Institution: University of Lincoln

Unit of Assessment: 34 Art & Design

Title of case study: Making Historic Plant Collections Safe: The Development of a Simple and Cost-effective Screening Tool for Use by Museums and Archives

1. Summary of the impact

Mercury has been used to preserve plants in museum collections since the 18th century. This has led to severe mercury contamination in historic plant collections across the world, which is today a global health concern. The research led to a rapid, cost-effective and non-destructive screening method for identifying mercury-based biocide residues in historic plant collections, significantly reducing exposure to toxic residues. This impacts directly upon professional conservation, restoration and curatorial practice, and informs public safety in the handling and access of important collections.
The National Museum of Wales (NMW) has used the methodology to identify and prioritise severely contaminated specimen sheets in its 800,000+ collection. Work has enabled conservators and curators to transform their safety practices and inform wider adoption by museums and institutions across the UK. In disseminating the outcomes across the sector, the research has attracted international interest and has been discussed and tested in a wide range of international conferences and museum forums.

2. Underpinning research

The underpinning research in these studies was funded by the NMW to inform directly the practices relating to contaminated collections and policies to protect conservators, curators and the public. This built on an EPSRC facility grant under the Access to XPS scheme (Grant No. EP/FO19823/1) which laid the ground for testing and application in museum and archive contexts.

It is well known within the museum community that plant collections were historically conserved using toxic compounds of mercury and arsenic, but it was not known until this research was undertaken, that residues of these compounds still remained in significant quantities today. Research surveys determined that the NMW herbarium in particular was severely contaminated with mercuric chloride and naphthalene residues, two of the most common biocides used historically and ubiquitous in many collections across the world, and which could not be handled safely. As museum plant collections are unique research resources, access to them is essential, from both conservator and user perspectives. Our research sought to transform safety practices across the museum and archives sector in order to improve both awareness and safety procedures. Three of Colston's REF2014 outputs are central to this work, and have been successful in extending analysis and research into a highly applied domain.

The research set out to develop a simple, cost effective and rapid screening method to identify the presence of mercury on specimen sheets (paper sheets to which the plant specimens are fixed). Since a significant proportion of specimen sheets have historic significance, a non- or micro-destructive method was preferable to preserve original materials. Due to the vast size of these collections, removal of the contaminated specimen sheet was not an option (in terms of the time expended), and routine chemical analysis to inform a rolling remounting programme was neither feasible in terms of time, nor economically viable. A dual solution to both screening and cost effective implementation was a critical feature in its effective impact.

On discovering distinct fluorescent spots on all of the specimen sheets over a range of emission wavelengths (Colston & Purewal 2002 and 2003), target observation and analysis as to the implications for museum curation and conservation practices was an imperative, hence the need to extend prior research to work closely in line with the sectors specific needs (Colston et al 2009-13). This included:

- Particle induced X-ray emission, using the linear accelerator at the Centre de Recherche et de Restauration des Musées de France, the Louvre (Paris) with funding from the EUArtech programme, determined the elemental compositional differences between the fluorescent and non-fluorescent areas on over 200 historic backing sheets from the NMW collection.
- X-ray photoelectron spectroscopy carried out at the EPSRC facility at Cardiff University to determine the mercury speciation for both fluorescent and non-fluorescent areas.
- Laboratory simulations and accelerated aging experiments were carried out using modern materials to validate the research hypotheses.

Key findings that led to impact

Our research determined that the development of the fluorescence is directly linked to the presence of mercury. There is compelling evidence to support the hypothesis that the observed fluorescence within the herbarium collection is due to the reduction of Hg(II) to Hg(I) during the oxidative degradation of cellulose, occurring as part of the natural aging process. This led to specific observations and findings relating to:

- Accelerated aging tests, and empirical observations indicate that the fluorescence takes at least 30 years to develop, as the degradation of cellulose has to progress sufficiently to propagate the production of the fluorescent Hg(I) species.

