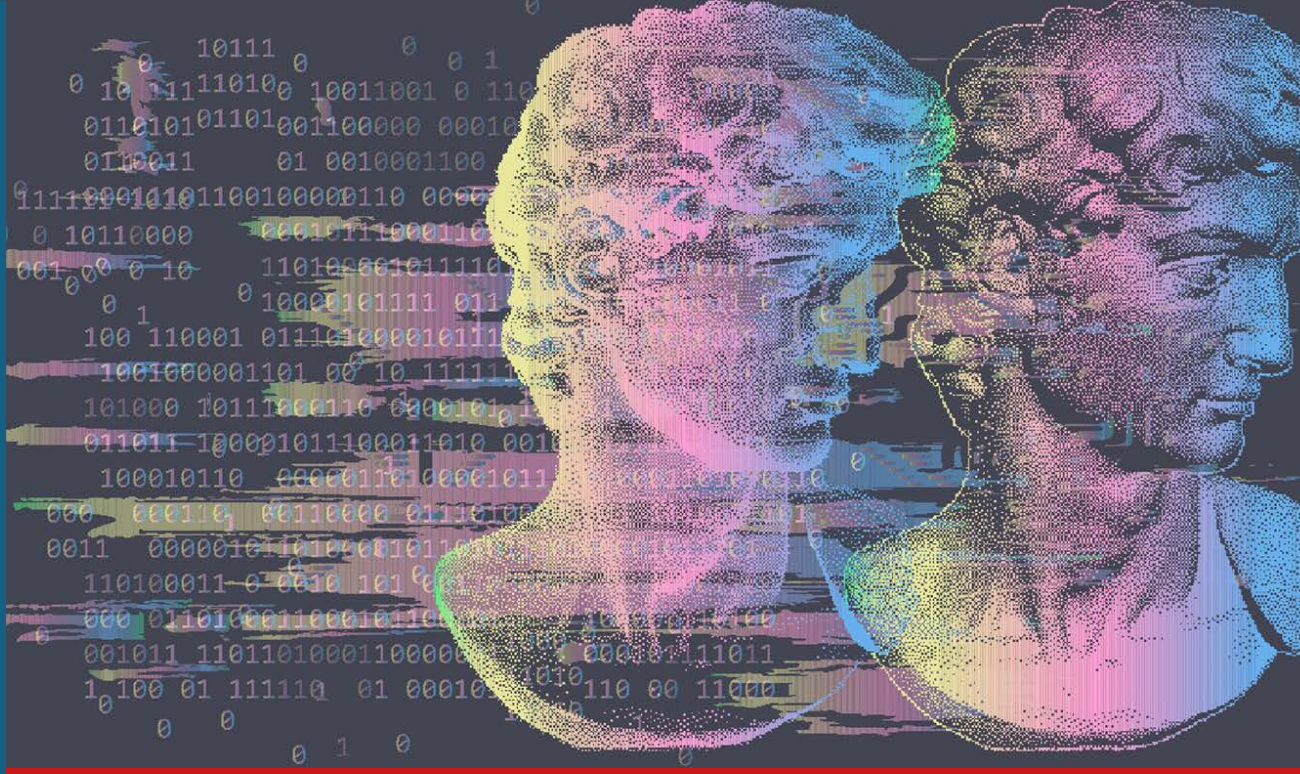

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2nd Conference of the Slovenian Node of the European Research Infrastructure for Heritage Science E-RIHS Slovenia
BOOK OF ABSTRACTS

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INTRODUCTION

Dear participants of the ERIHS conference,

It is our great pleasure to welcome you to this year's conference, dedicated to showcasing achievements and addressing challenges in the field of heritage science. The University of Maribor is proud to host this important event, as we are active members of the ERIHS Slovenia Steering Committee.

Heritage science is an interdisciplinary field that brings together humanities, natural sciences, and engineering. It focuses on research, preservation, and sustainable use of cultural and natural heritage. By doing so, we enhance our understanding and care for heritage, ensuring its preservation for future generations and improving its role in the lives of people today and in the future. In line with the mission of the European Research Infrastructure for Heritage Science (E-RIHS), ERIHS Slovenia also promotes collaboration among researchers from diverse disciplines and facilitates access to state-of-the-art research infrastructure, thereby strengthening the research culture.

The University of Maribor is intensively expanding its research activities in the field of heritage science. We are closely collaborating with the University of Ljubljana, the University of Nova Gorica, and the University of Primorska, as well as with other members of the ERIHS Steering Committee. Together, we strive to establish a leading knowledge network at the European level, which will contribute to the advancement of heritage science and facilitate the effective exchange of knowledge and resources among researchers. At the University of Maribor, we have established the Heritage Science Program Core, involving several faculties, and we are closely linking our research efforts with cultural institutions such as museums, archives, and libraries. This way, we create applied knowledge, which is transferred into practice to directly enhance the preservation of cultural heritage.

Today's conference offers a unique opportunity for the exchange of ideas and the presentation of the latest research, including innovative solutions enabled using artificial intelligence. The rich program features presentations from researchers, conservators, engineers, students, and policymakers. The event will foster networking and new collaborations, helping to build a strong and connected heritage science community in Slovenia and across Europe.

We sincerely hope that the conference will be inspiring and beneficial for all participants and that it will contribute to the further development of heritage science and the adoption of new technologies. We wish you successful work, fruitful discussions, and an enjoyable stay in Maribor!

Sincerely,
The Organizing Committee

INVITED LECTURES

Heritage Sustainability - from Islands to Continents
Dr. Fenella France, UCC Cork, Fulbright Scholar, Cork, Ireland

The Italian Node of E-RIHS: Expanding Capabilities in Heritage Science Research and Infrastructure
Dr. Costanza Miliani, The Institute of Heritage Science, National Research Council and national coordinator of E-RIHS.it, Milan, Italy

Heritage Sustainability - from Islands to Continents

Fenella France [1]

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While both continents and island nations are being impacted by extreme weather events and changing climate patterns, island cultural heritage is greatly impacted by the intensity and frequency of these occurrences. The economics of preserving our heritage is becoming a greater challenge, with large institutions in the USA and pacific nations reviewing environmental parameters as well as coordination and relocation of storage areas. At the Library of Congress, assessment of buildings, collection areas, and sustainability has led to some changes in approaches. In New Zealand and other parts of Oceania, more often than not, the approach is reactive out of necessity in addressing unexpected events, there is a strong commitment to long-term assessment of heritage sites, and preservation. Regional heritage communities have been working with larger heritage institutions to utilize historic information of events dating back through two centuries of data, working to utilize this knowledge towards greater agility and adaptability towards recurring climate events in a modern context. This approach begins to move away from a reactive response and towards the need to be proactive, although the reality for long term adaptation is in between. New Zealand had another geographical issue, being on the Pacific "Ring of Fire" where tsunamis and earthquakes join sea level rise due to tectonic plate movement. Literally moving heritage sites and storage, and the inclusivity of communities in preservation of their own culture, is how these Pacific Islands are addressing potential complete loss of their physical heritage and embracing the digital realm for sharing tangible and intangible heritage, along with the teaching skills for future knowledge of island heritage through sharing of historic methods of creation that may only be available in the digital realm due to rising sea-levels and islands going completely under water. This presentation will address the multipronged approach to heritage sustainability.

The Italian Node of E-RIHS: Expanding Capabilities in Heritage Science Research and Infrastructure

Constanza Miliani [1]

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The Italian node of the European Research Infrastructure for Heritage Science (E-RIHS) is currently composed of three research institutions bound by a joint research unit: the Consiglio Nazionale delle Ricerche (CNR), which acts as the legal entity for E-RIHS, the Istituto Nazionale di Fisica Nucleare (INFN), and the Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile (ENEA). A strategic expansion effort is underway to include the expertise and facilities of university departments (namely, Università di Bologna, Firenze, Perugia e Politecnico di Milano) and institutions within the Ministry of Culture. This will further enhance the Italian node's ability to contribute to the advancement and innovation in heritage science research, both at the European and national levels.
The Italian node plays a pivotal role in promoting access to laboratories, offering specialized training, fostering international collaborations, and developing new infrastructural capacity as well as human capital. By facilitating access to cutting-edge tools and expertise, the node supports researchers in the field of heritage science, ensuring they have the resources necessary to conduct pioneering research.
One key area of focus for the Italian node is the implementation of the Italian branch of the DIGILAB digital platform, a project that is being developed with funding from the Next Generation EU initiative. DIGILAB will serve as a digital laboratory for the integration and sharing of scientific data, providing a digital infrastructure that supports interdisciplinary research and collaboration across Europe.In summary, the Italian node of E-RIHS is dedicated to advancing the field of heritage science through strategic partnerships, infrastructural development, and international cooperation, all while reinforcing Italy's leadership in the European research landscape.

LECTURES 1

Assessment of historic wood construction: Case study of castle Leskovec
Prof. Dr. Miha Humar, University of Ljubljana, Biotechnical Faculty, Ljubljana, Slovenia

Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) fundamentals and application in heritage science
Dr. Martin Šala, National Institute of Chemistry, Ljubljana, Slovenia

Stone to Digital – Medieval and Early Modern Epigraphic Heritage
Assoc. Prof. Dr. Gregor Pobežin, University of Primorska, Faculty of Humanities, Koper, Slovenia
ZRC SAZU, Institute of Cultural History, Ljubljana, Slovenia

Fluorescence microscopy and immunology in heritage science
Dr. Janez Kosel, Institute for the Protection of Cultural Heritage of Slovenia, Ljubljana, Slovenia

BArCh-Wood: Interdisciplinary student research on climate change impacts on archaeological wood
Lana Nastja Anžur and **Špela Pok**, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Ljubljana, Slovenia

Assessment of Historic Wood Construction: Case Study of Castle Leskovec

Miha Humar [1*], Boštjan Lesar [1]

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The respective castle was first mentioned in 1436. The castle was rebuilt in the 18th century. The castle has been abandoned for the last decades. The roof has become leaky; thus, extensive decay has occurred in several wooden structural elements. Localised collapses have occurred on individual elements. The castle is in the process of renovation. Thus, the structural health of the wooden elements was assessed. To complete this task, the following measurements were performed in situ, moisture content measurements, resistograph measurements, screw withdrawal, and dynamic modulus of elasticity (dMoE) through measurements of the transit time in microseconds. In addition, the wood samples were isolated, and additional laboratory measurements were performed (microscopy, XRF). Most of the damage was caused by the brown rot fungi *Serpula lacrymans, Antrodia vaillantii and Gloeophyllum trabeum*. The wood-inhabiting insects caused minor damage, predominately *Hylotrupes bajulus* and *Anobium punctatum*. Wood decay fungi seem active, while the insect damage seems to have developed in the past. The decay was limited to sapwood mainly. More than 400 cross-sections were analysed. In average 14% of cross-sections was degraded, with approximately 40 cross-sections having more than 20% of cross-sections degraded. The mean dMoE of fir wood was 9433 MPa, the minimum dMoE is 3231 MPa and the maximum modulus is 13169 MPa. The modulus of elasticity of fir wood was slightly lower than reported in the literature (10000 MPa to 11000 MPa). This indicates that the mechanical properties of the wood have declined due to the action of insects and fungi. The minimum dMoE was recorded at the point where insect borings and decay were visible. The mean dMoE of the oak wood is 14609 MPa, ranging from 10683 MPa to 23830 MPa. The dMoE of the oak wood is consistent with the literature data (13000 MPa). This indicates that good quality oak wood has been installed, which has largely retained its mechanical properties. Based on these measurements, we identified the structural elements that need to be replaced and estimated the remaining mechanical properties of the remaining structure. These data are entry information to plan reconstruction and develop further uses of the castle. In addition, suggestions were provided to limit decay in the future. Biocidal treatment was proposed for elements where limited decay was identified to limit further development.

Figure 1: *Illustration of the methods utilised to assess the structural health of wooden construction in the castle: resistograph, Measurement of the transit time and screw withdrawal*

Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) Fundamentals and Application in Heritage Science

Martin Šala [1]*, Serena Panighelo [2], Ariana Traviglia [3], Artemios Oikonomou [4], Norman H. Tennent [5], Vid Simon Šelih [1], Johannes Teun Van Elteren [1]

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Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) is a highly sensitive and versatile technique for both elemental and isotopic analysis. It combines laser ablation, which allows precise sample introduction, with plasma ionization and mass spectrometry for detection. This presentation will provide an in-depth overview of the fundamental principles of LA-ICP-MS, covering critical aspects such as sample preparation, optimization of laser parameters, and its impressive detection capabilities. Particular focus will be given to its applications in heritage science, where LA-ICP-MS offers a minimally invasive method for analysing a wide range of cultural artifacts, artworks, and archaeological materials. The technique's ability to generate spatially resolved, high-precision chemical data is invaluable for understanding the material composition, provenance, and degradation processes of historical objects. One of the standout features of LA-ICP-MS is its effectiveness in analysing materials that are notoriously difficult to process through other techniques, such as glass, which resists traditional digestion methods. However, its application is not limited to glass alone. LA-ICP-MS allows for the micro-destructive analysis of nearly all elements in the periodic table, making it a powerful tool not only for identifying the major components of materials but also for detecting trace elements. These trace elements are crucial for "fingerprinting," helping to establish the source provenance of materials used in historical objects and artifacts. Two case studies will be presented to illustrate the diverse applications of LA-ICP-MS. The first focuses on archaeological glass artifacts, where the technique has been employed to classify objects into distinct subgroups based on their elemental composition. These subgroups, in turn, allow researchers to deduce the provenance of the glass and infer ancient trade routes. This work, published in several studies, highlights the power of LA-ICP-MS in uncovering the hidden histories of archaeological materials.The second case study involves the analysis of cross-sections from 17th-century paintings, with particular emphasis on the investigation of smalt- a blue pigment made from potash glass coloured with roasted cobalt ore. The study examined two Dutch paintings and one Chinese painting. Elemental mapping in regions associated with smalt particles revealed no significant differences in elemental concentration, suggesting that the source of the cobalt ore used in both European and Chinese paintings was similar. While this raises the intriguing possibility that the smalt pigment may have been traded from Europe to China, the lack of detailed knowledge about cobalt mining in China during this period leaves open the possibility that a similar cobalt source may have existed within China itself.

