission of gaseous sulfur compounds,
hydrogen sulfide (H2S) and carbonyl sulfide (COS), from various stone and wooden artefacts excavated from a marine underwater archaeological site, which could cause a special kind of corrosion "Black spots" on copper objects.

The bronze objects had been excavated from a marine archaeological site at Takashima, Japan, and they were exhibited in an air-tight show case together with other archaeological artefacts which had been excavated from the same site (Fig. 1).

After several years of exhibition, corrosion with a very distinct shape (Black spots) were found on the bronze artefacts. As it was reported that the Black spots were generated by presence of sulfur minerals and gaseous sufur compounds such as H2S, we suspected emission of sulfur compounds from other underwater artefacts which were in the same exhibition case.

In order to investigate levels of emission of H2S and COS from the artefacts, each artefact was inserted into a plastic Tedlar bag and sealed retaining some room air. After placing the artefacts in the bags for 53 to 144 days, air samples were collected into another new plastic bag and concentrations of H2S and COS were measured by gas chromatography.

The H2S and COS concentrations (ppb) in the sampled air from the bag containing the cannon ball which had been exhibited in the same show case with the bronze objects, were (0.462, 8.64) respectively after 70 days, clearly higher than those of the control air sample (0.084, 0.676). The values for the thinner wooden objects with lacquer paint were (0.208, 8.64) after 53 days.
Some artefacts from the site showed higher values. A wooden artefact showed (＜51.9, 299), compared to the values for control air taken from the storage area (＜0.13, 1.18) after 62 days. Stone artefacts showed high values compared to control air, but generally, wooden artefacts had markedly higher values. The highest values were of a thick wooden panel with big iron nails (226, 6020) after 62 days.

The results tell us we should have a clear rule for exhibitions, not to exhibit metal objects together with stone and wooden porous marine archaeological artefacts, which can emit high concentration of gaseous sulfur compounds.

Fig. 1 The state of the bronze (bottom, left) and other underwater artefacts in an air-tight exhibition case.

Organic pollutants in museums and their relationship with iron corrosion

Ren Xiaopeng, Yazheng Wang, Luyang Wang, Qing Zhou, Yujie Fan, Kai Liang, Yuning Li, Quanyu Wang, Ying Xu

In museums, organic pollutants emitted from building materials are ubiquitous, and several of them can cause damage to iron artifacts. However, the mechanism of the damage remains unclear, and no concentration criteria for iron safety is available. This study focused on organic pollutants in museums and their relationship with corrosion of iron artifacts.

Four museums located in different regions of China were selected, including Beijing, Qingdao, Wuhan, and Guangzhou. Sampling was conducted in 11 rooms. Air samples were collected for analysis of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs), and settled dust were collected for analysis of SVOCs. Temperature and relative humidity were monitored continuously. Simulated and archaeological iron block samples were placed at each sampling location, and their mass were measured periodically to evaluate corrosion levels.

Over 120 VOCs and SVOCs were detected in air and dust samples. Among them, more than 60% of pollutants had a detection frequency over 50%. The maximum and median concentrations of pollutants in the air were 2.9 mg/m3 and 0.0009 mg/m3, respectively, and those in settled dust were 500 μg/g and 0.1 μg/g. The results indicated that organic pollutants were widespread in museums.

Ranking of environmental factors were conducted based on both the results of multiple methods of statistical analysis, and chemical properties of pollutants. As a result, many chemicals may influence iron corrosion, most of which were seldomly reported before.

Cyclohexanone and acetic acid were found to be correlated with corrosion of simulated and archaeological iron samples, respectively.

Reaction mechanism of cyclohexanone on iron samples were investigated. Liquid cyclohexanone was added with iron powder and then heated for 24h. The liquid was then analysed to qualify reaction products. The results suggested that cyclohexanone can be oxidized to form multiple organic acids via catalyzation of iron, damaging iron artifacts.

Quantitative correlation between concentration of acetic acid and corrosion rates of iron samples were investigated. Iron samples were

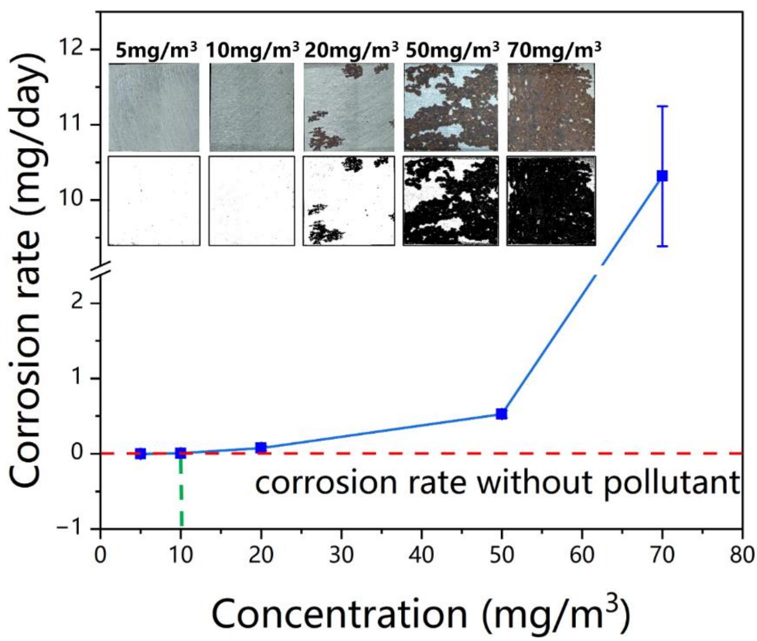

Figure 1.

exposed air containing acetic acid under 50℃ and 90%RH, and their mass and surface change were measured. As shown in Figure 1, when concentration of acetic acid was 10 mg/m3, corrosion rate of iron was similar to that without pollutant. The result indicated that under 50℃ and 90%RH, corrosion on iron plates may happen when acetic acid concentration is over 10mg/m3.

This study comprehensively investigated indoor air quality in the museum environment. We found that organic pollutants were ubiquitous and many of them may cause iron corrosion. Cyclohexanone can be catalyzed by iron to form organic acids. For acetic acid, 10 mg/m3 was a safe value of concentration for iron samples under 50℃ and 90%RH. Our work provided more understanding of pollutants in museums and their relationship with iron artifacts.

PM deposits on calcareous stone heritage: what are they, how they differ seasonally and are they dangerous?

Eva Menart, Monika Ogrizek, Asta Gregorič, Matic Ivančič, Daniele Contini, Urša Skube, Kristijan Vidović, Marjan Bele, Martin Šala, Marta Klanjšek Gunde, Martin Rigler, Ana Kroflič

Particulate matter (PM) is recognised as one of the main damage factors to cultural heritage outdoors, particularly for objects and monuments made of calcareous stone, such as limestone or marble. Indoor environments, however, are most likely not entirely safe from PM pollution either, particularly in the case of historic naturally ventilated buildings or semi-permanent structures, such as glass pavilions and similar non-hermetic indoor exhibition spaces.