- The application of naphthalene as a biocide is very common, and is likely to be present in the majority of herbaria in Britain and abroad. The presence of naphthalene increases the rate of fluorescence development on specimen sheets that have also been treated with mercuric chloride. The oxidative decomposition of naphthalene is a source of additional hydroperoxyl radicals, also produced during the oxidative degradation of cellulose. These hydroperoxyl radicals are responsible for the reduction of Hg(II).

A hand-held UV-A lamp provides a rapid and effective method of identifying those samples within collections that have been highly contaminated with mercuric chloride, and provides a means to prioritise which collections require immediate re-mounting. Furthermore, this is now informing the implementation of standard procedures to protect personnel and visitors handling the collections, and enable the removal of a large amount of hazardous chemicals from the herbarium environment.

3. References to the research

1. Purewal, V., COLSTON, B. and Morgan, D. (2009). Recognition of the relationship between a cellulose substrate and historic biocides applied to herbaria over time. *Bridging Continents – New initiatives and perspectives in natural history collections*. The Society for the Preservation of Natural History Collections, *SPNHC 2009*, Leiden.
2. Purewal, V., COLSTON, B. and Roerhs, S. (2008). Developing a simple screening method for the identification of historic biocide residues on herbarium material in museum collections. *X-Ray Spectrometry* **37** (2), 137–141.
3. COLSTON, B. and Purewal, V. (2008). Development of a novel approach to the identification of historic herbarium biocides. *Conservation Science Annual* at the *2008 Eastern Analytical Symposium*, November 2008, New Jersey, USA (INVITED).
4. Purewal, V. and COLSTON, B. (2008). New approaches to managing contaminants in herbaria.*Society for the Preservation of Natural History Collections Annual Conference*, Berlin.
5. Purewal, V., COLSTON, B. and Roerhs, S. (2007). The identification of historic pesticide and fungicide residues present on herbarium material housed within the National Museum Wales. *Proceedings of the 11th International Conference on Particle-induced X-Ray Emission and its Analytical Applications,* PIXE2007, Mexico.
6. Purewal, V. and COLSTON, B. (2006). OLD POISONS – New Approaches (2006). *Society for the Preservation of Natural History Collections Annual Conference* Albuquerque, New Mexico, May 2006.
7. Purewal, V. (2012) – Novel detection and removal of hazardous biocide residues historically applied to herbaria. PhD Thesis, University of Lincoln.

8. Purewal, V. and COLSTON, B. (2005). The Identification of Hazardous Pesticide and Fungicide Residues Present on Herbarium Mount Paper. *Metals in Paper*, Rome, February 2005.

4. Details of the impact

This work formed the basis of bids to the EUArtech programme and the EPSRC Facility. We were awarded ion beam time at C2RMF, Paris, through the EUArtech Programme (nominally £18k) to extend processing and characterization, and sample analysis was carried out at the University of Cardiff, as part of the *Access to XPS* initiative supported by the EPSRC. This enabled research to establish a link between fluorescence and the presence of mercury, informing a novel screening method that allowed us to work closely with the sector in designing adoption principles, practices and policies. Bids are underway to Leverhulme and STFC to extend the work and specifically to address a wider repertoire of chemical analysis common in specific historic periods.

The presence of large amounts of hazardous pesticide residues within historic plant collections is a legacy from past conservation treatments affecting many museums and institutions across the world. It was common practice from the 18th Century until the late 20th Century to regularly apply highly toxic compounds of mercury and arsenic to plant collections to prevent insect and fungal damage. Regrettably, it was not common practice to record the treatments that were applied, and identifying contaminated specimens within collections today is impossible without chemical analysis. For an institution legally required to protect its staff, visitors, volunteers and researchers, the detection and removal of hazardous material from the herbarium environment is a top priority. Unfortunately, many museum plant collections are vast, often containing hundreds of thousands of specimens, making such a task difficult, both costly and time-consuming, and impossible to achieve in many museums. Nevertheless, historic plant collections are primary research resources and access to them has to be maintained if they are to fulfil their role.