Stone to Digital - Medieval and Early Modern Epigraphic Heritage

Gregor Pobežin [1,2]

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This talk focuses on the application of digital technologies in the study of medieval and early modern epigraphy – a largely uncharted field in Slovenia –, targeting inscriptions from the northern Adriatic to the Alps. Through comprehensive analysis and digital publication, this undertaking highlights the importance of epigraphic material in reconstructing the historical, cultural, and civilizational context of the period. By utilizing digital tools, we aim to clarify and revise existing historical narratives, with a primary outcome being a digital corpus of inscriptions, complemented by geographically organized printed volumes.A central aspect of this undertaking is the use of international standards for text markup and exchange, particularly TEI (Text Encoding Initiative) guidelines. The digital corpus we strive towards will be a lasting collection designed to resist technological obsolescence. The structure of this database will align with the well-established practices of digital epigraphy, such as the Epidoc framework, enabling sophisticated search functions, visualization tools, and particularly internal linking of inscriptions with other historical data. This approach not only enhances the accessibility of the epigraphic sources but also allows for dynamic interaction with the data.Once the database is established, a key objective will be to integrate it with other existing European databases focused on objects and individuals. This will facilitate the creation of complex, interconnected research networks, enabling a more comprehensive and nuanced understanding of epigraphic data within broader European historical and cultural contexts.

Figure 1: *Inscription for Aurelio Vergerio (1548) with its XML transcription*

Fluorescence Microscopy and Immunology in Heritage Science

Janez Kosel [1]*, Lea Legan [1], Matej Bračič [2], and Polonca Ropret [1]

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Here we present the application of fluorescence microscopy and immunology for the analysis of archaeological ceramics and mould infested historical paper. Analysis of protein residues bound to archaeological ceramics can reveal the protein/animal type through their amino acid sequence, thus enabling direct identification of food types. Firstly, we present the application of ELISA assay and immunofluorescence microscopy for the analysis of protein residues bound to case-study archaeological ceramics using aptamers targeting egg ovalbumin, egg lysozyme, milk casein, haemoglobin, wheat gluten, fish parvalbumin and collagen. ELISA was performed on proteins extracted from powdered samples, and immunofluorescence microscopy was performed directly on sample's cross-section. Results showed that some samples tested positive for collagen, egg, and gluten. Gluten indicates the presence of wheat, and cereals have been proposed as a staple food for the early Slavic inhabitants of Ptuj, where some of the samples were collected. Additionally, traces of collagen suggest the preparation of bone broth. Secondly, aminopropyl-terminated polydimethylsiloxane (ATP) impregnation for the protection of historical paper against mould growth was evaluated using fluorescence microscopy and non-invasive FTIR spectroscopy. Results showed that at least a 10 % ATP paper impregnation was needed for an effective suppression of fungal biofilm development and tolerance to lower concentrations was species dependent, with *Penicillium canescens* ZIM-9717 tolerating 1 % of ATP and *Aspergillus niger* ZIM-9721 tolerating 1 % and 5 % of ATP. Lastly, we have shown that portable "on the spot" non-invasive FTIR spectroscopy in reflection mode can be effectively used for a rapid but highly sensitive detection and monitoring of mould biofilms on paper support materials. Therefore, non-invasive FTIR spectroscopy can provide for an initial overview or insight into the microbiological condition of library and paper materials.

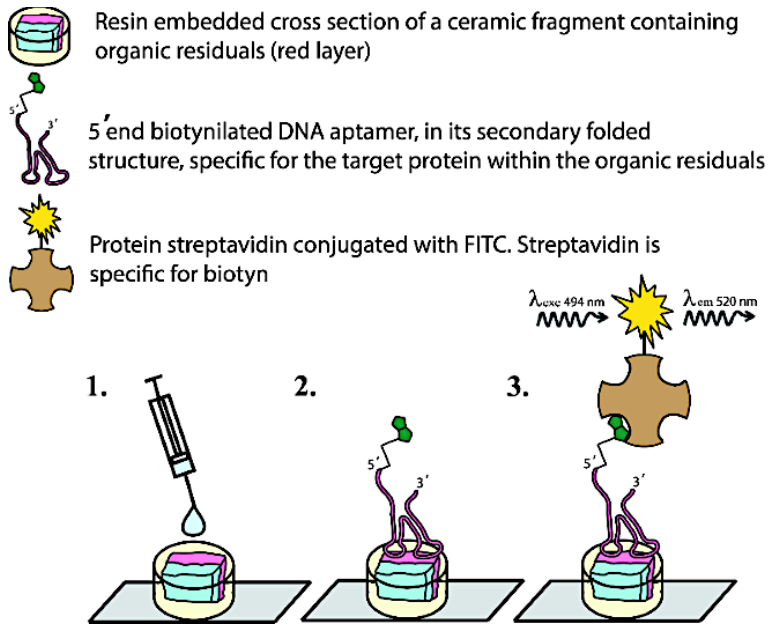

Figure 1: *Schematic representation of hybridization of aptamers onto a sample cross-section for immunofluorescence microscopy (1. blocking solution application; 2. aptamer application; and 3. streptavidin application).*

Barch-Wood: Interdisciplinary Student Research on Climate Change Impacts on Archaeological Wood

Lana Nastja Anžur [1], Špela Pok [1]*, Meta Pivk [2], Agni Prijatelj [3], Marko Zupan[3]

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The BArCh-Wood project was carried out as part of the research activities on climate change solutions organised by the University of Ljubljana (Eutopia network). At the same time, the project represents one of the activities organised by the Association of Young Researchers in Heritage Science Slovenia, Heri Sci. In the first phase, the project brought together mentors and students from 3 faculties (Faculty of Chemistry and Chemical Technology, Biotechnical Faculty, Faculty of Arts). Using complementary methods, we investigated the effects of environmental changes on archaeological wood, which can only be preserved under anaerobic conditions. Such conditions exist in peatlands, including in the Ljubljana Marsh area. However, intense temperature fluctuations and extreme droughts tend to affect the groundwater levels, leading to the transition from anaerobic to aerobic conditions. This affects the organic residues, which begin to decompose more quickly. An important indicator of decomposition is therefore the moisture ratio of the soil environment and the buried wood itself.

Figure 1: *Archaeological and modern wood samples with moisture sensor attached.*

First step in the research included soil assessment in a test field, located on the premises of Department for Wood Science. Soil augering was combined with morphological descriptions of individual soil horizons, to identify those with similar physio-chemical properties to the soil horizons in the Ljubljana Marsh area. Next, humidity sensors were installed on the samples of archaeological wood from the Ljubljana Marsh pile-dwellings. A test trench was then excavated. Samples of archaeological and analogue modern wood were buried at various depths in pedological horizons II, III and V. Using sensors attached to the samples which were inserted into the correlated soil horizons, we collected moisture and temperature data. The first data set was obtained from 13.6. to 28.8.2024. The measurements showed that climatic conditions have a strong influence on the level of wood moisture. There was also a noticeable difference in the wood species as the ability to retain water is higher in oak than in fraxinus wood. In this project, we have taken a step towards developing a methodology for monitoring of archaeological wood in real time and thus contributed to the discussion on the development of new approaches for conservation of palafitte sites. For more information you can follow the project on IG.

LECTURES 2

Utilizing Machine Learning and IR Spectroscopy to Reveal the Age of Historic Archival Materials
Dr. Hend Mahgoub, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Heritage Laboratory, Ljubljana, Slovenia

ToF-SIMS for Ink Differentiation
Prof. Dr. Matjaž Finšgar, University of Maribor, Faculty of Chemistry and Chemical Engineering, Maribor, Slovenia

Multiscale Approaches to Studying Human and Animal Skeletal Remains: Integrating Macroscopic, Microscopic, Isotopic, and Spectroscopic Analyses for Bioarchaeological Insights and Heritage Protection Management
Dr. Tamara Leskovar, University of Ljubljana, Faculty of Arts, Department of Archaeology, Centre for Interdisciplinary Research in Archaeology (CIRA), Ljubljana, Slovenia

Recent investigations by proton-beam induced spectroscopies
Dr. Žiga Šmit, University of Ljubljana, Faculty of Mathematics and Physics, Ljubljana, Slovenia

Non-destructive 3D and 4D X-ray imaging techniques for Heritage Science
Dr. Lucia Mancini, ZAG - Slovenian National Building and Civil Engineering Institute, Ljubljana, Slovenia

Utilizing Machine Learning and IR Spectroscopy to Reveal the Age of Historic Archival Materials

Hend Mahgoub [1]*, Patrick Layton [2], Sonja Svoljšak [3], Jasna Malešič [3], Nataša Golob [4], Maria Theisen[5], Johannes Tintner-Olifiers [2], Strlič Matija[1]

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Machine learning and IR spectroscopy are now regarded as crucial pillars in the analysis of cultural heritage materials, especially archival documents. This provides advanced, non-invasive methods for the determination of age, composition, and preservation status. The application of machine learning in this field is rapidly expanding, offering new interpretation and insights for understanding and preserving artifacts. By analysing complex datasets—including chemical compositions, spectral data, and images—researchers can identify materials, authenticate artifacts, detect degradation, and most importantly, predict the age of historical objects more effectively than traditional methods. Similarly, Infrared (IR) spectroscopic techniques, particularly Fourier Transform Infrared (FTIR) and Near-Infrared (NIR) spectroscopy, are widely employed for analysing historical materials due to their non-destructive nature and ability to yield detailed molecular information. Both techniques utilize the absorption of infrared light at specific wavelengths, generating spectral fingerprints that reveal the composition and condition of artifacts, which is critical for preservation and restoration efforts. Building on that and as part of the Austrian/Slovenian project Ancient Book Craft (ABC, 2022-2025, N1-0271) focuses on integrating IR spectroscopy and machine learning, supported by historical and codicological analysis, to develop robust methods for dating archival materials from the Medieval era. This project investigates various IR techniques (FTIR-ATR, FTIR-ER, NIR) alongside machine learning methods to assess their effectiveness in reflecting the age of historical paper using a well-dated dataset of 100 paper objects from the National and University Library (NUK) in Slovenia. The study will also explore the impact of storage environments, material types, and spectroscopic approaches on the transferability and accuracy of the developed dating methods. The ABC project is funded through the WEAVE program in collaboration with FWF (Austria) and ARRS (Slovenia). This research is underpinned by the Research Programme Group N-DAD.

Figure 1: *Calibration Methodology*

ToF-SIMS for Ink Differentiation

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This study highlights the application of time-of-flight secondary ion mass spectrometry (ToF-SIMS) to distinguish between blue inks. ToF-SIMS was employed to obtain detailed chemical profiles from the surface of blue inks, allowing for the identification of elemental and molecular fragments unique to each ink. Data collected from ToF-SIMS were further analysed using multivariate statistical methods, including principal component analysis (PCA) and multivariate curve resolution (MCR), which enabled clear differentiation between the inks.The technique's ability to resolve complex mixtures of ink components without damaging the sample makes it particularly useful for various non-destructive investigations. PCA efficiently reduced the complexity of ToF-SIMS spectra, while MCR provided chemically intuitive analysis by identifying distinct components associated with each ink. This combination of ToF-SIMS and advanced statistical methods demonstrates a practical approach to ink differentiation, with potential applications in fields requiring material identification and characterization.

Multiscale Approaches to Studying Human and Animal Skeletal Remains: Integrating Macroscopic, Microscopic, Isotopic, and Spectroscopic Analyses for Bioarchaeological Insights and Heritage Protection Management

Leskovar Tamara [1*], Christophe Snoeck [2], Carina T. Gerritzen [2], Doris Potočnik [3], Nives Ogrinc[3], Irena Zupanič Pajnič [4], Ivan Jerman [5], Borut Toškan [6], Lidija Korat Bensa [7], Steven Goderi [2], Črešnar Matija[1]

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We study human skeletal remains from archaeological contexts using multiple analytical scales and methods to enhance our understanding of past populations, with a focus on bioarchaeological insights as well as protection and management of these utterly important but fragile bearers of information from the past. Macroscopic analyses help establish biological profiles, demography, and burial practices, while microscopic analyses (e.g., bone histology) and spectroscopy provide additional details, such as age at death and preservation state, which are essential for subsequent isotopic and molecular analyses like ancient DNA (aDNA). Isotopic analyses (C, N, S, O, Sr …) are used to study nutrition, health and mobility, offering insights into dietary habits and migration patterns.We illustrate this approach by investigating diet, mobility, and economy of a prehistoric population of Brinjeva gora above Zreče (Slovenia), incorporating the relatively new and complex sulphur isotope analysis. Although methodologically similar to carbon and nitrogen analysis, sulphur presents challenges due to its dual role in indicating both dietary habits and migration, raising questions about its precise interpretation (CRIME project).The significance of skeletal preservation is further demonstrated by our studies combining ATR-FTIR spectroscopy with DNA preservation assessments. Given the impact of taphonomic processes on bone and teeth, their preservation state is crucial for successful aDNA analysis. Our research evaluates the use of ATR-FTIR spectroscopy as a fast, cost-effective pre-screening tool for assessing the preservation state of skeletal remains and their potential for successful DNA analysis (collaboration with Faculty of Medicine UL and Chemical Institute of Slovenia).By integrating diverse analytical methods, our aim is to provide a comprehensive approach to studying skeletal remains, thereby contributing to our understanding of ancient demography, dietary practices, the preservation of bioarchaeological heritage materials, and their effective protection and management, possibly including their non-invasive analyses, which are being explored (NextGenHS project).