To investigate the nature of PM deposits and their seasonal variation, four month-long sampling and air quality monitoring campaigns were carried out in an urban environment of Ljubljana, Slovenia. Limestone and marble samples were exposed in outdoor sheltered and unsheltered positions during each campaign, with one set of stones exposed consecutively in all four campaigns. The surface reflection of the stones was measured and surface morphology characterised, and afterwards chemical analysis of the deposits was carried out using laser ablation inductively-coupled plasma mass spectrometer (LA-ICPMS). Air quality monitoring focusing on atmospheric PM was carried out simultaneously, employing an array of analytical techniques in either online mode or using sampling for offline analyses. Collected PM samples on quartz fibre filters were analysed using LA-ICPMS and ion chromatography (IC), particle number concentration and number size distribution were measured in real time using a Scanning Mobility Particle Sizer (SMPS

Spectrometer), and measurements of total carbon (TC) and black carbon (BC) were performed with a Carbonaceous Aerosol Speciation System (CASS), using a size-selective inlet to measure PM2.5 specifically.

We found that the amount and composition of PM2.5 varied throughout the year, with the main source throughout the year being traffic, followed by secondary formation of acidic inorganic aerosols, such as sulfate in the summer and nitrate in the winter, and seasonal biomass-burning emissions. The deposits on stone samples roughly resemble the composition of airborne PM, meaning more exposure to a particular pollutant resulted in a larger amount of that pollutant on the stone surface, therefore more polluted air means a bigger threat to heritage objects made of stone. However, accumulation is not a linear process, which would allow for simple extrapolation, as various PM removal mechanisms are in play even in sheltered locations, which exclude rainfall. Since SMPS measurements in outdoor and non-hermetic indoor environments correlated very well, these findings could be applied to indoor environments as well (although PM removal mechanisms might differ in the absence of wind), particularly where no air filtration or climate control is employed. Long-term indoor PM exposure experiments are also currently taking place, with samples collected annually.

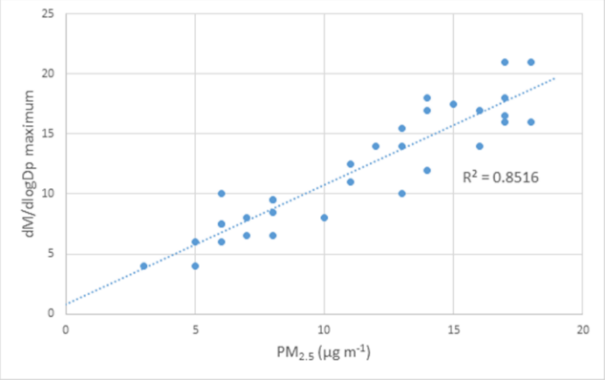

Figure: Correlation between PM measurements outdoors and in a non-hermetic indoor environment (glass lapidarium).

Pollution control and sustainability

David Thickett

Pollution control, beyond improving the envelope (building or room or showcase or frame) can be energy and hence carbon intensive. Data has been developed for a series of measures;

- Adding chemical filtration to air conditioning,
- Using room level systems such as stand alone filtering or dehumidifiers,
- Showcases and frames
- Adding sorbents to above,
- Using sorbents in pumps in above,
- Using mechanical control in above.

For each method partial life cycle assessments have been carried out. The cradle to gate data was estimated by disassembling equipment, identifying component materials with FTIR and XRF or SEM-EDX, weighing each materials and using lookup tables or environmental performance certificates. The electricity used to run mechanical equipment was measured under different conditions.

Over specifying concentrations clearly leads to excessive green house gas emissions. Risk based concentrations for acetic and formic acids, nitrogen dioxide and ozone for 28 materials are available in the MEMORI decision support model. Damage functions are being developed in the GoGreen project to further improve decision making in this area.

The data generated and approach described can aid in decision making and help heritage institutions move towards net zero.

Monitoring Air Quality at the Met Cloisters

Jana Butman, Eric Breitung, Lucretia Kargere

The Met Cloisters combines medieval art, original architecture, and cultivated gardens that its visitors can wander in and out of uninhibited. Gallery doors are propped open to invite visitors to navigate the built structure freely, which exposes the collection to the outdoor climate. This poses a unique preventive conservation challenge, as stable temperatures, humidity levels, and low particulate counts are ideal for long-term object care.

During the summer wildfires of 2023, New York City experienced record-breaking air pollution levels, peaking at over 460 on the Air Quality Index (AQI) with exceptionally high particulate matter counts (PM). Curators and conservators at The Cloisters expressed a need for scientific data about the level of pollution experienced by the galleries compared to outdoors to determine whether they need to close the building off during such an event.

As part of the Met's Scientific Research Department, I am conducting air quality studies at the Cloisters to determine how well our current systems work as preventive conservation measures. I have also researched and established new particulate matter sensors and monitoring protocols in the event of an extreme weather event affecting The Cloisters.

This project highlights the benefits of collaboration between curators, conservators, and scientists on questions of collections care. Researching and monitoring these environmental variables allows conservators and curators to take action to mitigate the effects of exposure to outdoor pollutants.

Time-resolved investigations on the effectiveness and capacity of air pollutant sorbers regarding the mitigation of acetic acid

Amelie Stahlbuhk, Christina Hinterleitner, Mathilde Schulze, Uta Sazama, Stefan Röhrs, Stefan Simon, Michael Steiger

In the museum environment, showcases fulfill a protective function in many respects - also with regard to anthropogenic pollutants. A low air exchange rate is intended to maintain a stable or at least buffered relative humidity (RH) inside or to exclude pollutants from outside the showcases. In such showcases, air pollutants released inside can barely escape and may reach high concentrations. A common air pollutant in this regard is acetic acid, which leads to corrosion of artifacts of various materials. Similar to materials for adjusting RH, sorber materials with higher reactivities than the artifacts and, thus, higher deposition velocities of acetic acid can be introduced into the technical compartment (TC) of the showcase with the goal of trapping acid emissions and minimizing the artifact's risk.

Despite the knowledge that some materials are more or less suitable for acetic acid sorption, studies on time-resolved acid sorption, maximum sorption capacity of the sorbers, and competition between water vapor and acetic acid sorption are often lacking. For this purpose, different sorber materials (silica gel ProSorb, activated carbon granulate, activated carbon with alkaline impregnation, activated carbon cloth with and without alkaline impregnation, and K2CO3 solution) were stored at realistic RH (40 and 50 %) and different acetic acid concentrations.

Two approaches were pursued. First, sorbers exposed to an acetic acid atmosphere in desiccators were examined gravimetrically and by means of TG-MS, allowing a quantitative comparison of affinities and insights into the dynamic processes, such as changes in the acetic acid affinity over time. In the second approach, the effectiveness of the sorbers was tested by measuring the reduction in the acetic acid concentration in air using an active GC/MS air sampling method, which was adapted to small sampling volumes. An emission chamber with a grid to divide it into a larger presentation volume and smaller TC was used to mimic the showcase. The chamber air was spiked with acetic acid via an acetic acid-emitting vial placed in the supposed "presentation volume" and the sorber was placed in the supposed "TC" below. Air was sampled periodically from both volumes separately.