Current research has led to the development of a screening method for identifying mercury-contaminated specimen sheets within any collection. It requires the use of a hand-held UV-A lamp, which is an accessible and affordable item for the majority of museums across the world, and central to self-detection and analysis. It has, so far, been adopted by five key cultural institutions as cited below.

The initial impact of this research is on museums and practitioners. It has changed professional conservation and curatorial practice, offering a means to address a serious problem that could not previously be solved. Subsequently, the research has impacted on the end-users of the collection and is growing in importance at museums across the country and beyond. In removing the risk of exposure to toxic chemicals, allowing them to be handled safely, ensures that all hazardous collections remain available as a vital research resources.

An example of direct impact at the National Museum of Wales:
The research, carried out in collaboration with the National Museum of Wales, was driven by the Museum's need to find a solution to a problem. A number of its conservation and curatorial staff were becoming ill after spending extended periods of time working on the museum's plant collections. It was common for staff members and some visitors to work in close contact with the collections, handling numerous specimens every day, as well as close identification work using hand lenses. The observed symptoms were associated with exposure to the mercury and naphthalene that had previously been identified in the collection during the Masters research carried out by their botanical conservator (Purewal, 1996-98).

The herbarium was closed to the public and staff for a period, and reopened with the introduction of changes in working practice, specifically to reduce the risk of exposure to staff and visitors. This was seen only as a short-term measure, allowing the collection to remain accessible, whilst the Museum searched for a means to ensure its collection was safe to handle in the long-term. Further research during 2009-13 has informed their approach as a regular element of their health and safety procedures.

NMW has used the methodology to:

- identify severely contaminated specimen sheets in its 800,000+ specimen collection, and to prioritise which collections required immediate re-mounting.
- ensure the implementation of safe, standard procedures to protect personnel and visitors when handling the collections.
- enable the removal of a large quantity of hazardous chemicals from the herbarium environment.

National impact
More widely, the methodology is now being adopted by museums and institutions across the UK. The NMW is actively engaged in training other museums to utilise the methodology in their plant collections (evidenced in available reports, correspondence and corroborative material). To date, this has included the Natural History Museum [March 2008, Dr Mark Spencer], The Royal Botanical Gardens at Kew [March 2011, Julia Carretero], the British Museum [July 2011, Faye Miles], the Royal Museum Cornwall [May 2008, Laura Ratcliffe] and the Royal College of Physicians [March 2013, Laura Sleath]. All have identified mercury in their collections using the methodology and have been able to determine whether specimens are safe to handle or need re-mounting.

International impact
There is been keen interest in the methodology which is being disseminated via international conferences: Rome (Metals in Paper 2005); New Mexico (OLD POISONS – New Approaches, SPNHC 2006); Mexico (PIXE 2007); Berlin (*New approaches to managing contaminants in herbaria*, SPNHC 2008), New Jersey (*Conservation Science Annual* at the *2008 Eastern Analytical Symposium*) and Leiden (*Bridging Continents – New initiatives and perspectives in natural history collections*, SPNHC 2009). Impact is growing and continues to be evident, and has already resulted in dialogue from the USA museum sector on adoption and refinement of screening practices in multiple contexts (Reading Museum, Pennsylvania, Ashley J. Hamilton, October 2013].

5. Sources to corroborate the impact

1. **Independent testimony** (all letters collated and contacts made available) supplied from:
   - World Museum, Liverpool
   - Natural History Museum
   - Royal Botanical Gardens, Kew
   - Royal College of Physicians
   - Natural History Museum
   - Royal Cornwall Museum
   - National Museum Wales.

2. **Reports and documentation**
   - NMW remounting programme (Report and document available)
   - Instatement of the tools in the building of a new herbarium (Photographs & reports available).

3. **Individual users and beneficiaries** (Emails and letters collated and available).