Institution: University College London

Unit of Assessment: 5 – Biological Sciences

Title of case study: Enhancing conservation methods and damage assessment to protect organic-based heritage objects

Period when the underpinning research was undertaken: 2000 - 2019

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by
Dr Marianne Odlyha	**Senior lecturer**	**1988 – present**
Dr Jonathon Slater	**Lecturer**	**1987 – present**

Period when the claimed impact occurred: 2013 - 2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact

Organic-based heritage objects form an important part of our histories and their preservation is vital. A research team at UCL/Birkbeck has changed conservation best practice by developing tools to evaluate levels of air corrosivity and testing methods to detect early signs of damage. Dosimeters and minimally invasive, sensitive methods are now used in museums throughout the world to protect priceless artifacts. English Heritage is currently reviewing conditions in 1000 showcases and frames as a result. The team's research has also led to implementation of new conservation treatments in museums and private collections in UK, Europe, and the US, for painting canvases and collagen-based heritage materials, and in South America (Brazil) for earthen architecture.

2. Underpinning research

Priceless and irreplaceable objects of cultural and historical interest need to be protected from degradation and conserved in a sustainable way. Researchers from UCL/Birkbeck have, over the last 20 years (a) developed devices to monitor levels of air corrosivity in museums (b) analysed the effects of pollutants on heritage objects to inform protocols for assessment of resulting damage to organic-based heritage materials and (c) evaluated effect of novel and sustainable nano-based materials used for conservation treatment.

The UCL/Birkbeck team was the first to demonstrate that volatile organic compounds (VOCs) can cause damage not only to inorganic objects but also to organic-based heritage objects (**R1**). Such pollutants became an increasing concern when investigators found that some materials commonly used in the construction of micro-climate frames and modern showcases allowed build-up of volatile organic acids at levels which caused damage to objects stored in these locations.

To monitor air quality surrounding works of art in museums, palaces, historic houses and display cases, the team used lead-coated piezo-electric quartz crystals (L-PQC) to measure levels of corrosivity in indoor air in these locations As part of the EU 7th Framework funded MEMORI project (Measurement, Effect, Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets Innovative research for market transfer), the team went on to study the effect of VOCs on a range of materials, including natural and synthetic varnishes on paintings and collagen-containing materials (parchment, leather), and determined threshold levels of volatile organic acids that would cause damage to these materials. (**R2**).

The dosimeter measures changes in crystal oscillation frequency as the surface coating's (lead) mass changes as it corrodes due to exposure to volatile organic acids. This response has been calibrated in the laboratory and at sites where levels of volatile organic acids have also been assessed using independent measurements from diffusive passive samplers. Furthermore, as a result of the MEMORI project these measurements can now be used to predict the extent of the damage that would be caused by these materials.

The measured signal is then interpreted in terms of a traffic light system which can inform the conservator as to whether the microclimate is acceptable for a class of materials or whether it needs attention. Coupled to appropriate electronics these dosimeters are capable of remote real-time monitoring and provide a readout for the level of risk posed to objects in that environment **(R1, R2).** The range of metal coatings on the dosimeters has now been expanded to detect a wider range of pollutants and these have been evaluated and the electronics improved making the system suitable for a wider range of circumstances (**R2**).

The team went on to develop a macro to nano-scaled approach for damage assessment of collagen-based materials using mechanical testing with programmed RH and Atomic Force Microscopy (AFM). AFM images were collected from large numbers of samples both artificially aged (by inorganic and organic pollutants, temperature, and relative humidity [RH]) and historical parchment/leather samples from diverse European archives. A damage classification scale based on mechanical response to RH and corresponding AFM images was developed **(R3).**

This damage classification system was then used to evaluate effects of novel nano-based conservation treatments including calcium carbonate and calcium hydroxide nanoparticle preparations. Alkaline-based calcium hydroxide nanoparticles were used for paper/canvas deacidification and consolidation. The evaluation assisted in further promoting the tools' commercialisation. Additional calcium-containing nanoparticiles were used for pH adjustment of collagen containing materials such as historical damaged parchment and historical vegetable-tanned leather. The team demonstrated that the treatment had a protective effect particularly on the latter **(R4).**

The team also applied the mechanical testing protocol with programmed RH cycling to assess the performance of newly developed nanocellulose-based consolidants for canvas, e.g. nanofibrillated nanocellulose (CNF) **(R5, R6).** These were tested alongside commonly-used adhesives (natural animal glue and synthetic Beva® 371).