Recent Investigations by Proton-Beam Induced Spectroscopies

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In-air proton beam of the Tandetron accelerator of the Jožef Stefan Institute in Ljubljana is equipped with X-ray and gamma ray detectors for the analytical methods of PIXE and PIGE. Proton beam in the air allows for easy handling of sensitive objects of cultural heritage, notably metals and archaeological glass. A small proton beam is also convenient for a brief identification of unknown materials. Recent investigations of metals involve studies of Early Iron Age bronzes from a new depot find and studies in numismatics. The former is part of a larger ongoing study, where bronzes will be analysed with XRF, PIXE and ICP-MS and results compared, and the latter involve a comprehensive study of bronze and brass coins in Asia minor issued by the emperor Mithridates VI and a casual study of Hungarian silver coinage issued since the first king until the Mongolian invasion. Studies of the glass involve a small study of the earliest glass beads in Slovenia, and two studies of glass during the early medieval period. Two sites were involved in collaboration with other researchers and include finds from Koper in Slovenia and Braničevo in Serbia. This historic period is interesting for the changes in glass technology and for the corresponding response in glass supply, recycling and consumption.From the technical aspect, the beamline is constantly upgraded with improved mechanical solutions and software development for deconvolution of the measured spectra.

Figure 1: *In-air beamline end station.*

Non-Destructive 3D and 4D X-Ray Imaging Techniques for Heritage Science

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World-wide cultural and natural heritage collections are very rich and diverse in their materials and provenance. These objects keep precious information about our history and evolution. The Slovenian National Building and Civil Engineering Institute (ZAG), in collaboration with other research institutes and museums, is using advanced technologies to investigate, both virtually and physically, such precious materials exploring the most suited strategies to preserve and valorise these finds. The aim of this talk is to present the possibilities of X-ray and neutron imaging techniques and related software tools for the non-destructive analysis of rare or unique artefacts. More specifically, the potential and importance of three-dimensional (3D) and 4D (3D + time) X-ray computed microtomography techniques in the field of heritage science will be presented through several applications and successful stories. The adoption of a multiscale and multimodal imaging approach complemented by additive manufacturing and advanced visualization tools will be illustrated as a high-accuracy method to improve accessibility to museums and heritage science as well as for the integrative restoration of samples.

Figure 1: *Banner of the LINXS Heritage Science Theme, https://www.linxs.se/heritage-science.*

POSTER SECTION

Mladi Strokovnjaki za Dediščinsko Znanost Slovenije: Herisci Young Professionals in Heritage Science Slovenia

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This year, a group of like-minded individuals established the Association of Young Professionals in Heritage Science Slovenia (Mladi strokovnjaki za dediščinsko znanost Slovenije – Heri Sci). Heri Sci seeks to connect young researchers across various disciplines and institutions, facilitating innovative interdisciplinary projects that leverage diverse yet complementary methodologies and perspectives. By doing so, we aim to develop integrated solutions to the pressing challenges in heritage research, contributing to the further recognition of Heritage Science and its identity as a distinct academic discipline.The association advocates for stronger cooperation among young researchers and established organizations and institutes, both domestically and internationally; fostering a collaborative environment for idea exchange and partnership building. On this basis, we've been honoured to be recognized as a subject of merit when the Slovenian node of the European Research Infrastructure in Heritage Science accepted our proposal for collaboration. They have supported our activities with scientific and material assistance. Moreover, the association is committed to raising public and academic awareness of heritage science's vital role in understanding and sustainably managing cultural heritage. We strive to spark interest among youth and the public, emphasizing the significance of heritage science field. For this reason, we have started a project to document the wall paintings in the Gothic church of St Anthony in Šepulje, Slovenia. The Nova Gorica department of the Institute for the Protection of Cultural Heritage of Slovenia has offered us its scientific support, and we expect to be able to further expand our research activities in 2025.Sustainability is a core principle of Heri Sci. We aim to explore the role of cultural heritage within the sustainable development agenda by conducting research that reflects and actively uses cultural heritage as a primary resource for green innovations. We've collaborated on a University of Ljubljana-sponsored project, BarCh-Wood, in which we aimed to identify the impact of climate change on the deterioration of archaeological wood in palafitte sites. The experiment was developed and is still ongoing at the premises of the Department of Wood Science of University of Ljubljana.Additionally, the association aims to enhance access to research funding for young heritage researchers by keeping members informed about available resources and providing training on successful grant applications. We also intend to establish networks with foreign and international associations. We've already hosted an event under the auspices of the European Association for Students and Young Professionals in Cultural Heritage (ESACH). Through these efforts, the Association of Young Professionals in Heritage Science aspires to create a vibrant, engaged community that advances the field of heritage science in Slovenia and beyond. We most warmly welcome students and early-stage researchers interested in heritage research to join us. For more information, you can follow us on IG @heriscislo.

Figure 1: *Herisci logotype*

Evaluating the Impact of Packaging Volatile Organic Compounds Emissions on the Degradation of Historic Paper Collections in Glams (Galleries, Libraries, Archives and Museums)

Randa Deraz [1]*, Fabiana Di Gianvincenzo [1], Manfred Anders [2], Katharina Schuhmann[2], Jasna Malešič [3], Irena Kralj Cigić [1], Abdelrazek Elnaggar [1], Matija Strlič [1,4]

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Volatile Organic Compounds (VOCs) emitted from packaging materials used to store historic paper collections in GLAMs may pose a threat to the preservation of cultural heritage [1]. Packaging materials like virgin cellulose, plastics-based, and naturally aged cardboard release VOCs that may accelerate historic paper degradation and reduce its degree of polymerization (DP), indicating chemical instability [2]. This study aims to evaluate the VOC emission rates and impact of different types of packaging materials from different suppliers in comparison with the industry standard, i.e. DIN ISO 16245 Type A and DIN 9706. Two sampling approaches were used to qualitatively assess emissions from packaging material: SPME and Tenax® TA sorbent tubes, followed by GC-MS analysis. Acetic and formic acid emissions from the sampled archive materials were also quantified using ion chromatography. A modified Oddy test protocol [3] was used to assess the impact of emissions from the tested packaging boxes, on archival paper collections. Preliminary results show that VOC emissions from naturally aged acidic cardboard materials interact with cellulose and cause a measurable decrease in DP (Fig. 1), especially when acetic and formic acid are present. While VOCs emissions are higher for polypropylene-based boxes (PP) than for cardboard materials, PP showed a preserving effect on cellulose chain degradation in the modified Oddy test results (as in the state-of-the-art cellulose corrugated board sample EB). However, recycled polypropylene has higher VOCs emissions with a slightly higher acetic acid emission and a moderately negative effect on cellulose chain degradation. These findings recommend boxes from virgin or post-industrial-recycling polypropylene (PIR-PP) as the most promising solution to mitigate the degradation of historic paper collections. Further research will include more quantitative analysis, standardization, and assessment of the shelf-life of the boxes. This research was funded by the European Union through the GREENART project (Horizon Europe research and innovation program, grant agreement no. 101060941), and supported by the programme group 'N-DAD: Non-destructive Analysis and Diagnostics'.

Effect	%
Preservation	>105
Neutral	95 - 105
Moderate	75 - 95
Significant	55 - 75
Severe	<55

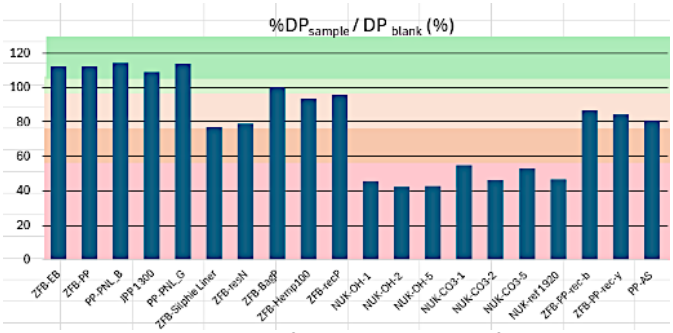

Figure 1: *Percent ratio of the DP measured for the sample over the DP of the control blank with evaluation ranges, as*

Heritage Science in HUN-REN ATOMKI

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Heritage science has a long tradition in HUN-REN Institute for Nuclear Research (ATOMKI). Its infrastructure and expertise in material characterization and carbon dating are used for a thorough investigation of art and archaeological objects. In the Laboratory for Heritage Science, a world-class, complex instrument park is created which enables more complex examinations in a wide range of scales.An ion-beam analytical set-up, installed at the beamlines of the ATOMKI Tandetron accelerator, serves to determine the concentration and distribution of elements both in vacuum and in-air (for larger or sensitive artefacts) with high lateral resolution. Objects which contain organic and inorganic carbonaceous materials can be subjected to dating using the C-14 method. By measuring stable isotopes, we can obtain information on feeding habits, environmental factors or migratory processes. Microfossil analysis of human and animal dental calculus remains can also help us to clarify the history of food and plant cultivation. The Laboratory for Heritage Science was established in 2017 for the examination of objects of cultural and natural heritage within the framework of domestic and international collaborations. Complementary to the accelerator based ion beam analytical system, additional instruments were installed, so the infrastructure of the laboratory consists of further analytical and imaging portfolio: 3D digital microscope, micro-XRF, scanning electron microscope - which can operate with variable pressure so it is suitable for the investigation of vacuum-sensitive or non-conductive samples, too – and Raman microscope configuration which can be used within the SEM chamber (see on the Figure 1).In addition to joint research with our partners, we carry out methodological research, including optimising measurements and data evaluation for the groups of materials we study, reducing the limit of detection, increasing accuracy, exploring new areas, and, very importantly in this field, defining the safe limits of materials testing methods.

Figure 1: *the instrumentation of the Laboratory for Heritage Science. From left to right: 3D digital microscope, micro-XRF, scanning electron microscope - Raman microscope configuration.*

Acknowledgment: *The laboratory was supported by the GINOP-2.3.3-15-2016-00029 'HSLab' project.*

SloveNile: Egyptian-Slovenian Heritage Science Platform

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SloveNile[1] is a Slovenian- Egyptian Heritage Science Platform seeking to become a benchmark for the GUILD[2] network through heritage science research, training, education and exchange, with Egypt as a strategic partner. This is based on recent and current intensive collaboration: in 2023, a colloquium[3] on heritage science cooperation between Egypt and Slovenia was organised. The meeting brought together experts and professionals from different backgrounds from several academic and professional cultural heritage institutions to discuss the scientific and research content of the Platform proposal and of further joint research projects. The challenges that were identified as urgent needs that SloveNile will address are: **(1)** the development of sustainability analysis tools based on the nine principles of green heritage science[4]; **(2)** the development of new scientific tools, methods and expertise for the study of Egyptian heritage in Slovenia and Egypt; **(3)** to build expertise and academic strengths for the development of new academic programs[5]; **(4)** to develop the role of integrated research infrastructures, such as the Slovenian node of the European Research Infrastructures for Heritage Science (E-RIHS Si)[6] and its Egyptian counterpart, in EU funded projects and new academic programs. The purposes of the project are to: **1) enable** the formulation of interdisciplinary scientific research contents in the field of heritage science; **2) form** research proposals by organising internal and external workshops, as well as conducting fundamental research involving young researchers; **3) create the** necessary basis for joint master programmes by organising meetings on topics such as (i) heritage sustainability, (ii) management of research infrastructure; **4) develop** a permanent platform[7] of joint Slovenian-Egyptian actions in heritage science connecting the members with national and international stakeholders from Slovenia and Egypt as well as globally.

[1] https://hslab.fkkt.uni-lj.si/2024/09/26/slovenile/
[2] https://www.the-guild.eu/news/2016/the-guild-welcomes-the-university-of-ljubljana.html
[3] https://plus.cobiss.net/cobiss/si/en/bib/159008515. Accessed: 20/04/2024.
[4] Elnaggar A. Nine principles of green heritage science: life cycle assessment as a tool enabling green transformation Heritage Science (2024) 12:7. https://doi.org/10.1186/s40494-023-01114-z . Accessed: 20/04/2024.
[5] https://hslab.fkkt.uni-lj.si/2023/02/20/hsll-visit-to-ain-shams-university-egypt/. Accessed: 20/04/2024.
[6] https://www.e-rihs.si/
[7] https://www.e-rihs.si/slovenile/

pH-Dependent Silk Yellowing During Accelerated Degradation

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This study investigated the effect of pH on the degradation of silk fabric during accelerated degradation. Silk samples were treated with phosphate buffers at pH 2, 4.5, 6, and 8, and compared with an unbuffered control. The specimens were subjected to accelerated degradation at 80 °C and 60% relative humidity for up to 10 weeks. The degradation process was monitored by measuring pH and colour, specifically focusing on the CIE Lab b* value. pH measurements were taken to monitor the stability of the material pH over time. Colorimetric analysis provided insights into the visual changes occurring in the fabric, with increasing b values indicating progressive yellowing.