The results show differences in the sorption curves regarding the time until saturation of the material (Fig. 1) and in the amount of acetic acid that was sorbed or removed from the air, respectively, after reaching saturation. The ratios of sorbed water vapor and acetic acid change with the acetic acid concentration. Finally, the results can contribute to a better understanding and characterization of sorber materials and dynamic processes influencing the effectiveness of mitigation measures to reduce acetic acid concentrations in showcases and may help to select the most effective material.

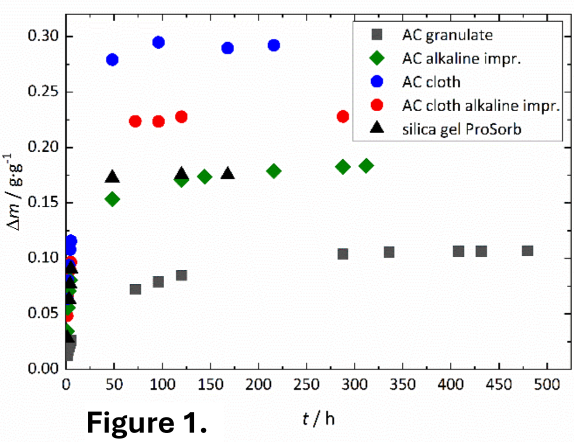

Figure 1.

Advanced (multi-)methods for safe handling of biocide-contaminated objects: Findings from the MUSA pilot study

*E. Spiegel1**, S.Rakete2, K.Deering2, C. Wübbe3, C. Grunwaldt4

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Many museum institutions, collections, archives, and historic buildings are contaminated with substances that are potentially hazardous to health. [1] These objects are often no longer exhibited or restored to avoid potential exposure, leading to their exclusion from exhibitions and loans. It is well known that these damaging old restorations pose a potential health hazard to employees and visitors due to the hazardous materials used. They also complicate or impair the accessibility, preservation, and mediation of cultural property [2-3].

To ensure the safety of employees, monitoring of hazardous substances in workplaces is required. However, conventional analytical methods used for systematic analysis or large-scale studies are often expensive. Therefore, the goal of the MUSA project is the development of user-friendly and affordable test kits for biocide monitoring in museum settings.

Electrostatic cloth was used as sampling material for 1) wipe sampling of surfaces and 2) passive dustfall collection for airborne dust analysis. Target substances included organochlorine pesticides and toxic metals. The samples were extracted and analyzed by GC-MS/MS or ICP-MS/MS, respectively. Both methods were applied at a pilot institution known for biocide contamination.

The pilot study results show that both, wipe sampling and dustfall collectors, were suitable for detecting the target biocides. Additionally, both methods were easily applicable even by personnel without laboratory background. In this pilot study, we were also able to identify workplaces with an increased exposure risk for employees (Fig. 1). In areas with higher air concentration, higher concentrations of the same hazardous substances were also detected in the dustfall collectors and wipe samples. In some cases, a correlation was observed between dustfall collectorsand air samples.

Wipe sampling and dustfall collectors can be a viable alternative to conventional ambient air monitoring. The simplicity of the test kit reduces the cost of analysis and therefore makes it easily accessible for the affected institutions.

Further implementation of the presented methods in museum settings is necessary to derive risk-based guidance values and to provide adequate measures to prevent exposure to biocides.

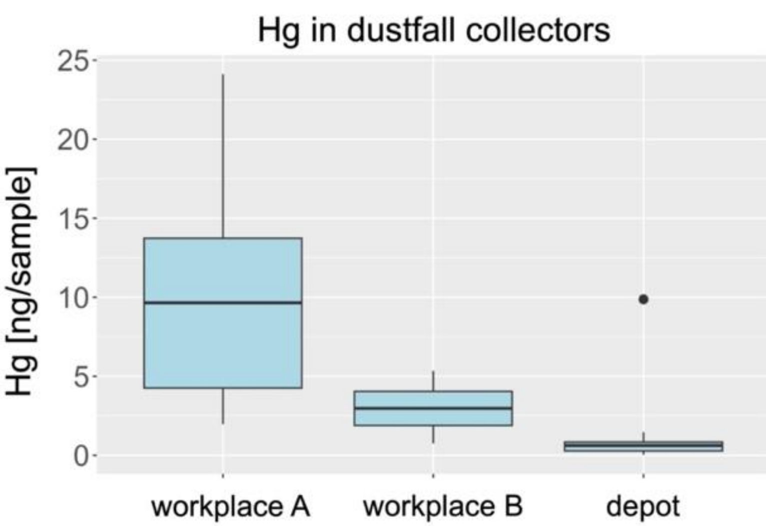

Figure 1.

Bridging Cause and Effect: A Holistic Approach to Risk Assessment in Heritage Conservation

Olivier Schalm

The assessment of risk in heritage collections has traditionally followed two distinct methodologies: (1) analyzing past damage (effect) through the observation of the preservation state of objects, and (2) monitoring the present behavior of potential hazards (cause) by monitoring the surroundings with measuring devices. While some experts argue that these approaches are inherently different and incompatible within a single risk theory, this contribution proposes a novel perspective.

A hazard can be considered an abstract entity, where its properties, such as temperature or relative humidity, describe the level of risk it generates or the intensity of its activity. Therefore, measurements of such properties provide valuable information about the hazard's behavior over time. Conversely, assessing accumulated damage offers a retrospective view of hazard impact. Bridging these approaches could enhance our understanding and management of risks in heritage conservation.

The heritage community recognizes the "10 agents of deterioration" as primary hazards. However, viewing these agents as isolated threats overlooks their interconnected nature. In reality, these hazards form a complex ecosystem where each can influence and exacerbate others (see Fig. 1). In addition, heritage collections encompass a diverse range of objects and materials, each responding differently to the same environmental conditions. Preventive conservation aims to optimize that network of interconnected hazards, creating a less aggressive environment that extends the lifespan of a diverse range of heritage objects.

The holistic approach proposed in this contribution considers risk as a property that highlights the importance of cause-effect relationships. Therefore, it is possible to evaluate risk through either cause measurement or effect observation. This approach also advocates the integration of multiple cause-effect relationships, acknowledging that several causes may contribute to the same effect or that some effects may serve as causes within this network.

Describing the ecosystem of hazards in this way will facilitate its optimization, ultimately improving the preservation of heritage collections.