3. References to the research

[**1**] Odlyha M, Slater JM, Grøntoft T, Jakiela S, Obarzanowski M, Thickett D, Hackney S, Andrade G, Wadum J, Christensen AH & Scharff M. (2018). A Portable Tool for the Evaluation of Microclimate Conditions within Museum Enclosures, Transit Frames, and Transport Cases, *Studies in Conservation*, 63:sup1:407-410, DOI: 10.1080/00393630.2018.1499841

[2] Agbota H, Mitchell JE, Odlyha M, Strilič M. (2014). Remote Assessment of Cultural Heritage Environment with Wireless Sensor Array Networks. *Sensors* 14:8779-8793. https://doi.org/10.3390/s140508779

[3] Odlyha, M., L. Bozec, A. Bartoletti, L.N. Melita,R. Larsen, K. Mühlen Axelsson, E. Dahlin, T.Grøntoft, P. Baglioni, R. Giorgi, D. Chelazzi, and R. Bergerat. (2014). Damage assessment of parchment at the collagen fibril level using atomic force microscopy and mechanical testing at the macro level. In *ICOM-CC 17th Triennial Conference Preprints, Melbourne, 15–19 September 2014,* ed. J. Bridgland, art. 0607, 7 pp. [Paris: International Council of Museums. (ISBN 978-92-9012-410-8)

[4] Baglioni,M., Bartoletti,A, Bozec,L.Chelazzi, D., Giorgi,R., Odlyha,M., Pianorsi ,D., Poggi,G.,Baglioni,P. (2016). Nanomaterials for the cleaning and pH adjustment of vegetable-tanned leather. *Applied Physics A* doi:10.1007/s00339-015-9553-x

[5] Bridarolli,A. Odlyha,M., Nechyporchuk,O.,(2018). Evaluation of the Adhesion and Performance of Natural Consolidants fo Cotton Canvas Conservation ACS *Applied Materials and Interfaces*, 10, 39 33652-33661 doi.org/10.1021/acsami.8b10727

[6] Alexandra Bridarolli, Anna Nualart-Torroja, Aurélia Chevalier, Marianne Odlyha and Laurent Bozec (†Marianne Odlyha and Laurent Bozec senior authors) (2020). Systematic mechanical assessment of consolidants for canvas reinforcement under controlled environment *Herit Sci* 8:52 https://doi.org/10.1186/s40494-020-00396-x

4. Details of the impact

Research from UCL/Birkbeck has transformed the way museums, archives and cultural heritage sites conserve their collections by raising awareness of the dangers of volatile organic pollutants and providing simple and economic ways to protect collections. They have also promoted and demonstrated the effectiveness of sustainable materials for conservation treatments. Through wide-ranging collaborations, workshops and international presentations, the methods and tools devised at UCL/Birkbeck are now embedded in best practice guidelines and applied to collections around the world, from national museums to small private collections. Since 2013, more than 120 conservators at cultural heritage sites and in museums in at least 14 countries have used these new conservation methods, better protecting thousands of priceless objects.

Implementation of L-PQC to detect volatile organic pollutants in museums across Europe

Traditionally, the presence of VOCs, such as acetic and formic acids have been detected in museums using lead coupons (shiny lead strips of known mass) or expensive passive diffusive samplers. The L-PQC dosimeters developed at UCL/Birkbeck provide conservators with an effective and inexpensive alternative. The metal-coated piezoelectric quartz crystals (PQC) detect and evaluate levels of corrosivity more quickly, more accurately and also remotely. Thousands of artifacts are now being protected following evaluations using L-PQC in the UK and Europe (**S1**). The head conservator at Spain's SIT Madrid said: '*Since August 2013 until 2020, … L-PQC (lead coated piezoelectric quartz) …were used to test air quality in showcases and microclimate frames in public museums and private art collections in Spain.… As part of our projects for 2020, we are offering the air quality measure service to private art collectors in EU*' (**S2**).

Remote monitoring using PQC arrays with additional metal coatings (Fe,Cu,Ni and Sn) for detection of corrosivity from inorganic pollutant gases O_3, NO_2 and SO_2, have been used within the Royal Palaces of Abomey in Benin (UNESCO World Heritage site) and Apsley House (English Heritage) and differences due to geographical location recorded (**S1**).

Best practice guidance and decision support model for preservation of organic-based heritage objects worldwide

The UCL/Birkbeck team's research and unique database including a combination of model samples subjected to accelerated ageing and a range of historical samples, has directly informed a decision support model published by English heritage (**S3, S4)**.

Objects and samples from collections from around the world are tested periodically. The decision support model acts as an early warning system (based on traffic lights code) where red alerts conservators to the need for intervention.

It provides guidelines for optimal display and storage conditions to preserve organic-based heritage objects. The guidelines are used by more than 120 heritage institutions worldwide

to ensure best practice in conservation and preservation. The Senior Conservation Scientist at English Heritage said: "*Dr Odlyha's work has been of immense benefit to managing the national collection of over 1 million objects in English Heritage's care. …The research was critical to the MEMORI decision support model.*"

The decision support model has been shared with over 300 professional and student participants in 14 international workshops and is currently used in major international museums in more than 15 major cities from Paris to Uzbekistan (**S1**). English Heritage is using the model to check all its 1000 showcases and painting frames. As part of the programme it has to-date, refurbished over 90 showcases and 32 painting frames across 19 sites, better preserving more than 3000 precious objects as a direct result of its findings (**S1**).