The results demonstrate that all samples, regardless of pH, evidenced some degree of degradation over time. The pH 2 buffer maintained the most stable pH throughout the experiment but led to the most severe yellowing. Conversely, samples treated with pH 6 and pH 8 buffers showed more moderate colour changes despite experiencing greater pH change.A notable finding was the non-linear relationship between pH and yellowing, suggesting a complex degradation mechanism. The unbuffered control sample, starting at a near-neutral pH of 6.85, exhibited an initially higher b value 6.74 compared to the buffered samples, indicating that buffer treatments may provide some initial protection against yellowing.The study revealed that the degradation rates were highest in the early weeks of exposure. Furthermore, the decrease of pH over time suggests the formation of acids in silk over time under all conditions. These findings contribute to our understanding of silk degradation mechanisms and have implications for conservation practices. While buffering can influence the degradation process, factors such as temperature, relative humidity, and the initial condition of the silk are crucial for effective preservation. Comprehensive conservation strategies that consider multiple factors are necessary to protect silk artifacts effectively.

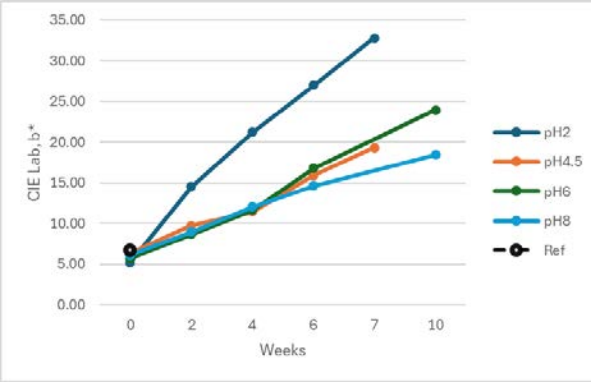

Figure 1: *The influence of accelerated degradation on buffered silk yellowing (CIE Lab, b* values)*

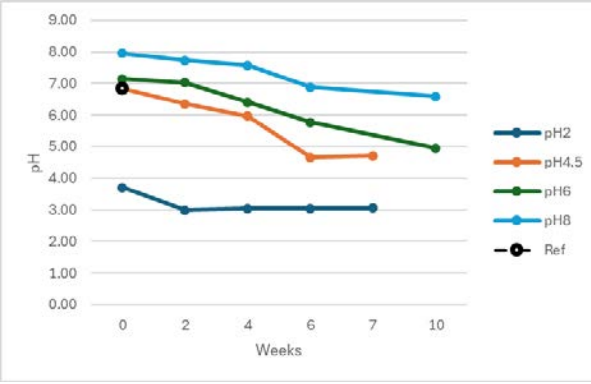

Figure 2: *The influence of accelerated degradation on buffered silk pH values*

Acknowledgements: *Funding through the SAFESILK project (N1-250, FWO (The Research Foundation – Flanders) and ARIS (Slovenian Research and Innovation Agency), N-DAD Programme group and I0-012 E-RIHS.SI (both ARIS) is acknowledged.*

ZAG and the New European Bauhaus

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The Slovenian National Building and Civil Engineering Institute (ZAG) became a full member of the New European Bauhaus (NEB) community in 2024, as this program combines innovation, ambition and creativity, which are also the strategic values and mission of ZAG. Since one of the main domains of ZAG is in the built environment, which also includes cultural heritage, even before entering the NEB community, it gained experience in innovative low-carbon and sustainable materials, such lime-gypsum binders with the addition of bio – based components (straw) or the recycling of historic roof concrete tiles, for the needs of renovation of cultural heritage buildings. Fire resistance tests are also carried out in the ZAG laboratory. These tests are important indicators of the fire resistance of materials found in cultural heritage buildings in the lime mortar system with bio-based components and wooden constructionBy involving the craftsmen and the local community, ZAG experts successfully transfer knowledge to the daily practice, in such a way that new materials are applied in the most authentic way and sustainably preserves the heritage even after its renovation. In the context of NEB's values, ZAG transfers its knowledge and experience also to the higher education environment, where it cooperates with its experts in educating professors, students, artists and other cultural workers on how to revive degraded spaces with heritage potential with the help of science and art and the use of 3D technologies.

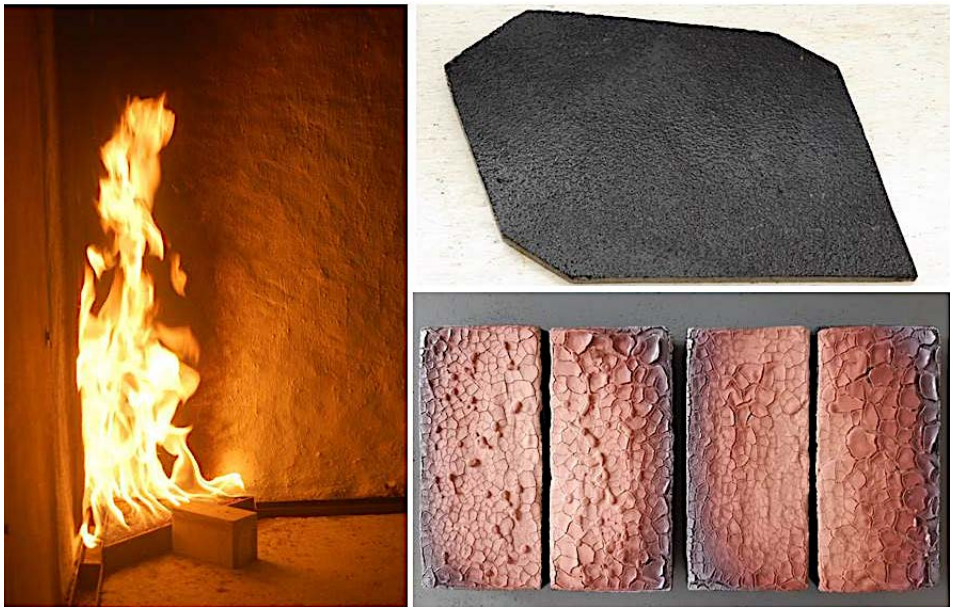

Figure 1: *Fire resistance test of bio-based lime mortars, recycled concrete roof tile and sitarjevc pigment glazes*

Conservation and Research Hand in Hand - St. Mary´s Column from Radlje ob Dravi (Case Study)

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The severely damaged calcareous stone (biofilm, black crusts, missing parts, pulverisation, cracks,...), made the conservation of the St. Mary´s Column an challenging intervention. The aim of all the research was to determine the material composition, assess the degradation and find a suitable cleaning process and consolidation methods. The statue of St. Mary was examined using an USB microscope and portable UV camera, which indicated the necessity for a detailed analysis of specific areas. Research have shown that the monument was once painted with white lime paint, but it could not be confirmed for sure whether the paint was original. Raman identified gypsum and calcite in the white sample and soot in the upper grey patina layer. The UV camera indicated the presence of remains of the gilding on the crown of St. Mary, which was also consistent with archival written sources. The cleaning process was extremely demanding. Preliminary chemical cleaning tests and analytical diagnostics (invasive and non-invasive), using Raman, FTIR and X-ray fluorescence spectroscopy, optical and fluorescence microscopy, as well as microbiological analyses were carried out in order to better understand cleaning issues. Due to results of cleaning tests (aqueous systems and ionic exchange resins), and detection of scytonemin (a secondary metabolite and a pigment synthesised by many strains of cyanobacteria), it was concluded that biological/organic matter incorporated within the calcium carbonate is the most likely problem of the black appearance of stone's surface on parts constantly exposed to weather conditions, while on the less exposed parts conversion of calcium carbonate to calcium sulphate with incorporated impurities is the probable cause. Hence, different cleaning techniques were employed in conservation treatment. The monument was cleaned using a combination of water vapour, ion exchange resins and cellulose clay poultices. Prior to conservation, three calcite forming consolidants were tested by sponge water absorption test, surface hardness measurement, DRMS and colorimetry, of which *Consolidation formulation water* proved to be the most appropriate for this monument and has been used to consolidate the fragile parts of the statues. Missing parts of the base were replaced with natural stone, while any damage to the statues was filled in with NHL replacement mortar.

Figure 1: *St. Mary´s Column before conservation.*

Figure 2: *St. Mary´s Column after conservation.*

Semantically Enriched Geodata for Improved Documentation of Wall Art: Sgraffito in the Entrance Hall of the Alpine Sanatorium at Slivniško Pohorje, Slovenia

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A significant portion of exterior wall artwork is situated on perimeter walls, currently undergoing intensive treatment to enhance energy performance. Despite exemptions granted, monument-listed buildings should maintain comparable standards regarding the built environment and energy efficiency as unprotected structures. Innovative solutions are crucial to encourage owners' interest in maintaining, conserving, and restoring wall art, preventing irreversible damage. According to the 2021 Slovene Building Act, project documentation must be produced using BIM (Building Information Modeling). Digital information on wall art must be kept in conjunction with the building where it is displayed. Sgraffito is primarily integrated into the building due to its embedding in masonry. To address the lack of information about historical buildings, reality capturing techniques such as laser scanning and photogrammetry are employed. These methods gather additional information related to the building's visual appearance and geometry.Captured data requires high accuracy preparation with suitable geo-point density based on relief ruggedness and sgraffito size. Sufficient density allows analysis using scalar fields functions, creating a visual representation of point relations. Measured and analysed points can then be semantically enriched with collected information such as micro-sampling and microclimate data. Semantically enriched data can be utilized throughout documentation, elaboration, research stages, and can be updated with future findings and changes.It's essential to establish a workflow like generating a BIM-based model on cultural heritage guidelines and required information for every step in the process. Once points in the point cloud are enriched with gathered data, focus shifts to finding intersections with the building where it's exhibited and selecting the most crucial for understanding position, materiality, or visual presence.

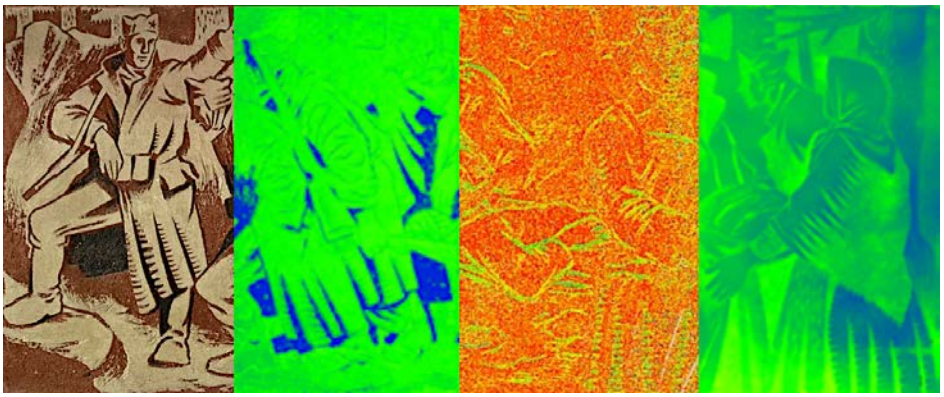

Figure 1: *Janez and Ida Vidic, Sgrafitto in the entrance hall of the alpine sanatorium, Slivniško Pohorje, Slovenia, 1949-1955*

The Scents of Emona

Barbara Pia Jenič [1]

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Is it possible to unite science and art in an interdisciplinary project?
The multi-sensory performance of the Senzorium zavod Slovenia in 2014 offered visitors an immersive experience that brought them closer to the everyday life of Roman Emona. In line with the principles of the sensorial language, this performance conveyed its images and messages by engaging and stimulating the audience's senses. Smells play an important role in the performance, as they act as a time machine and, in combination with the soundscape, convey the spirit and atmosphere of the time. The fragrant and soothing sensations are accompanied by the words of ancient authors such as Seneca, Horace, Petronius, Ovid and one of the few Roman poets Sulpicia, which both seduce and provide a deeper insight into Roman Emona.“Despite the many feature films and documentaries about the Roman era, this was the first time we really experienced Roman life”, as some of the visitors remarked. In today's world, where the need for immersive events, especially in museums, is growing, there is no need to start from scratch. There have long been tried and tested tools for conveying content to visitors with all their senses in an immersive, experience-orientated and playful way.