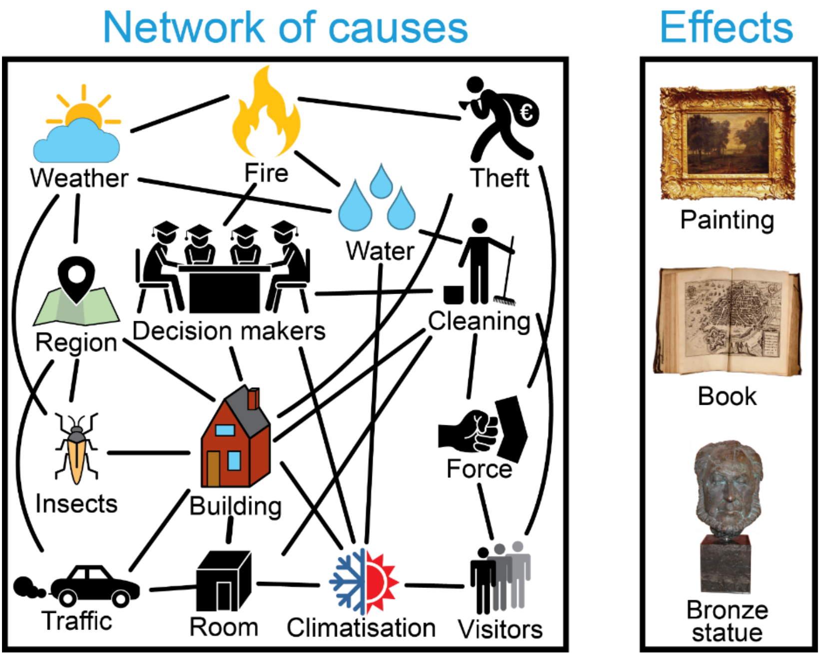

Figure 2.

Poster Presentation Abstracts

In alphabetical order by surname of presenting author

Free Wood: minimizing acid emissions from wood products

Elyse Canosa, Anja Kampe, Leo Munier, Eleni Tsichlaki, Björn Nguyen, Alexander Pfriem

Wood is a desirable material to use for display cases and storage crates because it can be considered a sustainable alternative to plastic and metal, is easy to use, has an appealing look, and is affordable. However, wood is known to emit acetic acid and formic acid gas, both of which can cause deterioration of cultural heritage objects. Free Wood, an international project between universities, small businesses and government agencies in Germany and Sweden, has aimed to develop and test wood products with significantly reduced acetic and formic acid emissions.

Sample blocks of maple, beech and walnut were impregnated with alkaline solutions using an alternating pressure process. This treatment process intended to target the sources of acetic and formic acid emissions (hemicelluloses) and remove them. Following treatment, the samples were characterized using microscopy to observe treatment penetration depth, FTIR spectroscopy to find evidence for the removal of hemicelluloses, and three-point bending tests to determine changes in mechanical strength. Additionally, emissions analysis of the samples was performed using headspace GC-MS, passive sampling, and Oddy testing. Characterization found that total impregnation of the samples resulted in a reduced carbonyl band in the FTIR spectra, suggesting the removal of hemicelluloses from the wood. This was also evident in the emissions testing, which showed significant reductions in acetic and

formic acid concentrations and clear visible improvement of Oddy test results after treatment. Visual and mechanical features of the wood products were slightly affected from the treatment but overall, the process shows promise as a method to produce wood materials for use in cultural heritage environments.

Exploring the degradation of hemicelluloses and cellulose in paper by volatile organic compounds

Keerthana Chari, Eric Conte, and Eric Breitung

While cellulose is the dominant component of paper, even the purest cellulose paper contains traces of a secondary polysaccharide, hemicellulose. Hemicelluloses are critical to the structure of paper, adhering cellulose and lignin fibers together. Yet, current studies on paper degradation attribute the loss of physical and chemical integrity to cellulose only, overlooking the potential impacts of hemicelluloses. There is a particular lack of knowledge about hemicellulose degradation when paper is exposed to common volatile museum compounds, acetic acid and hexanal. When paper degrades by the dominant mechanism of acid hydrolysis, both hemicelluloses and cellulose produce the monosaccharide glucose, while hemicelluloses alone produce the monosaccharides arabinose and galactose. Here, we present preliminary ion chromatography and fold testing data, tracking glucose, arabinose, and galactose in paper degraded by acetic acid and hexanal. We observe differences in the ways that acetic acid and hexanal impact monosaccharide levels and physical paper quality, which can provide new clues towards the unexplored role of hemicelluloses in paper degradation.

A comparative study of essential oils used in papyrus sterilization, with a case study from the early Islamic period

Bahaa Fawwaz

The study was conducted on a papyrus housed at the Museum of Islamic Art in Cairo, Egypt. This papyrus was inscribed with black ink. Twelve fungal species were isolated and identified. Five types of fungi were ultimately identified to complete the study. The isolated fungi were then incubated for three months after the aging procedure.

This study investigates the in-vitro growth inhibition of Aspergillus niger, Aspergillus flavus, Penicillium chrysogenum, Trichoderma longibrachiatum Rifai, and Paecilomyces variotii on papyrus. The hyphal growth was observed using the environmental scanning electron microscope (ESEM). Natural oils, such as lavender oil, lemongrass oil, and rosemary oil, were used.

The impact of these natural oils on the newly aged papyrus was assessed using scanning electron microscopy and color analysis to identify the most effective oils for inhibiting fungus growth.

A survey on the procedures adopted in cinematographic archives for monitoring and mitigating Vinegar Syndrome

Francesca Frasca, Lisa Vergelli, Susan P. Etheridge, James Layton, Anna Maria Siani

A key issue in cinematographic archives is preserving cellulose tri- and diacetate motion picture films (hereafter called, films) affected by "Vinegar Syndrome" (VS). This term commonly refers to the vinegar smell occurring when cellulose tri- and diacetate films are deteriorating. The chemical process involves the deacetylation of the film support caused by the reaction of water with a bound acetyl group, resulting in hydroxyl substitution and production of acetic acid. This reaction can be initially triggered by specific microclimate conditions. Once triggered, the process is autocatalytic, meaning it cannot be stopped or reversed. Consequently, the acetic acid released by a VS-affected film can more rapidly induce deacetylation in other films.

Consultative surveys can be a mainstay for leading to a comprehensive understanding of current practices and exploring new strategies. The ensemble of information gathered from surveys is pivotal to highlight current challenges and identify potential improvements. For this reason, a survey was designed to target film archivists and conservators who work with cellulose acetate films. The online survey was conducted from December 5th, 2023, until January 15th, 2024, targeting members of the Association of Moving Image Archivists (AMIA) and the email list of the International Federation of Film Archives (FIAF). It included 16 quantitative and qualitative questions (both open and close) to gather statistics and detailed information on: a) the amount of collection affected by VS; b) devices and procedures used for monitoring the level of VS; c) strategies for mitigation and recovery of films in good conservation state as well as for disposal of films with severe VS.

A total of 96 individuals responded to the survey, mostly belonging to public and private organisations, worldwide distributed. Less than 30% of respondents' collections were estimated being VS-affected by most respondents. The most used devices for monitoring the level of VS were dye-coated paper strips, that change colour according to the amount of acetic acid released by the film. However, there is no unique strategy to test collections for VS, nor a fixed frequency for testing as it can be performed once a year, every 6-10 years or never. There was greater agreement among respondents on the use of ventilated cans and/or cold storage to mitigate VS affecting films. However, only 54% of respondents affirmed to isolate films in special vaults; the others complained about a lack of space and/or budget. In the case of films with severe VS, there is no unique policy for the recovery, as it is evaluated case by case according to the availability of other copies, curatorial interest, and item's uniqueness.

