

Institution: University of Kent
Unit of Assessment: 8
Title of case study: Mary Rose: Protecting our Heritage through Chemistry
<p>1. Summary of the impact</p> <p>The warship Mary Rose served Henry VIII's navy for 34 years, including spells as the flagship. She sank while engaging the French navy in the Solent in 1545, and unsuccessful salvage bids meant the ship remained on the seabed for almost half a millennium. The University of Kent has been the central academic partner of the 30-year and £35 million Mary Rose salvage and conservation project. It received Heritage Lottery funds, which the University of Kent used to develop new conservation chemistry, underpinned by synchrotron studies. Kent researchers have subsequently taken up permanent employment with the Mary Rose Trust to implement this new technology. The Mary Rose exhibition opened at Portsmouth Historic Dockyard in May 2013, is one of the most important additions to UK culture in recent times. The research at Kent was critical to this achievement, and the new chemical technology is subsequently finding new areas of impact.</p>
<p>2. Underpinning research</p> <p>Context and Traditional Conservation projects</p> <p>Salvage projects, such as the Mary Rose, UK and the Vasa, Sweden, have shown wooden ships can remain relatively intact while buried within silt under sea beds for hundreds of years. However, this does not mean that the environment is benign, which was first highlighted during the restoration of the Vasa. The Swedish warship spent 333 years under the Stockholm archipelago after collapsing on her maiden voyage. She was salvaged in 1961 and put on display in 1990; a project approximately 20 year ahead of the Mary Rose. Although the oak beams were seemingly in excellent condition when first raised above the surface, the ship dramatically deteriorated while in the museum [Nature 415 893 (2002)]. The problem lay in the nature of the treatment used to stabilise the wood after salvage. In this process, a preservation solution of boric acid and sodium borate was applied to neutralise the acidity, along with polyethylene glycol to replace the water and prevent warping as the wood dries. What quickly became apparent was that the acidity of the wood increased and sulphate salts began to coat the surfaces, which "threatened the continued preservation of the Vasa". It was suggested that the problem originated from hydrogen sulphide produced by bacteria within the waterlogged wood while submerged. The preservation solution initially lowered the acidity on treatment, but the slow oxidation of the sulphur containing material, catalysed by the presence of iron from structural bolts etc, was creating an ongoing acidity problem, which "could produce 5,000kg of sulphuric acid when fully oxidised." The University of Kent solved this issue by understand the oxidation process [1, 2, 5], and developed a completely different treatment that neutralises both the inherent acidity, as well as acting as a buffer for the ongoing sulphur-related problem [3, 4, 6].</p> <p>Key Research Findings at University of Kent</p> <p>Dr Eleanor Schofield was appointed a postdoctoral research scientist by Professor Alan Chadwick [Kent 1970-present] of the School of Physical Sciences, University of Kent between January 2009 and June 2011 to study "abiotic production of acid in waterlogged archaeological wood and remediation strategies". She focused on addressing the sulphur issue, while Aaron Berko, University of Kent, focussed on iron removal for his PhD during the same time. The Kent team developed detailed chemical mechanisms of how sulphates, naturally present in sea water, interacted with bacteria to form reduced sulphur compounds, such as hydrogen sulphide, which can undergo further reactions with iron to form iron sulphides [1]. Although not particularly harmful themselves, lifting the wood out of the water sets off a new set of reactions, where the air oxidises the plethora of sulphur compounds formed under the seabed into harmful sulphuric acid that attacks the wood. Using this knowledge, the Kent scientists studied a number of alternative treatments, making use of synchrotron beam lines at Stanford, USA and Diamond, UK, to</p>

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characterise their effectiveness [2]. It was shown that strontium carbonate nanoparticles (in an isopropanol solution) reduced both the inherent acidity (as achieved by the Vasa treatment), as well as the ongoing acidity originating from the reduced sulphur compounds [4, 6]. This new technique has been extensively implemented on the Mary Rose project and represents a major achievement as the new treatment developed at the University of Kent permanently stabilises waterlogged items, preventing further degradation and requires no additional treatments.

3. References to the research

The conservation section of the Mary Rose website (<http://www.maryrose.org/archaeology-and-conservation/mary-rose-publications/>) describes a total of 5 research publications (references [2]-[6] below) directly impacting on the restoration of the warship. All 5 articles are work carried out in the School of Physical Sciences at the University of Kent, and all have an author from the University of Kent as first author, as well as the corresponding author. The work at the University of Kent constitutes all of the research done to preserve the Mary Rose. References [1], [5] and [6] best indicate the quality of the underpinning research).

1. **Wetherall, K. M.***, **Moss, R. M.**, Jones, A. M., Smith, A. D., Skinner, T., **Pickup, D. M.**, **Goatham, S. W.**, **Chadwick, A. V.** and **Newport, R. J.** "Sulfur and Iron Speciation in recently recovered timbers of the Mary Rose revealed via X-ray absorption spectroscopy", *J. Archaeological Science*, 35, 1317 (2008)
2. **Berko, A.**, Smith, A.D. Jones, A. M., **Schofield, E.J.**, Mosselmans, J. F. W. and **Chadwick, A.V.*** "XAS studies of the effectiveness of iron chelating treatments of Mary Rose timbers", *Journal of Physics Conference Series: 14th International Conference on X-ray Absorption Fine Structure (XAFSI 4)*, 190, 012147 (2009).
3. **Chadwick, A.V.***, **Berko, A.**, **Schofield, E.J.**, Jones, A.M., Mosselmans, J. F. W., Smith, A. D. "How X-rays are helping defeat the effects of micro-organisms in the preservation of Mary Rose" *L'Actualite Chimique*, 356-357, 106 (2011).
4. **Schofield, E.J.**, Sarangi, R., Mehta, A., Jones, A. M. and **Chadwick, A. V.*** "Nanotechnology and Synchrotron light in the service of Henry VIII: preserving the Mary Rose" *Materials Today*, 14, 354 (2011).
5. **Chadwick, A. V.***, **Berko, A.**, **Schofield, E.J.**, Jones, A. M., Mosselmans, J. F. W., Smith, A. D. "Application of Microfocus X-ray Beams from Synchrotrons in Heritage Conservation" *International Journal of Architectural Heritage*, 6, 228 (2012).
6. **Chadwick, A. V.***, **Schofield, E.J.**, Jones, A. M., Cibir, G. and Mosselmans, J. W. F., "Ionic Nanoparticles in Heritage Conservation", *Solid State Ionics*, 225, 742-746 (2012)