Figure 1: *Roman Emona, an immersive, multi-sensory schooling experience (Photo: Sunčan Stone)*

Heritage Science Research of the Western Façade Wall Paintings of the Church of the Annunciation of Mary in Crngrob, Slovenia

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This study focuses on two medieval wall paintings bearing valuable cultural significance – *The Passion Cycle* and *The Holy Sunday*, decorating the western façade of the Church of the Annunciation of Mary in Crngrob near Škofja Loka, Slovenia. Investigation of paintings' material composition, their technical features, historical modifications and deterioration processes was carried out due to their accelerated degradation and need for conservation. Over 40 samples of paint layers and renders were analysed as thin-section, cross-section and/or in their crude state by different diagnostic techniques such as optical microscopy, scanning electron microscopy with energy-dispersive X-ray spectroscopy, and Raman and infrared spectroscopy. In addition, the paintings were investigated non-invasively, on site, by means of portable equipment rendering Raman, infrared and X-ray fluorescence (XRF) spectroscopy analyses. The study conducted thus far showed dolomitic lime was used as a binder for renders with predominant silicate aggregate. Similar binder was identified in paint layers, while no organic compounds indicating *secco* painting techniques were detected as yet. Microscopic analyses show possible use of different painting techniques, e.g. lime painting technique, possibly on a fresh smoothed plaster and/or a fresh lime wash. Pigments typical for medieval wall paintings, such as red and yellow ochres, green earth, lime white and azurite were detected in paint layers. Severe transformation of calcium carbonate into calcium sulphate was determined on the surface of all analysed locations and samples taken. Different material compositions of the 20th Century additions (e.g. retouches) were defined as well, indicating more than one restoration treatment took place in the past. This study will benefit future conservation-restoration treatment and provide new insights into the technical art history research of wall paintings in Slovenia. The research is part of the project *An integrated approach for conservation of cultural heritage wall paintings* (J2-4424), funded by Slovenian Research and Innovation Agency (ARIS).

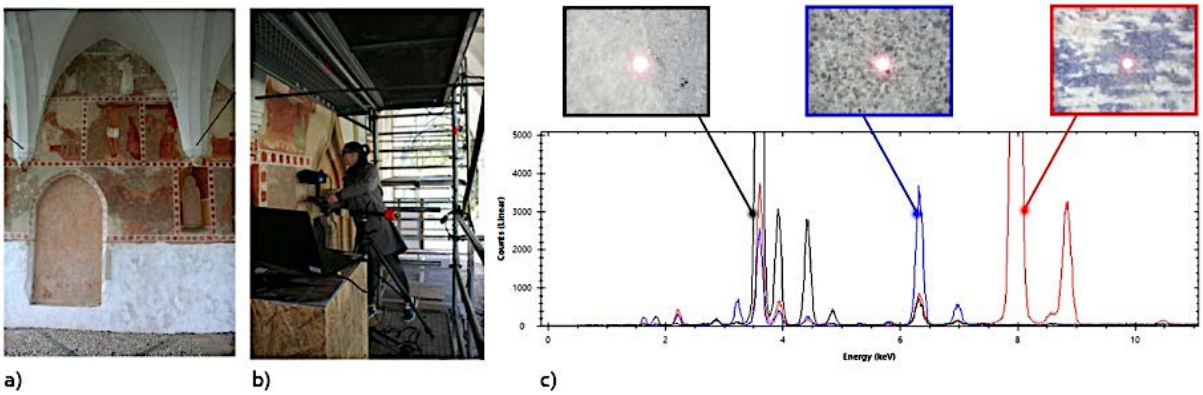

Figure 1: a) *Detail of The Passion Cycle wall painting.* ***b)*** *During XRF analyses on The Passion Cycle.* ***c)*** *Snapshot of XRF spectra measured at different locations of wall paintings. (Photo: M. Kavčič)*

Stucco Marble Altars in Slovenia: Materials Investigation

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Building Baroque altarpieces was usually a complex process, where architects, joiners, sculptors, painters, and plasterers worked together to achieve a result that would suit the commission. Stucco marble is a special technique to decorate different surfaces, mainly altars and walls imitating appearance of stone, however with cheaper materials. Only little is known about the technologies of the 17th and 18th centuries (Baroque period) as rare craftsmen who practiced the technique then, withhold their expertise. In that time, it was also prohibited passing it on by law, which is why we still do not know all the secrets of stucco marble making in the Baroque period. The interdisciplinary project, connecting art historians, art restorers and material scientists, aims to reveal materials used by baroque artists on selected stucco marble altars in Slovenia, analyse their state of preservation and connect archive data with analyses results.Several altars have been so far analysed by non-invasive and invasive techniques. We identified inorganic as well as organic materials. The main inorganic material is gypsum, as expected, however different pigments and fillers have been added to achieve desired appearance and properties. Similar is true for organic additives: proteins were added to main mass, however also some other materials have been identified, especially different drying oils and wax. Knowledge about composition of stucco marble can help restorers to understand and preserve better the objects. Due to prohibitions in the past, it is also of interest for public. Project is financed by Slovene Research and Innovation Agency under the project number J7-50093.

Figure 1: *A detail of stucco marble decoration of a side altar in Ursuline Church of Holy Trinity in Ljubljana (photo: K. Kavkler).*

X-Ray Microtomography as an Imaging Tool in Heritage Science Studies

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Accessing an object's internal information in a non-destructive way has been an ongoing problem in many disciplines. Historically, several scientific fields afford serial slicing of specimens to investigate their inner structure (e.g. biology, geology). However, this is not always possible for unique or rare objects in heritage science [1]. X-ray computed microtomography is a powerful imaging technique that is widely in use today to characterize all sorts of objects, regardless of the scientific field. The application of modern, non-destructive techniques in testing and/or analysing works of art and museum objects is of great importance and almost essential for conservators, restorers, and archaeologists. Herein, we present a non-destructive assessment technique, namely X-ray microCT scanning (µXCT), to analyse and evaluate historical artefacts before any destructive analysis is carried out on such objects. ZAG has been involved in providing crucial µXCT data for more than a decade, allowing researchers to unfold the hidden features of their samples, especially when the technique is needed for heavily degraded and often fragile objects. The case studies originate from Slovenian archaeological sites with different stages of preservation and the results present the multidisciplinary investigation between different institutions. Using µXCT has revealed information about several historic developments, such as the production techniques of archaeological ceramics; understanding the manufacture and restoration of sculptures; visualizing layers of paintings that were painted over; identifying the model, maker and component position of machines based on concealed data; and finding hidden inclusions without causing any damage. For museums, the technique also provides a digital copy of the artefact that can be shared across the world, facilitating dissemination and reducing potential damage to the original artefact by offering an alternative to the physical handling of the artefact.To conclude, tomography reveals hidden aspects of historical artefacts, offering high quality information that deepen our understanding and often raises new questions.

Figure 1: *X-ray microtomography EasyTOM XL Ultra from RX Solutions at ZAG.*

Acknowledgment: *The authors gratefully **acknowledge** the financial support of the Slovenian Research and Innovation Agency (research core funding No. P2-0273 and No. I0-0032).*

Microbiological Evaluation of the Spectatius Family Marble Tomb and of the Bronze Statue »Žanjica«

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Our objective was to identify microorganisms related to the formation of various deterioration symptoms occurring on the Spectatius family marble tomb, the largest monument of the Roman Necropolis in Šempeter, Slovenia; and on the bronze statue »Žanjica« sculpted by Zdenko Kalin in 1947 (Brdo pri Kranju, Slovenia). The characterisation methods were fluorescent microscopy, microbial cultivation and DNA sequencing (sequenced molecular markers were ITS1/4 for fungi and 27F/1492R for bacteria). On the marble tomb we were able to identify 21 fungal isolates, 16 being filamentous moulds, primarily dominated by xerophilic *Cladosporium* spp. (mainly *Cladosporium langeronii* RN 28) and some *Alternaria* species; and 5 yeast or yeast like species namely *Torula fici, Filobasidium wieringae, Rhodotorula babjevae* and *Blastobotrys peoriensis*. Locations on the tomb, which are well sheltered against rainfall, contained higher concentrations of xerophilic fungi to those, which are completely or partially exposed to rain. The black fungal species of *Cladosporium* spp. and *Alternaria* spp. formed the bulk of melanized-greyish patina present on the bottom reliefs and within the cracks of the inner dome of the Spectacius tomb. Moreover, the red coloured yeast *R. babjevae* caused a thick red pigmentation right under the top roof of the monument's left side. From the bronze statue biofilm only bacteria were isolated mainly the *Sphingomonas* spp. (*S. cynarae, S. melonis* and *S. ginsenosidivorax*). *Sphingomonas* spp. are known for their removal and uptake (as nutrients) of various heavy metals. Direct isolation of DNA from biofilm (without cultivation on agar media) revealed the bacteria *Novosphingobium umbonatum*, which is highly resistant to heavy metals through Atm1, an ATP-binding cassette protein that mediates active efflux of heavy metals conjugated to glutathione. Therefore, bacterial species isolated from the bronze statue »Žanjica« all exhibited a high degree of resistance to heavy metals such as bronze.

NextGenHS: Next Generation Analytical Tools for Heritage Science

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NextGenHS focuses on the development of new analytical methods and techniques for historic biomaterials, for the purpose of their better interpretation, management and conservation. This requires an interdisciplinary collaboration of analytical and material scientists, as a scientific interpretation of the results is not possible without a deep understanding of the structure and decay processes. As an analytical challenge, heritage biomaterials represent complexity on diverse scales:
(i) **Compositional complexity.** The vast majority of heritage biomaterials are either of natural origin (e.g. wood, bone) or represent processed natural materials (e.g. parchment, paper). As such, they reflect the natural composition of the tissues from which they have been made. (ii) **Structural complexity.** Many heritage objects are composite structures, either quasi-2D, such as layered decorated surfaces (e.g. paintings), or materials with a diverse 3D distribution of chemical and mechanical properties, e.g. wood or bone. (iii) Long periods of **degradation** under unknown conditions may have locally altered the composition and structure significantly and introduced further heterogeneity, with the analytical understanding of the environments representing a further challenge.

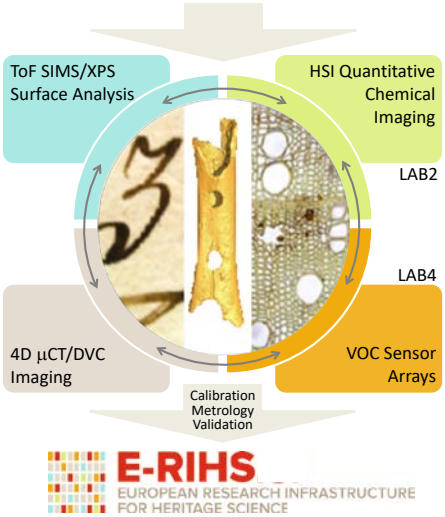

Figure 1: *Through interdisciplinary method development (involving the entire analytical pipeline from question framing, sampling, calibration, metrology, validation and interpretation), NextGenHS will develop four new analytical infrastructure facilities (LABs) offered for international access through E-RIHS.*

Acknowledgment: *NextGenHS is a large interdisciplinary basic research project funded by the Slovenian Research and Innovation Agency (only eight of these projects are financed each year). NextGenHS involves 39 researchers from different fields of expertise from 8 research institutions. One of the main motivations of the project is the development of methods to be included in the E-RIHS services.*

The Role of Oxalic Acid in the Acidification of Historical Paper

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The stability of paper strongly correlates with its pH value, since a low pH value increases the rate of cellulose hydrolysis. The type of sizing (e.g. alum-rosin sizing), raw materials used (e.g. groundwood) and the formation of acidic degradation products are the factors that strongly influence the paper pH. In our research, a collection of 89 naturally degraded samples of European paper produced between 1844 and 1990 (both lignin-containing and lignin-free) was analysed for low molecular weight organic acids. Also, a non-invasive Raman spectroscopic method with PLS regression was developed to determine the lignin content of historic paper.Oxalic acid was the compound determined in the highest concentrations, representing up to 79 % of the total molar content of all determined acids. Lactic, acetic, formic and succinic acids were the other determined compounds, all highly intercorrelated due to similar formation pathways.A MLR analysis of the pH and acids resulted in two linear relationship equations between the log(oxalic acid) and pH, for acidic and “neutral” samples (pH above 6.5) respectively. The strong influence of oxalic acid on pH can be explained with its properties: oxalic acid is a dicarboxylic acid with low pKa values and low volatility. PCA and Spearman rank correlation revealed that oxalic acid content is strongly correlated with the paper lignin content as well as the age of the sample. These results indicate that lignin inclusion is the main contributor of oxalic acid in paper and that the formed oxalic acid accumulates in the material. As such, oxalic acid is the main reason for paper acidification during natural degradation, contributing to the lowering of pH at a rate of about 0.008 unit per year (assuming other variables remain constant). These findings are of great importance to the paper conservation field.