By gathering and analysing data from experts and insiders in the field, it is possible to highlight areas in need of improvement and promote collaborative efforts to preserve these invaluable cultural treasures for future generations.

Acetic Acid in Mixed Material Showcases: A Case Study from the Louvre Abu Dhabi

Georgina Garrett, Theofanis Karafotias

This is a case study from a showcase the Louvre Abu Dhabi. The museum, which opened in 2017, presents a survey of world culture that illustrates connections across cultures and as a result showcases often contain groupings of objects from very different contexts and made of several different materials.

The project initiated following the discovery of a white crystalline growth on a limestone object on display for several years in a mixed object showcase. This was sampled and analysis indicated the presence of acetic acid in the showcase. A pollutant survey carried out by the preventive conservation unit in the museum had previously established that the showcases in the museum are not significant sources of organic acids. Attention turned to the other items in the showcase including wooden and metal artworks and showcase furniture such as podiums. A simple experiment to determine the source of the acetic acid was designed and carried out. This testing involved sealing the individual items in enclosures that trapped any off-gassing and taking intermittent readings of the acetic acid level of the enclosure using colorimetric detector tubes.

The results of this testing indicated that whilst one wooden museum object is the most likely source of the pollutant, other items from this showcase including a composite object and wood-based podium also produced relatively high levels of acetic acid. Further testing of a second podium from the same manufacturer that had not been in this showcase showed negligible acetic acid off-gassing.

This outcome seems to indicate cross-contamination of the first podium and raises the possibility of this happening with the composite object. The implications for this regarding collections care and preventive conservation are discussed alongside practical mitigation methods implemented in this case.

VOC-Sampling inside display cases with focus on BEMMA evaluation

Wolfgang Horn

Museum display cases aim to protect art and cultural goods not only from theft and vandalism, but also from dirt and dust. An often-heard argument within a call for tender of new display cases is that there should be no emission inside of the display case. This is nearly impossible for new ones especially when they must also fulfill the requirement of an air change rate of less than 0.1 per day. For example, constructions or decorations in exhibition spaces, storage containers in depot rooms, and exhibition display cases release volatile substances that might lead to irreversible changes or, under certain circumstances, damage to the stored or displayed objects. In Germany beneath the well-established Oddy-test also the BEMMA procedure is used to evaluate the construction materials. For larger amounts of display cases control measurements of VOCs at the end of construction or buildup is quite common. However, what is necessary to measure the air inside of display cases. What are the circumstances when the display cases were closed before the test period? Is it possible to organize a clean environment for reliable measurements. How comparable are the resulting VOCs with results from BEMMA test and control measurement at the end. The BEMMA procedure should include a further VOC-test at 60 °C. What are the benefits of this enlargement. Mainly materials that have a high potential to store VOCs inside of the material in combination with a less permeable surface should be evaluated stricter than others.

Development of Emission Test Method Using Sampling Bag

Tomoko Kotajima, Masaki Suzuki, Masahide Inuzuka

Chemicals emitted from interior materials are a long-standing issue in museum environment. It is desirable to identify the source of emissions and take appropriate action. However, in storage rooms, interior materials that may be the source of emissions are fixed to walls and floor surfaces, making it difficult to conduct emission tests to identify the source. The purpose of this study was to develop a simple emission test method to collect in-situ samples of chemical substances emitted from interior materials fixed to floor surfaces, etc., to identify sources of chemical substance emissions in storage rooms.

In this emission test, we focused on a commercially available sampling bag with an open edge for inserting samples. We modified the open edge of the bag to enable flat surface measurements (hereinafter referred to as "bag"). The top of the bag had an air vent, through which air is supplied to and collected from the inside of the bag. The test was conducted according to the following procedure. The open edge of the bag was spread on the floor and a CO2 meter was placed inside the bag. The air in the bag was replaced with N2 and the bag was allowed to stand for a certain period. The air in the bag was collected using a sampling tool and analyzed for components.

Using the floor surface of a museum storage room as the test sample, the CO2 concentration was measured using the test method, and the number of ventilation cycles in the bag was calculated. The same test was also conducted with an acrylic plate on the floor. The CO2 concentration in the bags of all the test samples placed on the floor surface increased slowly over time, and it took about 24 hours to reach the same level as the storage room concentration. In the test on the acrylic plate, the concentration shift was even smaller than in the test on the floor surface. These results demonstrate the airtightness of the bag, confirm that the bag can temporarily isolate the floor surface from the surrounding environment. In addition, the same test was conducted at several locations on the floor surface, and the ventilation frequency was generally similar for all test samples.

Emission tests using the test method were conducted on floor surfaces. In the test, bags were placed at several locations in a room, each with a different settling time. It was assumed that the same production batch of flooring material was used, the chemical emissions were consistent across different measurement locations. The obtained acetic acid and formic acid concentrations were converted to emission rates, which were approximately similar. This result substantiates the assumption and demonstrates the reproducibility of the test.

This test method suggests its effectiveness in identifying chemicals emitted from fixed interior materials such as floor. This test method is still under development, and we would like to continue testing to improve the accuracy of the test.

Green Future Archaeological Conservation and the Environment

Ahmed Mostafa Mahmoud

The archeological objects constitute an important part of the world wide cultural heritage. The impact of the microbial activity on the deterioration of cultural heritage is a global problem and their disinfection over time is a challenging task. the chemical and mechanical preservation of archaeological objects can formed some deterioration features (erosion and surface damage) accompanied with the hazard on public health and ecosystem. So, new environmentally friendly safe, safe method for protection of archeological objects are Essential Oils to preserve the archeological objects from microbial damage the main recommendation in this study is the use of Essential Oils as a promising treatment for protection of cultural heritage. Antimicrobial activities of the six Essential Oils (EOs) (Clove , Menthe , Basil , Camphor , Anise , Cinnamon) were tested against Nine isolated deteriorated fungal species (cladosporiwm cladosporioides, paecilomyces varietal, aspergillus fumigates , aspergillus flavus , aspergillus niger , penicillium chrysogenum , penicillium funiculosum , aspergillus alutaceus and Aspergillus parasiticus) archaeological objects (Mummies and skeletal remairs they are on display in Kafr El_shikh Museum , Egypt). The results confirmed that the cinnamon is a promising Eco _friendly treatment for the preservation of the archaeological objects due to the highest antimicrobial activity and the most acceptable which is esthetically acceptable for archaeological objects disinfection with negligible toxicity to human and environment guaranteeing agood quality of life for the employees and users.

Design principles of a low cost microchamber to explore unexpected salt formation in 20th-21st century artists' oil paints

Georgia Millsom, Enrico Manfredi-Haylock, Bronwyn Ormsby, Judith Lee and David Payne

Magnesium sulphate heptahydrate, otherwise known as epsomite, is a white crystalline salt known to form on 20th century oil paintings as a degradation product. This water-soluble salt disrupts the surface of oil paint layers and contributes to water sensitivity during conservation treatments. This is an ongoing issue for conservators as water-based cleaning systems are ubiquitous for cleaning of unvarnished modern and contemporary works of art.