Advancing detection of damage to collagen-based materials using Atomic Force Microscopy in the UK

Atomic Force Microscopy (AFM) for application to collagen-based materials can detect damage at the collagen fibril level and also reveals presence of localised gelatinised areas. These areas are prone to cracking and can lead to loss of script. Since 2013, a database of AFM images has been established which has facilitated damage assessment on fibres from documents and from leather book-bindings e.g. Charles Darwin notebooks in English Heritage collections, Down House (**S1)**. The protocol was used in the MEMORI project to evaluate effect of exposure of parchment and leather to volatile organic acids and the resulting damage categories included in the decision support model which is currently widely used by English Heritage. The possibility of *in situ* imaging with portable AFM has allowed conservators to assess damage non-invasively on the object, including an historical 18th century parchment manuscript at The National Archives (London, UK), a historic violin, and surfaces of paintings at the Tate during treatment (**S5**).

Application of novel nano materials for sustainable conservation of cellulose based artifacts worldwide

In paintings conservation, Dr Odlyha introduced the damage assessment protocol involving mechanical analysis to evaluate effects of alkaline-based nanoparticles applied to cellulose containing materials (paper and painting canvases) to negate acidic conditions which develop as these materials age and eventually lose their strength. These results and evaluations of these products has assisted the Centre for Colloid and Surface Science, Florence (CSGI) in marketing these preparations. The products have now been sold in 18 countries across Asia, Europe and North and South America in sufficient quantities to protect more than 100,000 cellulose containing objects including painting canvases (**S6**). In addition, nanocellulose-based products which were introduced to consolidate the canvases in the NANORESTART project were tested using this protocol and further developments were made (**S7)**. Odlyha has collaborated with Lacerta Technology (UK) to test and develop the approach using programmed RH cycles with mechanical testing together with dielectric analysis (**S8**). The positive evaluation of these conservation treatments has led to their use by practising paintings conservators across Europe, including via an ERASMUS programme collaboration between UCL/Birkbeck and the School of Conservation in Copenhagen**;** in art conservation studios in Paris (Aurelia Chevalier, working with the Louvre); Centre for Colloid and Surface Science (CSGI), Florence; ZFB, Leipzig, Germany; and the Department of Arts and Conservation, University of Barcelona where paintings conservators are trained (**S9, R8).**

Head conservator at the School of Conservation, Denmark said: "Dr.Odlyha has been a prominent researcher with her work forming part of the group of researchers that laid the basis for an entirely new way of understanding the behaviour and deterioration of canvas paintings in art museums…." Participants at the sector's leading conference held at Yale University in 2019 to review conservation research hailed Odlyha's research as "*one of the most prominent and wide-ranging new treatment options announced at the conference".* (**S10**)**.**

Improving conservation of earthen architecture in Brazil

The methods developed at UCL /Birkbeck have also been used to test the effect of using termite mounds in restoration of earthen architecture. Previously, synthetic materials had been used for restoration, but these have different moisture absorption properties to the original materials, affecting stability. The results of tests carried out by UCL/Birkbeck on two large manor houses in Brazil, built using earthen architecture, have led to changes in their practice (**S11).**

5. Sources to corroborate the impact

S1 Letter from Senior Conservator English Heritage and additional figures provided by email.
S2 Testimonial letter from SIT Departmento Tecnico (SIT) Madrid Spain.
S3 MEMORI project website http://www.memori.fraunhofer.de/ and final report summary https://cordis.europa.eu/project/id/265132/reporting
S4 David Thickett, Frances David & Naomi Luxford (2005) Air exchange rate - the dominant parameter for preventive conservation?, The Conservator, 29:1, 19-34, DOI:10.1080/01410096.2005.9995210
S5 Presentation at COST action WoodMusick project in Brussels (Oct 2017): Correlation of Mechanical Behaviour with Advanced Chemical Analysis of Varnished Wood M.Odlyha, A.Lluveras-Tenorio et al
S6 Figures from SCGI on number of Nanorestore product units sold (nanorestore Paper and Nanorestore Plus sold (56,950 units sold 2018-2020). Assumed 1L enough to protect 2 paintings.
S7 NANOFORART project website http://www.nanoforart.eu
S8 Testimonial letter from Lacerta Technology, UK
S9 Odlyha Birkbeck-KADK ERASMUS programme agreement [PDF]
S10 Letter from Royal Danish Academy of Fine Arts of Conservation Consolidation on application of novel nanocellulose-based materials for consolidation of painting canvases.
S11 Testimonial letter from Associate Professor of Analytical Chemistry, University of Sao Paulo, Brazil; Programme for the 17th Conference of the Iberoamerican Network of Earthen Architecture and Construction.