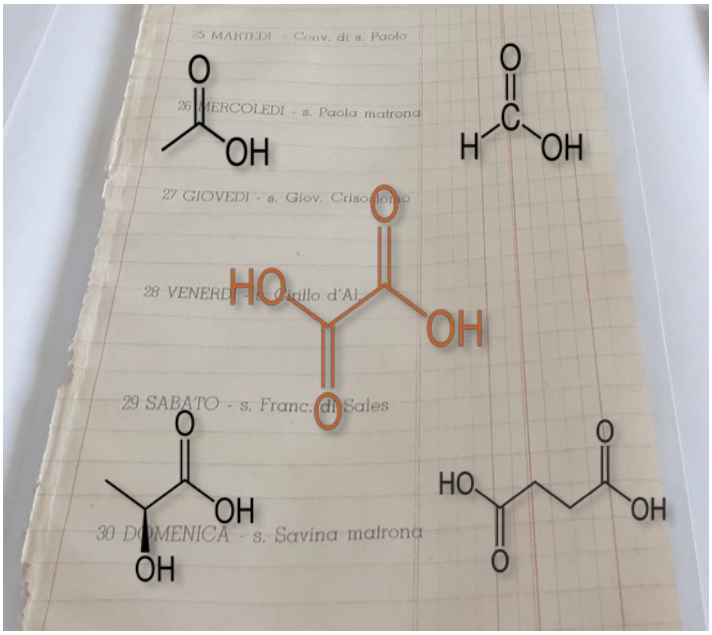

Figure 1: *The role of oxalic acid in the acidification of historical paper*

UNESCO Chair in Education and Interpretation to Promote Integrated Heritage Approaches - a Living Lab for Students and Teachers

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The Chair recognises that the key to sustainable heritage management lies in interpretation and education through integrated heritage approaches, as professional trends indicate the need for an inclusive approach to managing cultural and natural heritage. Its focus is on participatory and "values-based" approaches that can achieve integrated and sustainable management of natural and cultural heritage through community involvement. In terms of scientific disciplines, the Chair covers heritage studies, anthropology and cultural studies, archaeology, geography, history, intercultural studies, management and biology. It develops living laboratory activities involving students, schoolchildren and the local community through its study programmes in Cultural Heritage, Heritage Tourism and Sustainable Development Management and the management of the Simon's Bay Archaeological Park, its activities within the UP Science Centre and the Summer Schools. Within the framework of the renewed undergraduate programme in Cultural Heritage, which is taught in Slovenian and English, the Chair provides modern education in the field of heritage, including heritage science, science communication and heritage education, on an international level.

Uncovering the Material Composition of the Original Aljaž Turret: A Historical and Scientific Study

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The Aljaž Turret is Slovenia's highest cultural monument that stands atop Triglav at 2864 m. It was erected in 1895 by the priest and composer Jakob Aljaž to assert Slovene national identity and protect the mountain from foreign control. In September 2018, the turret was airlifted from the Mt. Triglav to the Institute for the Protection of Cultural Heritage of Slovenia for comprehensive restoration treatments. The cylindrical Aljaž Turret, made of galvanized metal panels on an iron frame, was originally white with a darker conical roof. It has been frequently repainted over the years, reflecting different historical periods. This study employed various invasive and non-invasive methods to investigate the numerous surface coatings of Aljaž Turret and identify their degradation products. The original coating was found to contain zinc white (ZnO) pigment and an oil binder. Later coatings primarily used alkyd or epoxy resin binders. Synthetic organic pigments and dyes from the 20th century, such as crystal violet (CV), pigment orange 5 (PO5), pigment green 7 (PG7), and pigment violet 23 (PV23), were identified using infrared (FTIR), Raman, and Surface-Enhanced Raman spectroscopy (SERS).The Aljaž Turret on Mt. Triglav is exposed to extreme weather and environmental conditions, which lead to significant degradation, especially corrosion. Raman and FTIR spectroscopy identified iron oxides (hematite, magnetite, lepidocrocite) in layers on the iron structure, cuprite (Cu2O) on the brass plate, and zinc hydroxycarbonate on galvanized sheet metal. Metal oxalates and carboxylates were also found in oil-based coatings. Aljaž Turret is one of the most recognizable Slovenian national symbols, therefore understanding its material composition and degradation products is crucial for its preservation and protection.

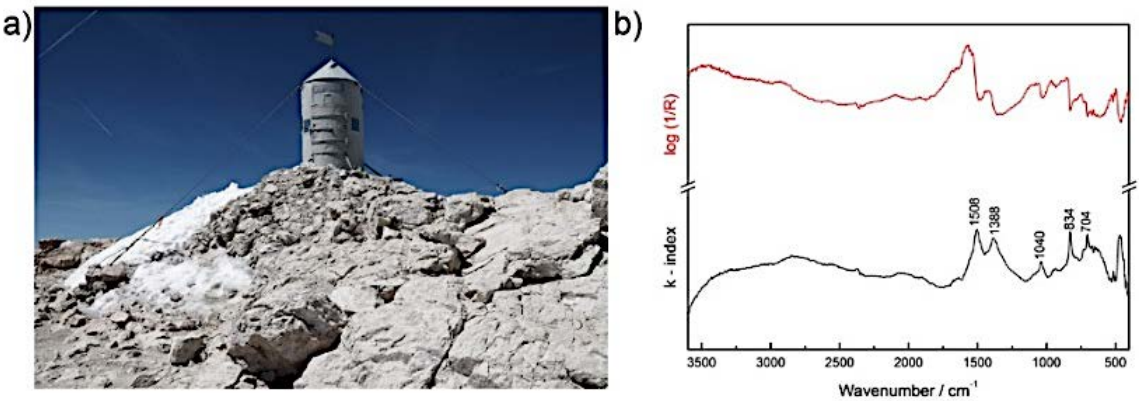

***Figure 1: a**) The Aljaž Turret before thorough restoration. (Photo: M. Kavčič, IPCHS) **b)** Reflection FTIR spectrum (red line) of zinc hydroxycarbonate compared with the k-index profile (black line) obtained using the KK operation of the total reflection spectrum.*

Acknowledgment: *Authors would like to thank the colleagues from Restoration Centre IPCHS and National Museum of Slovenia.*

Properties of Wood from the Sitarjevec Mine

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The mining tradition in Litija, dating back to the Iron Age, involved the intensive use of wood in the mines, especially for support and protection. The Sitarjevec mine was reopened for tourism in 2017, and the central tunnel was opened in 2021. Wood remains a key material in the mines, although other materials have replaced it in the past. We found that the microclimatic conditions in the mine are relatively constant, corresponding to the development of wood fungi. The high relative humidity and the acceptable temperature allow the fungi to grow. We detected a high concentration of spores in the mine air, mainly of fungi belonging to the genus *Penicillium* and *Fibroporia vaillantii*, the mine fungus. This fungus can cause wood decomposition and is expected in mines' humid environments. The presence of fungi is important as they can affect visitors to the mine. The high relative humidity (96.6%) and constant temperature (10.1°C) in the mine create favourable conditions for fungal growth, but the relatively low temperature is not a limiting factor for wood decomposition. The high concentration of fungal spores in the mine is explained by the presence of fungi in the mine itself. In addition, we have observed that the wood contains a high level of inorganic contaminants and many crystals.

Figure 1: *Mycelium of a mine fungus on wood at the Sitarjevec Mine (left) and Crystals recorded on the surface of wood from the Sitarjevec Mine*

An Example of e-RIHS Access: Evaluating Treatments Applied to Verdigris-Containing Mock-Up Paper Samples

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Mag. Christa Hofmann from the Austrian National Library, in collaboration with Dr. Ute Henniges from the Stuttgart State Academy of Art and Design, applied for the e-RIHS.si project. The goal of the project was to evaluate a proposed conservation treatment for copper green pigments on paper, intended for use on historic maps and atlases threatened by copper corrosion. The primary research question was whether treatments containing mixtures of antioxidants - specifically, tetrabutylammonium bromide (TBABr) and benzotriazole (BTA) in isopropanol, both of which had proven effective individually—could stabilize copper green pigments on paper. To address this, the project proposed measuring the degree of polymerization (DP) on mock-up samples. Paper samples containing Verdigris pigment (Figure) were prepared and sent by conservators who were also the project proposers. Historical rag paper, either unsized or sized, was used. Watercolour containing Verdigris pigment was applied to the paper samples by brush (either thick or thin application) or by print. The samples were then immersed in a solution of TBABr in isopropanol, and remoistenable tissue containing BTA was applied to the area containing Verdigris pigment, and vice versa. Samples were exposed to increased temperature and relative humidity. The average molecular mass of cellulose tricarbanilate derivatives (Mw) prepared from the paper samples was determined using size exclusion chromatography, and the DP was calculated from the Mw. The results indicate that the paper's sizing had the greatest impact on its stability. Application of Verdigris pigment and accelerated degradation caused a decrease in DP in sized paper samples by 11 to 26%, while it was significantly higher in unsized paper samples (48-69%). The differences between untreated and treated sized paper samples were not significant, meaning that the treatment did not affect their aging stability. In case of unsized paper samples, the highest degradation was measured for untreated samples and among them on thick application of Verdigris pigment which is likely due to higher content of copper ions catalysing oxidative degradation of cellulose. Between two different treatment techniques, the results of DP decrease were not statistically different. The project provided preliminary results suggesting that documents degrading due to Verdigris could benefit from treatments containing a combination of antioxidants. However, a significantly more in-depth study is required before the treatment can be applied to historical documents.

Figure 1: *Untreated, unaged reference sample (1, left) and aged paper samples with Verdigris pigment, either unsized (2, 3, 4) or sized (3, 4, 5), and either untreated (2, 5) or treated with a combination of antioxidants (3, 4, 6, 7).*

Imaging Techniques for Mapping Lignin in Historic Paper

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Lignin is a frequent constituent of historic paper, where it can affect the degradation of cellulose [1]. However, a clear correlation between the presence of lignin and cellulose degradation is still missing. In this study, we used two different imaging techniques to create a chemical map of lignin distribution in paper samples. Paper samples from real historical books [2] were used, which were subjected to further degradation in a climate chamber set at 90 °C and 30 % relative humidity for 18 days and at 80 °C and 65 % relative humidity for 36 days, respectively.Confocal Raman microscopy and FTIR spectroscopic imaging were used. Raman microscopy allowed for a sufficient magnification of the samples, allowing us to focus on a single fibre. However, sample fluorescence turned out to be too intense to obtain useful chemical images. FTIR spectroscopic imaging was used to create chemical maps of a whole cross-section and maps of both lignin distribution (spectral range from 1498 cm^{-1} to 1543 cm^{-1}) and the distribution of carbonyl and carboxyl groups (spectral range from 1700 cm^{-1} to 1750 cm^{-1}) [3] could be obtained. These maps demonstrate a correlation between lignin distribution and increased content of oxidised functions, although it is not possible to assign these specifically to cellulose. A comparison of the two maps shows that oxidation is present also in areas where lignin is scarce, indicating oxidation of cellulose (dashed line in the figure below). Areas with more lignin coincide with areas with the highest intensity of oxidation, which indicates oxidation of lignin itself (full lines in the figure below). The results show that even if oxidation of cellulose is (directly or indirectly) caused by lignin, such influence is not localised.

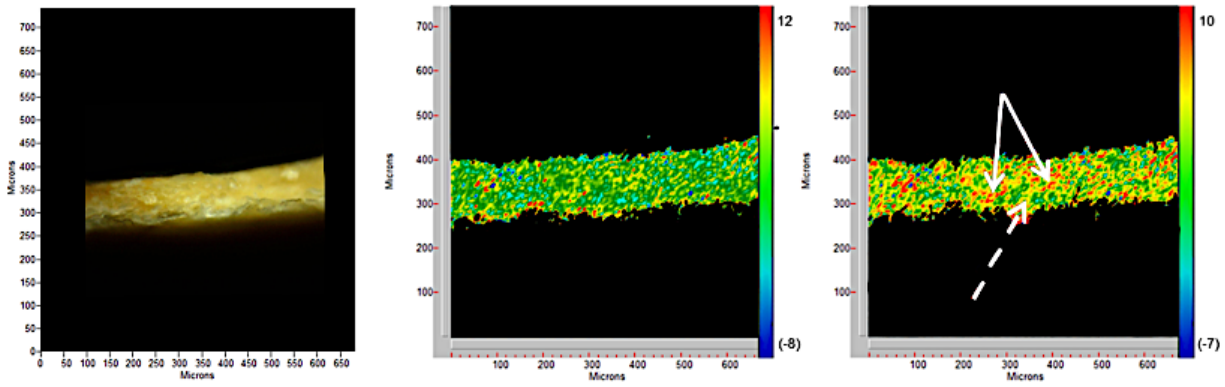

Figure 1: *Left: cross section of a sample photographed with visible light. Middle: chemical map of lignin distribution obtained using FTIR imaging (1498 cm^{-1} – 1543 cm^{-1}). Right: chemical map of oxidised groups distribution obtained using FTIR imaging (1700 cm^{-1} – 1750 cm^{-1}) – dashed line shows oxidation of cellulose, full lines show oxidation of lignin. Warmer colours indicate a larger signal area in the selected spectral range.*

A Multidisciplinary Approach Combining Sensory and Chemical Analysis to Characterise the Smell of Ancient Egyptian Mummified Bodies

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Mummification was practiced in Ancient Egypt where various balms, oils, and waxes were used to preserve the body and its organs. Nowadays, many mummified bodies is being excavated and stored, and most of the ones in museum collections have been treated. As a result, the presence of conservation products and/or pesticides is added to the presence of original materials such as oils and resins.This study explores a selection of nine Ancient Egyptian mummified bodies, dating from the New Kingdom to the Byzantine period. The work proposes an innovative multidisciplinary approach to study the volatile organic compounds (VOCs) emitted from ancient, mummified bodies by combining sensory analysis with evaluators, chemical analysis with thermal desorption-gas chromatography coupled with mass spectrometric and olfactory detection (TD-GC-MS-O), and microbiological investigation. The result is the different type and concentration of volatiles emitted by the mummified bodies stored in different areas of the museum, highlighting higher amounts and variety of volatiles for those stored in the display cases in the exhibition area. The main descriptors from sensory analysis are woody, spicy, and sweet in both environments. Volatiles were classified into categories based on their origin: the original mummification materials and their degradation, plant oils used for conservation treatments, synthetic pesticides, and microbiological deterioration. Although some compounds can be assigned to more than one group, as some oils used in the embalming process have recently also been used as insect repellents, this study demonstrates the possibility to classify the different compounds on the basis of chemical and olfactory analysis of the volatiles. The majority of the compounds identified with mass spectrometry were also identified with olfactory detector, allowing to determine the olfactory profile of each mummified body under investigation.