This work aims to understand the conditions under which epsomite forms and grows, to ideally inform optimal storage and display conditions for these artworks, but also to understand the behaviour of these salts under typical museum display and storage conditions.

Recent research has been carried out exploring salt formation in simplified representative oil paint samples exposed to 23%, 50%, and 75% RH, at 25 °C and under light and dark conditions [1]. However, the formation and behaviour of these salts within BIZOT museum conditions has yet to be explored. These wider parameters are not universally adopted, but are a significant move away from tighter environmental controls typically employed in the 20th C.

Methods of artificial ageing commonly used within heritage science do not generally offer the ability to control all of the significant ageing related factors, such as humidity, temperature, atmosphere (gaseous pollutant) and lux, without dramatically increasing cost. This is to be addressed within this project through the design of microchambers to facilitate independent control of these parameters. The microchamber has a low-cost design and will be airtight, samples will be in an atmosphere of air mixed with low quantities of SO_2, which is known to impact salt formation and has thus far been explored at elevated concentrations [2].

To achieve this, a vacuum bag will be used as the enclosure, with 2 samples placed into the bag inside a 3D printed sample holder, to prevent the bag from touching the samples. A petri dish with a salt solution to control the humidity will be placed below. The bag will be heat sealed to ensure no leakage of the atmosphere occurs over the ageing period. The sealed vacuum bags will then be placed in a large, insulated bag, to ensure a constant temperature across all conditions, with an LED light. Filters will be used to change the light levels samples are exposed to. We anticipate this design could be applied to other scenarios where artificial ageing under stringent conditions is required, with a limited budget.

[1] J. Harrison, J. Lee, B. Ormbsy, D. J. Payne, The influence of light and relative humidity on the formation of epsomite in cadmium yellow and French ultramarine modern oil paints. Heritage Science. 9:107 (2021)

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Development of a Paper Oddy Test Variant

Karisma Moll, Michael Samide

The Oddy test remains the museum standard for determining suitability of a material to be used in the display or storage of artwork. One issue with this approach is that it assumes any pollutant that is deemed suitable by the Oddy test (no corrosion observed on the metal coupons) will inherently be suitable for every other kind of artefact material (cloth, paper, plastic, etc.) and vice versa.

This work is focused on the development of an Oddy test variation that uses cellulose in place of a metal coupon to determine material suitability for collections on paper (or wood). The Paper Oddy test is performed similarly to a traditional Oddy test, with some modifications. The material to be studied is placed in an Oddy jar along with water and alpha-cellulose powder, sealed, and incubated at 80C for two weeks. After incubation, the alpha-cellulose is removed and washed with water. Cellulose, when exposed to various pollutants (commonly acidic pollutants), will break down and form glucose along with other mono-, di-, and oligosaccharides. These saccharides become markers of degradation and can be quantified in the wash solution obtained from the exposed cellulose powder.

In this work, we have employed two known colorimetric methods to determine the quantity of degradation products formed during the Paper Oddy test. The first method uses an anthrone reagent to detect the concentration of hexoses present (referred to as “glucose equivalents”) by changing color from yellow (no hexoses present) to blue, with the darkness of color corresponding to increasing concentration of hexoses. A second method uses an orcinol reagent to detect the concentration of pentoses present (referred to as “arabinose equivalents”) by changing color from clear (no pentoses present) to green, with the intensity of color corresponding to concentration.

By calibrating each of these quantitative methods, we can determine the total amount of degradation products (glucose equivalents + arabinose equivalents) for cellulose exposed to known, concentrated pollutants as well as for cellulose exposed to potentially polluting materials. Upon comparison to a control sample, we can assign a grade of Pass, Temporary, or Unsuitable to those materials for use with collections on paper. This Paper Oddy method has been applied to 10 materials well vetted by the traditional Oddy test (provided by both the Met and the IMA) and the results for this method will be compared to a similar Paper Oddy variant test being developed by The Metropolitan Museum of Art which employs paper strips and instrument-based means of saccharide detection. Reproducibility and ease of implementation will be discussed.

The Danish "Sustainable Museum Storage" Project

Morten Ryhl-Svendsen, Poul Klenz Larsen, Lars Aasbjerg Jensen

In the project ""Sustainable Museum Storage"", supported by the Danish Ministry of Culture (SLKS), six modern low-energy storage facilities for museums, archives and libraries in Denmark are examined for their conservation quality and environmental footprint. The project has a broad focus, including life cycle analysis of the buildings, the operation's energy consumption and the indoor climate and air quality performance. As the project is underway (2024-2025), the results are provisional. Here we present the first results for indoor environmental monitoring. In summary, we observe that although only two out of the six facilities use gaseous air filtration, the level of indoor air pollution is surprisingly low everywhere, despite all being very airtight buildings and with a high load of potentially emitting objects inside (mainly collection items). We attribute this to the fact that the storage temperatures are lower than in normal room conditions, as well as the possible air-purifying effect of mechanical humidity control. The latter is an unexpected but nonetheless positive side effect of using desiccant wheel dehumidifiers, which can remove acids from the air in the same process as removing moisture. The infiltration of outdoor air pollutants is low at all six facilities; we attribute this to the design of the buildings and their low air exchange rate. A summer period monitoring campaign is underway at the time of writing and the results will be ready for presentation at IAQ2024. This project is a continuation of earlier work reported in [1] and [2].

References:

[1] Ryhl-Svendsen, Jensen, Klenz Larsen & Bøhm, 2012, Low-energy Museum Storage Buildings: Climate, Energy Consumption and Air Quality (Final report): https://zenodo.org/records/8403982

[2] Ryhl-Svendsen & Smedemark, 2024, Environmental Conditions for Danish Storage Buildings: A Summary of 20 Years of Air Quality Surveys, Studies in Conservation, DOI: 10.1080/00393630.2024.2351761

Evaluation of the Role of Preventive Conservation in Storage of metallic Artifacts

Yasmin AE Sayed, Mohamed Soliman Ali, Rawan Ahmed, Mahmoud Ahmed

This article investigated the climatic effects of relative humidity, temperature, pollution, light, and other environmental conditions on the decay of iron artefacts. Furthermore, the influence of various storage circumstances, procedures, and materials was thoroughly investigated, including the effect of packaging materials, wrong item handling, or unsuitable storage conditions, which could cause chemical and/or physical harm to the artifacts. Disasters like earthquakes and fires were also discussed. Also this paper aims to how to deal with the concept of preventive conservation of metallic artifacts, the identification and targets of preventive conservation. While the second part of the study included the optimum environmental conditions which should be present in storage areas as (relative humidity, temperature, light) as well as materials and methods used for handling, transporting and storing the metallic objects.

Analytical and conservation study of Mummy "Portrait from Roman period in the store of the Coptic Museum – Cairo – Egypt.”