* Corresponding author. **Bold** signifies author from University of Kent.

Key funding:

- Chadwick, A.V., Newport, R.J., "An investigation of remediation methods for the sulphur problem in Mary Rose timbers.", Heritage Lottery Fund grant administered by the Mary Rose Trust, 01/07/2008 to 30/06/2011.

4. Details of the impact

The research was supported by the Heritage Lottery Fund through an award to Professor AV Chadwick, University of Kent that was administered by the Mary Rose Trust. The project was specifically targeted to solve an existing problem in the treatment of waterlogged wood that is described above. Eleanor Schofield was appointed as a postdoctoral research assistant during the period of the award. As a result of the training she obtained at the University of Kent, and the progress she made with the development of new chemical treatments, she subsequently became Conservation Manager for the Mary Rose Trust, with overall responsibility for chemistry related conservation. She has overseen the implementation of the University of Kent technology to treat numerous salvaged items. The figure below shows one of the many gun carriages on display that were treated using the University of Kent method. These items would not be on display if the University of Kent research had not been carried out.

Beneficiaries and Significance of the Conservation of the Mary Rose

The work led by the University of Kent has a local impact on the economy of Portsmouth and the South East, a national impact in the position of the Mary Rose within British history, and an international impact on the conservation and heritage industry.

The restored Mary Rose forms a centrepiece attraction in Portsmouth's Historic Dockyard: in its new purpose-built museum it is a major visitor attraction and cultural asset to its region. The Dockyard attracts around 500,000 visitors a year, approximately 15-20% from overseas and it is anticipated that these numbers will grow further with the opening of the Mary Rose (Portsmouth Historic Dockyard Ltd.). The Mary Rose Trust received £2m from visitors, in donations and trading income in 2012; it also has an active learning and outreach programme (Mary Rose Trust Annual Review 2013).



Kent research enabled the conservation of artefacts, such as the gun carriages (left) that would otherwise not be on display. The *Mary Rose* project is a lasting legacy to Tudor life that will be enjoyed for many generations to come. The uniqueness of the exhibition (right) prompted historian David Starkey to describe it as the "British Pompeii"

The preservation of Mary Rose has major historical significance as a well-preserved example of Tudor history. Without the preservation of the artefacts – of which the ship itself is the greatest – it would not be possible for the museum to tell the full story of this period of history: "In the original museum less than 10% of the recovered artefacts were on display. In the new museum many thousands more artefacts will be displayed in context, many never seen before. Preparing all this material has been a huge task. The remarkable state of preservation of some of these articles can be confusing because everything wooden on display in the new museum is a conserved original. There are no organic replicas on display." (Mary Rose Trust Annual Review 2013). The impact of the work is also evidenced by interest from other conservators. Dr Emma Hocker, a conservator at the Vasa commented on the research at the University of Kent: "We at the Vasa Museum are always interested in new treatments to neutralise acids in wood. What is intriguing about the University of Kent's method is that it is not a one-off treatment, but since the nano-particles remain in the wood, they act as a buffer ready to neutralise any new acidic outbreaks."

5. Sources to corroborate the impact

1. Professor Mark Jones, Head of Collections of the Mary Rose Trust. [Contact 1]. Who can confirm the relationship of the underpinning research from Kent to the Mary Rose project and the impact on the Mary Rose Trust.
2. Dr Eleanor Schofield, Conservation Manager at the Mary Rose Trust. [Contact 3]. Who can confirm the detailed relationship between the technical aspects of the Kent research and the conservation of the Mary Rose ship.
3. Emma Hocker, Conservator, Vasa Museum. [Contact 2]. Who can confirm the wider impact of the research on international conservation efforts, and specifically for the Vasa ship.
4. The Mary Rose Trust has an extensive website describing the extraordinary history of the ship, including a large section on the Archaeology and Conservation process, a link is provided in

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the section 3 above. A section of the website is quoted below, that corroborates the involvement of the University of Kent: “*University of Kent – development of strontium carbonate nanoparticle treatment to sequester sulfate and neutralise the wood / exploration of chelating agents to remove iron from the wood and therefore eliminate the catalyst for sulphur oxidation and acid production.*”

<http://www.maryrose.org/archaeology-and-conservation/mary-rose-research/>

5. Interview with Eleanor Schofield from the University of Kent on nanoparticle preservation. The transcript of an interview with Eleanor Schofield in Materials Today on the use of nanoparticles in the conservation of the Mary Rose is given at :

<http://www.materialstoday.com/blog/2013/1/30/interview-with-eleanor-schofield-nanoparticle-preservation/783.aspx>

A recording of the actual interview is given at :

http://about.elsevier.com/media/MT_Schofield_maryrose.mp3

6. Website: <http://www.maryrose.org/archaeology-and-conservation/mary-rose-publications/>
All 5 articles are work carried out in the School of Physical Sciences at the University of Kent, and all have an author from the University of Kent as first author, as well as the corresponding author.