***Figure 1**: Sampling the headspace of the coffin with mummified body with calibrated pumps and sorbent tubes filled with Tenax TA® (left), and passively with SPME fibre (right).*

The Perceived Value of Museum Services: Conceptual Model

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This contribution introduces a conceptual model of perceived value applied to museum services. Perceived value is a fundamental concept in contemporary marketing, and it refers to the consumer's overall assessment of the benefits gained from a product or service relative to the costs incurred. It plays a key role in determining consumer satisfaction, loyalty, and behavioural intentions. In any case, consumers' perceptions account for what is tangible and intangible about their experience. We believe that museums can benefit from monitoring the perceived value of their services despite the general lack of research in this area. While museums often focus on improving visitor experiences, the multidimensionality of perceived value offers deeper insights into how visitors evaluate these experiences. The museum experience can be educational, culturally enriching, nostalgic, and pragmatic, thus offering the visitors various functional, emotional, and social benefits. However, it also requires more than just money for the visitors to receive all this. The cost of the museum experience also encompasses nonmonetary aspects, such as the time invested, the effort involved with investigating the exhibition, and the cognitive load of processing an extensive amount of information. Museums must acknowledge all these factors to create an impactful, memorable, and valued experience. This is paramount also when introducing new exhibitions or displays, and especially when these may invite new or uncommon sensory mediums. The proposed model specifically examines the impact of olfactory exhibits on the perceived value of museum visitors in Slovenia. By focusing on olfactory stimuli, the model aims to deepen our understanding of how sensory experiences influence consumer evaluations of museum services. It offers a novel marketing-oriented approach to enhancing relationships between museums and their target audiences.

PVCare: Advances in Understanding of Acidic Gas Emissions from Poly(vinyl chloride)

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Poly(vinyl chloride) (PVC) is not only one of the most commonly used polymers in everyday life, but also an important part of the history of the 20th and 21st centuries. However, its degradation poses significant challenges to curators and conservators, particularly due to harmful emissions. One of the well-known products is HCl, whose formation at high temperatures is well-researched, but its generation and impact under museum conditions remains unclear. Acidic emissions could pose a potential risk not only to the museum objects, but also to people working with them [1,2]. To evaluate the impact of the emissions, cross-infection of the PVC samples was investigated using a variation of the Oddy test with a cellulose paper as the reference [3]. The results indicated that unplasticized PVC emitted more harmful compound then plasticised, and the emissions from older PVC led to more damage of cellulose paper.Acidic gas emissions were determined using the Markes Micro-Chamber/Thermal Extractor µCTE120 in surface emission mode, sampling on specially cleaned silica gel sorbent tubes and charcoal sorbent tubes followed by extraction and analysis using an ion chromatograph with conductivity detector. The emission experiments were carried out in the temperature range of 80 – 120 °C taking a sequence of samples. The results showed that the HCl emission process consists of two phases, with the second part showing a levelling-off emission rate that linearly depends on inverse temperature according to the Arrhenius equation. Based on the calculated activation energy, HCl emission rates at room temperatures were predicted. Besides HCl, we also quantified formic and acetic acid emissions. However, to assess their influence (in comparison to HCl) further experiments are required.

Figure 1: *The set-up for an emission experiment.*

Acknowledgment: *This work was supported by the Slovenian Research Agency (ARIS) project N1-0241 (PVCare) and by the Programme Group P1-0447 (N-DAD: Non-destructive Analysis and Diagnostics).*

Smelling Death: The Olfactory Legacy of the Plague

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This presentation explores the sensory dimensions of mortality during a plague outbreak in 18th century Slovenia, with a particular focus on the mid-18th century plague altar in the church of St Andrew in Makole.The author conducts a nuanced sensory analysis of the artwork, which is attributed to an unknown artist and whose significance goes beyond mere religious symbolism. The study examines the prevailing miasma theory of the time, shedding light on ideas about the odour of the plague, public health regulations and societal responses to disease. Through its vivid depictions of scenes related to the plague, the altar serves as powerful testimony to the community's understanding of mortality and health crises during this turbulent period, offering insights into the interplay between sensory experience and public health in historical contexts.The focus on the olfactory legacy of the plague and the exploration of societal responses to the disease through sensory dimensions fits with the aims of anthropology of smell, which seeks to understand human experience and cultural practises in relation to their environment. Furthermore, the analysis of the artwork in relation to historical concepts of public health, such as miasma theory, utilises Roland Barthes' concepts of 'punctum' and 'studium' to provide a subtle sensory reading. This innovative approach, which has not previously been applied to the contextual analysis of artworks, offers a new perspective on the motifs of the altarpiece.

Acknowledgment: *The research is part of project "Smell and intangible cultural heritage" (ARIS J7-50233).*

Non-Invasive Analysis of Selected Works on Paper from the National and University Library and the National Gallery of Slovenia

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The research was conducted as part of a Slovenian Research Agency (ARIS) project, "Characterisation and Stability of Inks on Paper" (Z1-4404). The primary goal of the project was to develop an analytical methodology for accurately characterizing and classifying inks from Slovenian national collections in the most non-invasive way possible. A selection of documents and works of art on paper from the National and University Library and the National Gallery of Slovenia, covering the period from the late 19th to the early 20th Century, has been chosen for analysis and characterisation. The selection includes drawings and manuscripts by prominent authors such as Hinko Smrekar (drawings), Oton Župančič (Ciciban manuscripts), Zofka Kvedrova (letters/manuscripts), Ivan Grohar (drawings), Jurij Šubic (drawings), Ivan Vavpotič (drawings), Ivana Kobilca (letters/manuscripts), and Fran Podrekar (drawings).Non-invasive analytical techniques such as Raman, infrared, and X-ray spectroscopy were employed using portable instruments, allowing for on-site analyses. Different inks, including carbon-based and iron gall inks, were identified. Additionally, a drawing with vibrant colours by Fran Podrekar, was examined, revealing the presence of pigments such as iron ferrocyanide (Prussian blue), lead chromate (chrome yellow), and mercury sulphide (vermilion/cinnabar).

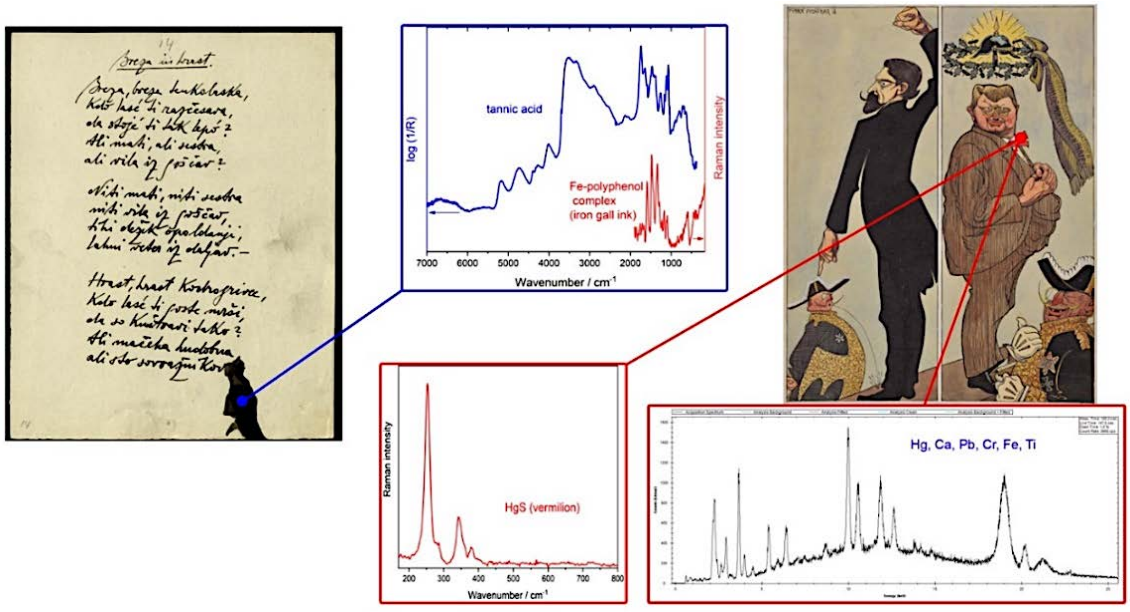

Figure 1: Left: *Župančič manuscript (photo: National and University Library), showing the location of non-invasive infrared and Raman analysis used to identify iron gall ink.* ***Right:*** *Podrekar drawing (photo: National Gallery of Slovenia), indicating the location of non-invasive Raman and XRF analysis used to identify vermilion.*

Acknowledgment: *This work has been financially supported by the Slovenian Research and Innovation Agency (ARIS), project Z1-4404. KR would like to express gratitude to Meta Kojc (NUK) for her assistance.*

The Non-destructive Analysis and Diagnostics Programme Group

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The N-DAD (Non-Destructive Analysis and Diagnostics) Programme Group aims at improving analytical methods for the non-destructive study of complex materials. Led by researchers at the University of Ljubljana, the Programme Group focuses on spatially resolved analytical techniques and their application across a range of fields, including cultural heritage conservation. The primary objective of N-DAD is to enhance diagnostic capabilities by developing advanced methodologies for characterizing materials. By utilizing a combination of chemical imaging, spectroscopy, and machine learning-driven data analysis, the Programme Group aims to provide more detailed and accurate information about the structural and chemical composition of materials, all while avoiding the traditionally used destructive sampling methods. One of the key challenges addressed by N-DAD is the analysis of heterogeneous and complex systems in cultural heritage conservation, historical artifacts, paintings, and building often require detailed study to preserve their integrity while maintaining their historical significance. The integration of machine learning into the analytical process allows for more efficient and accurate interpretation of complex data, making it possible to extract meaningful insights from large datasets and improving the overall diagnostic capabilities.

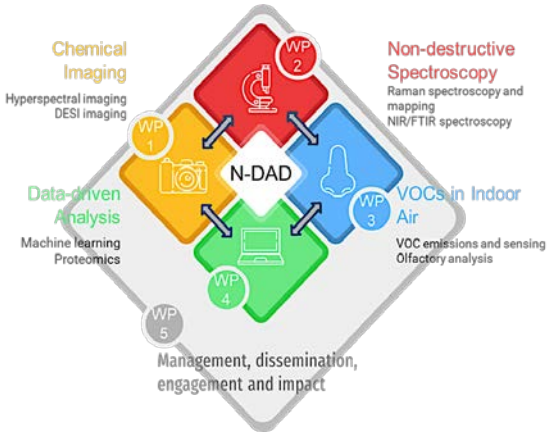

Figure 1: *Work-package structure of the N-DAD Programme Group*

The N-DAD programme group is closely aligned with international research efforts, particularly within the European Research Infrastructure for Heritage Science (E-RIHS) that promotes the integration of scientific research and cultural heritage. By contributing to the development of new tools and techniques, N-DAD supports E-RIHS's goal of fostering interdisciplinary collaboration and advancing the field of heritage science. Funded by the Slovenian Research and Innovation Agency starting from 2024, the N-DAD Programme Group exemplifies the University of Ljubljana's commitment to cutting-edge research and its contribution to addressing both scientific and societal challenges. The Group's outcomes are expected to have long-term implications for a wide range of industries, particularly those where material integrity is crucial for quality, safety, or preservation.

Researching the Use of Encaustic in Roman Wall Painting

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In 2017, ancient wall and ceiling paintings from the first century were discovered during archaeological research on the Museum Square in Celje. These paintings are of an exceptional quality – on a pair with the Pompeian paintings both in terms of execution and iconography. They are also impressive for the excellent preservation of the paint layer, which, despite being executed in the *secco* technique and exposed to environmental conditions for 2,000 years, has retained its vibrancy.During the restoration and research process, unfamiliar characteristics of the surface were discovered. A regular sampling procedure was carried out on the painting by the Restoration centre's Department of Natural Sciences Research, and it was discovered that the painting was not a true fresco. Further analysis was carried out to identify the binder used for the painting. The use of FTIR spectroscopy and GC-MS revealed the presence of wax in the paint layer in both the wall and ceiling painting, which means that there is a possibility that the painting was done in the encaustic technique. Based on the research carried out and the technical characteristics of the ceiling painting in question, it is assumed that the method of cold encaustic was used. The term cold encaustic is contradictory, as no heat is required for application, but there is no agreement on the nomenclature in the existing literature.In collaboration with José Cuni's son, Jorge Cuni, who continues to research water-soluble encaustic to this day, and based on the research and analysis, various versions of the wax emulsion were prepared. Bleached natural beeswax was used and then saponified using various saponifiers. Linseed oil was used as an additive, which contributed to less cracking of the colour layer. Emulsions prepared with potassium or sodium hydroxide that contained 30% wax and 15% linseed oil, proved to be the most successful.