Nagah Sayed, Rasha Shaheen

This research paper represents a rectangular model of fabric covered with a layer of painted gesso that represents a human being with the image of a man's face bearing Roman features (EL fayum Portrait). It is not complete in parts and is executed in the manner of mummy portraits from the Roman era, which appeared from the first century BC until the third century AD to be placed on top of the mummy of the deceased. The unique piece is that it combines the technique of cartonnage, which is layers of fabric covered with colored plaster, and the technique of portraits of mummies, which were executed on wooden surfaces topped with a layer of colored plaster, and it is preserved in the Coptic Museum. The artefact was exposed to various factors of damage, which led to the deterioration of its condition and the loss of a large proportion of its parts, as about 50% of its parts are missing.The treatment and Conservation work has been completed and carried out after it was severely damaged as a result of many different factors of damage, both environmental before its discovery and when extracting it from the excavations, as well as the human factors of damage represented by people who are not sufficiently knowledgeable and experienced in how to treat and conserve these collections. When the piece was extracted from the excavations, it was not completed correct treatment process, but materials were used to randomly collect the remaining disassembled parts of the cover.adhesives were also used that led to more damage in the form of cracks, cracks and separations. Then the cover, which is unique in this museum of this type, was kept in very poor storage conditions of high humidity, heat, dust and pollutants that led to physicochemical and microbiological damage. And it remained for many years inside the store without any appropriate restoration work related to the piece, so examinations and analyzes were conducted to identify the components of the antiquity as well as the rates of damage to the layers of the carton using (U.SB – SEM – FTIR-EDAX) to carry out the Restoration and conservation work and then display in one of the museum's halls

Reconstruction of the scent of Leonardo da Vinci's painting

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The portrait of Cecilia Gallerani was painted by Leonardo da Vinci ca. 1490. and the paiting was named Lady with Ermine. The ermine is the symbol of Ludovico Sforza who commissioned a portrait of his beloved from Leonaro da Vinici. The painting is considered as the most important object in Polish collections The object is a part of the permanent exhibition shown to the public in the Czartoryski Museum, a part of National Museum in Cracow. The aim of the study was to sample the volatile organic compounds which are emitted from the painting and they are creating the scent of the object. The samples of VOCs emitted from the painting were collected into TENAX sorption tubes. In the next step the collected VOCs were analyzed in the thermal desorber – gas chromatography - mass spectrometry – olfactometry (TD – GC/MS – OL) apparatus system. The chromatograms, mass spectra and olfactograms were detail analyzed. Based on the obtained data we selected five main compounds which are dominating the scent of paining. Only the most abundant compounds and with the strongest influence on the scent of object, were selected. It can be concluded that the set of selected compounds were mainly aldehydes which can be correlated to walnut panel and oil paints of paining. The reconstructed scent of painting was made available to visitors who assessed the impact of smell on the perception of the painting. The most important group of people surveyed were visually impaired visitors. These investigations are the part of project: ODOTHEKA - Olfactory heritage research: capture, reconstruction and conservation of historic smells. The main purpose of the project is to create the library of historical objects' scents, objects which have great importance for the Polish and Slovenian collection, and make them available for the visitors so that it is possible to visit the exhibition using all four senses of sight, hearing (audio guide), touch (a modern copy available for touching) and smell.

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Studies on improving the interaction between display and technical volume for effective use of adsorbent media in passive showcases

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Organic air pollutants from internal sources, particularly volatile organic compounds (VOCs), continue to pose a high risk to objects on display in showcases. Acetic acid is one of the most prevalent and harmful pollutants in museum environments. It can be emitted from the construction material of the showcase or from objects on display themselves. In airtight showcases with low air exchange rates it can accumulate highly and cause corrosion, as well as other damaging processes, to vulnerable objects.

A key aspect of this project is the investigation of the effectiveness of passive showcases in their protective function. Special attention is given to the communication between the display volume (DV) and the technical compartment (TC) for adsorbent media, for example, moisture or air pollutant sorbents. In this context, this study examines how changes in the interaction between these volumes impact the conditions around the objects, with the aim of optimizing the mass transport of humidity and air pollutants in sustainable passive enclosures for better object preservation.

Preceding investigations on desiccators and emission test chambers by the project team will be transferred to showcases in a laboratory environment. First, the exchange velocity between DV and TC was determined using drying agents. Humidity loggers in the TC and DV measure the rate at which water vapor and relative humidity equilibrate between the two volumes, indicating the effectiveness of mass transport within the showcase.

This experimental setup was repeated under different configurations within the showcases to determine changes in the diffusion rate and adjustment times. The different configurations concentrated on the plate between the DV and the TC, and the open area between them was decreased from 20% to 10%, to 2.5%, and finally to 0.25%. As anticipated, the preliminary outcome indicated quicker transport for larger openings in the base plate.

Analogous to this experimental setup with a drying agent, the corresponding experiments were carried out with an acetic acid source in the DV and activated carbon cloth as an adsorbent medium in the TC (Fig. 1). After two weeks, air samples were taken from both DV and TC and examined using GC/MS to determine the acetic acid concentration at both locations. For comparison, the experiments with passive enclosures were repeated with active air circulation inside the showcase. The results of these test series will be evaluated to obtain characteristics that define a showcase in which adsorbent media can be used effectively for the safe and sustainable display of vulnerable objects.

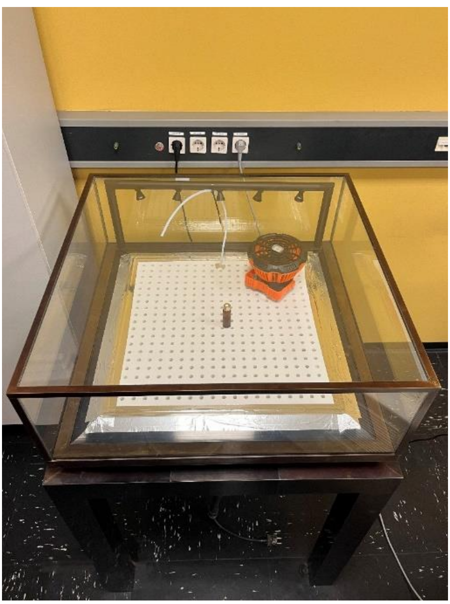


Figure 1.