Figure 1: *Reconstruction of a detail of the Roman ceiling painting using cold encaustic*

Xerophilic Fungi as a Risk Factor for Synthetic Materials in Heritage Restoration and Conservation

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The conservation of fine art paintings on canvas is often challenged by the susceptibility of the materials to fungal attack. Fungi can cause canvas deterioration, as well as cracking, peeling and discoloration of paint layers. The biodegradability of originally used natural materials has led to the use of synthetic alternatives in conservation practice. Our work aimed to determine the biodeterioration potential of xerophilic fungi on synthetic restoration materials (Lascaux 498 HV, Lascaux 303 HV, Acrylharz P550, Laropal A81, Regalrez 1094, and BEVA 371) at low relative humidity conditions (70% RH). Xerophilic fungal species (*Aspergillus puulaauensis, A. destruens*) were selected from a collection of 50 species isolated from deteriorated canvas paintings and were grown on synthetic consolidants and animal glue applied to object glasses. Fungal growth was monitored by light and scanning electron microscopy (SEM). Changes in the chemical structure of the materials were followed using Fourier transform infrared photoacoustic spectroscopy (FT-IR PAS). Enzymes possibly involved in their degradation were evaluated in culture media using chromogenic substrates based on p-nitrophenol by spectrophotometric analyses. Genomes and transcriptomes of selected fungi on synthetic materials were analysed. The results indicate that synthetic consolidants are relatively resistant to degradation by fungi compared to natural material such as animal glue, but certain fungal species degrade them, e.g. *A. puulaauensis*, which exhibited robust growth on laboratory mock-ups with Lascaux Acrylic Glue 498 HV and Regalrez 1094. It's transcriptome assembly and differential gene expression analysis while growing on these materials revealed overexpression of enzymes potentially involved in material degradation, e.g. esterases and oxidases. Our investigation revealed that xerophilic fungi, *A. destruuens* and *A. puulaauensis*, commonly found as colonizers of canvas paintings, are capable of degrading synthetic materials commonly used in conservation and restoration practices.

Acknowledgment: t*he Slovenian Research and Innovation Agency for Young Researchers grant for A. Kujović, and project J7-1815: "Restoration of moldy canvas paintings: improvement or deterioration?".*

Fifty Years of Mold Infestation in Slovenia's Famous Hrastovlje Church Wall Paintings: an Urgent Call for Preservation Efforts

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The church of St. Trinity in Hrastovlje features three naves adorned with preserved wall and ceiling paintings, created in 1490 by Janez of Kastav. Over the centuries, the church underwent several alterations, including the applications of multiple coats of whitewash over the paintings. In the 1950s, the paintings were uncovered and restored. A further conservation-restoration intervention took place in the 1980s, when an extensive examination of the church's internal conditions was conducted. Microbial presence was already documented in the 1980s. However, due to the recognition that microbial growth could not be efficiently controlled before addressing structural issues, the restoration of the infested wall paintings was postponed. The water leakage at the church/tower junction has been a subject of debate and attempts at repair since the 1960s. Despite these efforts, black discoloration of the wall paintings, particularly on the northern (N) and north-western (NW) walls, remains visible (Fig. 1), which was the target of our research. Analysis of the condition of the wall paintings, including the presence of microorganisms in the visibly affected darkened areas, was conducted in the summer 2024. Using classical culturing techniques and DNA barcode-based identification, this investigation led to the determination of 17 fungal and five bacterial species. Fungi were also detected through direct microscopic examination of wall tape prints with black discolorations, with *Cladosporium halotolerans* being the dominant species. The fungi isolated from NW wall belong to genera commonly associated with the deterioration of stone surfaces, including seven yet undescribed species. While on the N wall fungal flora specific for indoor of water affected buildings prevailed. Additionally, some additional species, like new species of the genus *Acremonium*, known for its role in biomineral formation, was found on precipitated salts on the walls. The evidence presented underscores the urgent need for action to address the mold infestation affecting the Hrastovlje wall paintings. An interdisciplinary approach, utilizing modern techniques, is essential to preserve this Slovenian cultural heritage gem, but it requires adequate financial support to achieve lasting results.

Figure 1: *Degraded wall paintings of the Holy Trinity Church in Hrastovlje. (Photo: A. Batič)*

Non-invasive In Situ Techniques in Preservation of Built Heritage

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Non-invasive in situ techniques are becoming widespread, in order to interact as less as possible with the Cultural Heritage objects. This is especially important to limit sampling and material consumption, which promotes the preservation of Cultural Heritage for future generations. In this presentation several in situ techniques for assessing the deterioration of built heritage materials and to evaluate conservation-restoration treatments, such as consolidation, are presented. The monitoring and assessment of the condition of the monuments, in terms of their physical-mechanical properties, is performed by ultrasonic transmission measurements (USV). Velocity of propagating (pulsating) acoustic waves can be used to quantify performance indicators, such as crack depth, width and distribution, delamination, strength, elastic modulus etc., either with direct or indirect transmission. The use of Ground Penetrating Radar (GPR) and ultrasound tomography has proven to be an effective strategy for evaluating historic concrete structures and reinforcement corrosion in objects such as concrete bridges. While GPR excels at detecting the location of steel reinforcement, ultrasound tomography complements it by assessing the concrete quality and reaches deeper into the structure, identifying internal defects that may not be visible through GPR alone. To study the effectiveness of surface consolidation, several techniques can be used: micro-hardness by portable hardness testers, USV and Karsten tube penetration test for changes in microstructures of porous materials, while spectrophotometry is applied to monitor the potential colour changes. Examples of the application of these techniques are shown in several case studies involving stone monuments, wall painting and historic concrete objects.

Figure 1: *Assessment of marble monument state with ultrasound velocity measurements (left). Spectrophotometry measurement of color changes after application of a consolidant on wall paintings (right).*

Unveiling the past: Non-destructive FTIR Analysis of Historical Garments for the Purpose of their Virtual Reconstruction

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The clothing heritage is an essential part of cultural history. In addition to its artistic and aesthetic value, historical garments offer important insights into the socio-economic characteristics of their time. The preservation of these garments is therefore of interdisciplinary importance. Unfortunately, textiles inevitably deteriorate over time and reach a point where they can no longer be restored/conserved and displayed in museum exhibitions. Digital replicas offer a valuable solution as they allow these garments to be preserved not as static images, but as detailed 3D models that preserve as much information as possible from the original garments. However, to create accurate 3D digital replicas, it is important to know the properties of the original textile materials from which the garments are made. Conventional methods for characterising fabrics often require destructive sampling, which is unsuitable for delicate historical garments that need to be carefully preserved. Therefore, non-destructive methods are essential for analysing the structural and mechanical properties of these textiles as they are crucial for creating digital 3D replicas and allow for more realistic and accurate representations. Among the structural properties of textiles, the raw material origin of the textile materials is the first parameter to be analysed and is the subject of this study for a blouse from the collection of clothing culture of the Regional Museum Maribor (N.6847). The silk blouse under study dates from the beginning of the 20th century. The blouse was worn by the upper middle class on special occasions, especially indoors. This means that the blouse was not usually exposed to the outside environment, which would further promote the deterioration of the textiles incorporated into it. For this research, a silk blouse was examined with a portable Perkin Elmer Spectrum 2 FTIR device and all the textile materials it contained were analysed, e.g. base material, lining, lace, embroidery thread. The portability of the device enabled on-site measurements in the museum's storage rooms and minimised the environmental risks associated with transporting the blouse. The analysis revealed a unique layering of silk and cotton fabrics that emphasises the practical design of the garment: the cotton lining provides durability in the high-wear areas, while the base fabric of a silk provides the aesthetics of the blouse, which is complemented by silk lace and embroidery. Using a non-destructive method to identify the raw textile materials in the blouse helps to ensure that the original garment is preserved, while a virtual 3D replica can safely capture and share on this knowledge. A detailed material description in the digital replica increases both accuracy and longevity. Further analyses, such as the characterising the structural and mechanical properties of fabrics, could provide a comprehensive profile of textile material. Extending the method to include these additional analyses is the next step towards a complete and accurate virtual reconstruction of the historical blouse.

Figure 1: *Women's blouse from the beginning of the 20th century (N. 6847, Regional Museum Maribor)*

CONFERENCE PROGRAMME

08:00	REGISTRATION
	OPENING ADDRESS
09:00 - 09:15	**Prof. Dr. Zdravko Kačič,** Rector of the University of Maribor
09:15 - 09:20	**Dr. Polonca Ropret,** Institute for the Protection of Cultural Heritage of Slovenia
09:20 - 09:25	**Prof. Dr. Gorazd Bajc,** University of Maribor, Faculty of Arts
09:25 - 09:30	**Irena Porekar Kacafura,** Univ. Grad. Eng. Conservator-Restorer, Regional Museum Maribor
09:30 - 09:35	**Emina Frljak Gašparović, M.Sc.,** President of the Slovenian Society for Conservation-Restoration
09:35 - 09:40	**Prof. dr. Predrag Novaković,** President of the Slovenian Archaeological Society
09:45 - 10:00	E-RIHS AWARD CEREMONY Presented by **Prof. Dr. Lidija Fras Zemljič** and **Prof. Dr. Matija Strlič**, honouring exceptional contributions to heritage science
10:00 - 10:45	COFFEE BREAK
	INVITED LECTURES
10:45 - 11:25	*Heritage Sustainability – from Islands to Continents* **Dr. Fenella France** UCC Cork, Fulbright Scholar, Cork, Ireland
11:25 - 12:05	*The Italian Node of E-RIHS: Expanding Capabilities in Heritage Science Research and Infrastructure* **Dr. Costanza Miliani,** The Institute of Heritage Science, National Research Council and national coordinator of E-RIHS.it, Milan, Italy
12:05 - 13:30	LUNCH AND POSTER SESSION
	LECTURES
13:30 - 13:50	*Assessment of historic wood construction: Case study of castle Leskovec* **Prof. Dr. Miha Humar,** University of Ljubljana, Biotechnical Faculty, Ljubljana, Slovenia
13:50 - 14:10	*Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) fundamentals and application in heritage science* **Dr. Martin Šala**, National Institute of Chemistry, Ljubljana, Slovenia
14:10 - 14:30	*Stone to Digital – Medieval and Early Modern Epigraphic Heritage* **Assoc. Prof. Dr. Gregor Pobežin**, University of Primorska, Faculty of Humanities, Koper, Slovenia, ZRC SAZU, Institute of Cultural History, Ljubljana, Slovenia
14:30 - 14:50	*Fluorescence microscopy and immunology in heritage science* **Dr. Janez Kosel**, Institute for the Protection of Cultural Heritage of Slovenia, Ljubljana, Slovenia

14:50 - 15:10	*BArCh-Wood: Interdisciplinary student research on climate change impacts on archaeological wood* **Lana Nastja Anžur** and **Špela Pok**, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Ljubljana, Slovenia
15:10 - 15:55	COFFEE BREAK
	LECTURES
15:55 - 16:15	*Utilizing Machine Learning and IR Spectroscopy to Reveal the Age of Historic Archival Materials* **Dr. Hend Mahgoub,** University of Ljubljana, Faculty of Chemistry and Chemical Technology, Heritage Science Laboratory, Ljubljana, Slovenia
16:15 - 16:35	*ToF-SIMS for Ink Differentiation* **Prof. Dr. Matjaž Finšgar,** Faculty of Chemistry and Chemical Engineering, University of Maribor, Maribor, Slovenia
16:35 - 16:55	*Multiscale Approaches to Studying Human and Animal Skeletal Remains: Integrating Macroscopic, Microscopic, Isotopic, and Spectroscopic Analyses for Bioarchaeological Insights and Heritage Protection Management* **Dr. Tamara Leskovar,** University of Ljubljana, Faculty of Arts, Department of Archaeology, Centre for Interdisciplinary Research in Archaeology (CIRA), Ljubljana, Slovenia
16:55 - 17:15	*Recent investigations by proton-beam induced spectroscopies* **Dr. Žiga Šmit,** University of Ljubljana, Faculty of Mathematics and Physics, Ljubljana, Slovenia
17:15 - 17:35	*Non-destructive 3D and 4D X-ray imaging techniques for Heritage Science* **Dr. Lucia Mancini,** ZAG – Slovenian National Building and Civil Engineering Institute, Ljubljana, Slovenia
17:35 - 18:35	DISCUSSION AND COFFEE BREAK **Prof. Dr. Gorazd Bajc,** University of Maribor, Faculty of Arts, Maribor, Slovenia **Prof. Dr. Domen Mongus,** University of Maribor, Faculty of Electrical Engineering and Computer Sciences, Maribor, Slovenia

2ND CONFERENCE OF THE SLOVENIAN NODE OF THE EUROPEAN RESEARCH INFRASTRUCTURE FOR HERITAGE SCIENCE E-RIHS SLOVENIA: BOOK OF ABSTRACTS

MATEJ BRAČIČ, TATJANA KREŽE (EDS.)

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Heritage science is an interdisciplinary field that brings together humanities, natural sciences, and engineering. It focuses on research, preservation, and sustainable use of cultural and natural heritage. By doing so, we enhance our understanding and care for heritage, ensuring its preservation for future generations and improving its role in the lives of people today and in the future. In line with the mission of the European Research Infrastructure for Heritage Science (E-RIHS), ERIHS Slovenia also promotes collaboration among researchers from diverse disciplines and facilitates access to state-of-the-art research infrastructure, thereby strengthening the research culture. The book of abstracts is a collection of presentations held at the 2nd E-RIHS.si conference on the latest research in cultural heritage, including innovative solutions enabled using artificial intelligence.

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