Acetic acid detection and cinematographic archives

Lisa Vergelli, Francesca Frasca, Chiara Bertolin, Gabriele Favero, Anna Maria Siani

Preservation of cultural heritage collections is directly and indirectly influenced by environmental conditions (microclimate and air pollution). While monitoring microclimate conditions has become a common practice and is regulated by standards and guidelines, the practice of measuring gaseous pollutant concentrations (organic and inorganic chemical compounds) in indoor spaces housing collections is still poorly carried out. A comprehensive review of the scientific literature conducted by the authors over the 1990-2021 period has evidenced that acetic acid is the primary organic air pollutant monitored in indoor spaces housing collections. We have identified 22 scientific articles where acetic acid was monitored in 32 case studies worldwide belonging to the category of: museums/galleries (15), book archives/libraries (8), worship places (7), and palaces/castles (2). Incredibly we have found that acetic acid monitoring was never conducted in cinematographic archives, although it is well-known that cellulose di- and tri-acetate support of motion picture films can be affected by Vinegar Syndrome, responsible for the emission of acetic acid and triggered by the same chemical compound. It was found that, among the instruments employed for acetic acid detection (both active and passive samplers), the only direct-reading instrument used in literature was the Gastec dosimeter tube; all other methods were based on laboratory analysis (e.g., liquid, gas or ion chromatography) of samples collected after in situ exposure (e.g., charcoal filters, silica gel or Tenax TA tubes, Radiello air samplers, Palmes tubes, and samplers by Swedish Environmental Institute and Norwegian Institute for Air Research). Devices commonly used by film archivists were never mentioned. For this reason, this contribution will present these devices and their use in cinematographic archives. In fact, acetate films are traditionally inspected by film archivists through the deployment inside the film can of dye-coated paper strips, whose reading is based on color change in relation to pH change, i.e., to the emission of acetic acid by film deterioration. There are two manufacturers of these strips: Acid Detection Strips® that are produced by the Image Permanence Institute and Danchek Strips® that are commercialized by Dancan Cine Film Service S.L. The former employed worldwide, the latter mostly in Europe. Ad hoc laboratory test was conducted to compare the performance of these strips and to explore methods for quantifying the color change readings. In addition, some investigation performed by the authors in European film archives (in quarantine and long-term storage rooms) will be presented and discussed. Although measuring acetic acid concentration is not a common research topic, this contribution has brought together the existing literature and completed the framework of current technologies employed in the field of preventive conservation, especially in cinematographic archives.

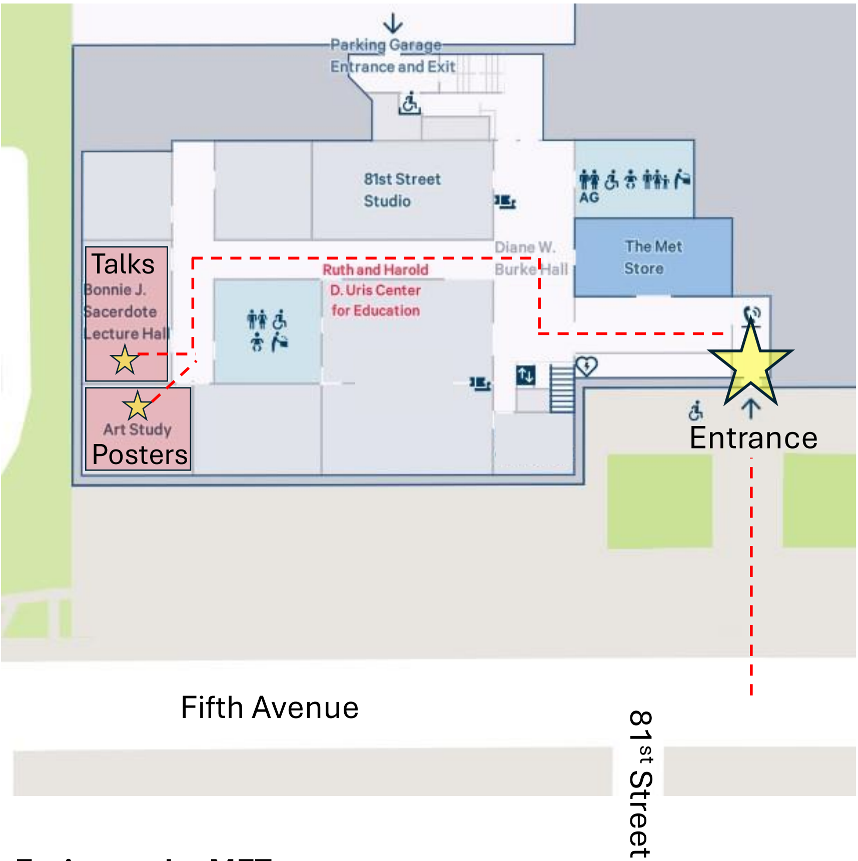
Air pollution threatens Forbidden City buildings inside and out

Zhang Guoqing, Zhang Jieming, Zhang Xincheng

The Forbidden City was the political centre of China during the Ming and Qing dynasties. However, air pollution has made the harm to the heritage resources worse in the context of modernization and climate change. The Forbidden City boasts a lengthy history of historic architectural structures, but its protective role for the interior has diminished as its enclosure structure has suffered damage. It is easy for harmful gasses from the atmosphere to seep into the interior. Unlike most museums, a significant proportion of the halls are presented to the public in a form that preserves the original appearance of the Qing palace. It is inevitable that the cultural relics on exhibit in these palaces come into direct touch with external air pollution. The Palace Museum has installed air quality monitoring stations within the Palace because it has long been worried about these contaminants. SO2, NO, NO2, O3, PM2.5 and PM10 were monitored.

Through the monitoring in recent years, it has been found that these pollutants have different seasonal trends. Ozone was the main pollutant in summer, exceeding China's air quality standards with a maximum of 250 μg/m3. NO and NO2 were highest in autumn and winter, the highest concentration of NO2 approaching 45 μg/m3. PM2.5 and PM10 were high in winter and spring due to the dry climate and sandy conditions in Beijing. The highest concentration of SO2 not exceeding 10 μg/m3. In order to understand the air quality situation in those halls of the Forbidden City that show the original appearance of the Palace, we conducted tests on 8 halls sequentially. The detection of the palace is distributed in different places in the palace, including the Hall of Mental Cultivation, the Pavilion of Rain and Flowers, the Hall of Supreme Principle, the Palace of Earthly Honour, the Pavilion of Buddha's Light, The Building of Buddhist Brilliance, the Hall of Spiritual Cultivation, the Studio of Exhaustion from Diligent Service. Laser detectors were used to measure SO_2, NO, NO_2, O_3, PM2.5 and PM10, and some of the halls were also tested for organic acids.

The results showed that there were high concentrations of SO_2 in all palaces, with an average concentration of 500 μg/m3. Ozone is an important indoor pollutant in the Hall of Mental Cultivation and the Pavilion of Rain and Flowers, with results of 20 μg/m3 and 70 μg/m3. Among nitrogen oxides, the concentration of NO_2 was not very high, but some areas had high concentrations of NO, probably because UV rays were not well controlled. PM10 concentrations were high, and the daily average of 150 μg/m3 was exceeded. The average concentration of PM2.5 was 2.7 mg/m3, but the highest exceeded 80 mg/m3 in the Hall of Mental Cultivation. The test results showed that the cultural relics displayed in their original state face the threat of air pollutants, improved new materials and innovative techniques are desperately needed for the cultural relics on display at the Forbidden City.



Eating at the MET

You will receive a boxed lunch on Tuesday. Please note that food and drink are not allowed in the galleries. You can either stay and eat your lunch in Sacerdote or Art Study (no tables available) or you may take your lunch to any of the following places:

Indoor

- The Eatery (Ground floor)
- American Wing Café (1st floor)
- Petrie Court café (1st floor)
- Great Hall Balcony café (2nd floor)

Outdoor

- Central Park (exit at 81st Street and head south on Fifth ave; turn right into Central Park)
- Fifth Avenue café tables (right outside the 81st street entrance)