Evaluating “Greener” Alternatives for Polyvinyl Butyral (PVB) Removal in Wall Painting Conservation

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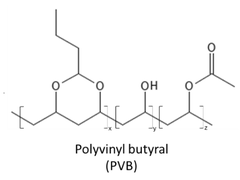
Introduction

Discovered in Ningxia Province (China) in 1996, the murals from Tian Hong’s tomb (510–574 CE) were detached and preserved at the Guyuan Museum of Ningxia. Before detachment, they were consolidated with polyvinyl butyral (PVB), which has since degraded, causing blanching and reduced legibility.

Due to the fragility of the original paint layer and the cohesion retained by PVB, safe removal is challenging. This study explores safer, more sustainable cleaning strategies using “greener” solvents and controlled application systems.

Details of the wall paintings before detachment.

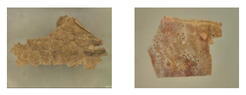
Detachment



Detached mural with blanched PVB coating.

Methodology

- Optical microscopy (OM)
- SEM-EDS
- FTIR spectroscopy
- Raman spectroscopy



Solvents
- Ethanol (EtOH)
- Dimethyl carbonate (DMC)
- Ethyl lactate (EL)

Delivery methods
- Swabs (traditional method)
- Polyhydroxybutirate (PHB) organogels
- Pullulan nonwovens

Characterisation → **Mock-ups creation** → **Cleaning systems** → **Cleaning assessment**

- PVB coating,
- Protein-based paint layer,
- Lime plaster and sand,
- Ceramic tile

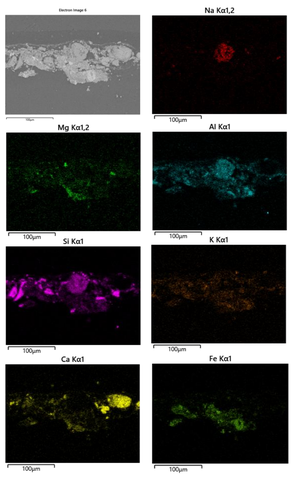
- Solvent Star diagrams
- Visual inspection,
- Digital Microscopy,

Results

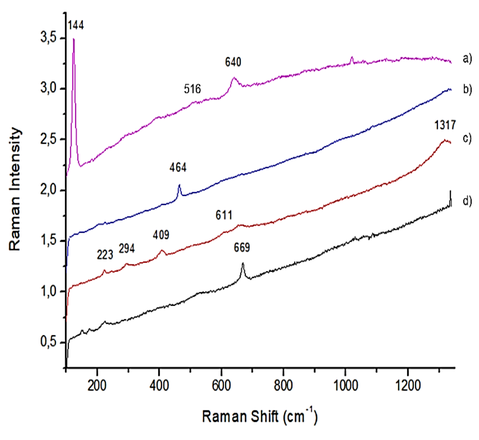
Characterisation

Pictorial layer

- Silicate and carbonate minerals in the substrate.
- Haematite with anatase impurities was identified in red paint areas, and calcite in white paint areas.



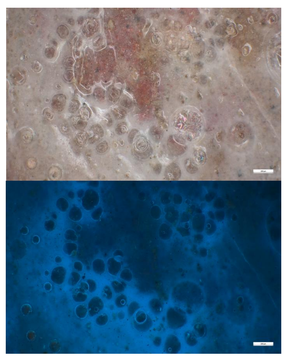
SEM image and EDS maps of the elemental distribution.



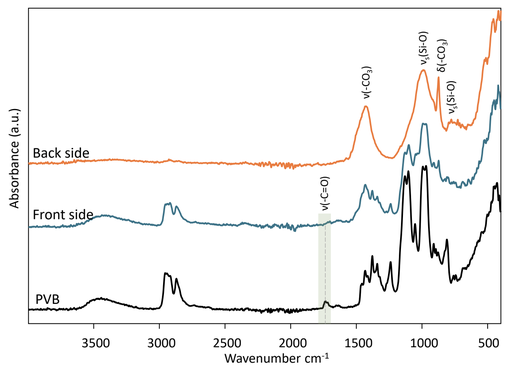
Raman spectra: a) anatase; b) quartz, c) haematite; d) magnetite.

Coating layer

- PVB was present, with no evidence of other polymers.
- Likely degradation of PVB.



OM images under visible and UV light.



Comparison of ATR-FTIR spectra from the back side (red), front side (blue), and PVB resin (black).

Sample characterisation guided the development of mock-ups and informed the selection of cleaning methods.

Reduction of PVB coating – mock ups

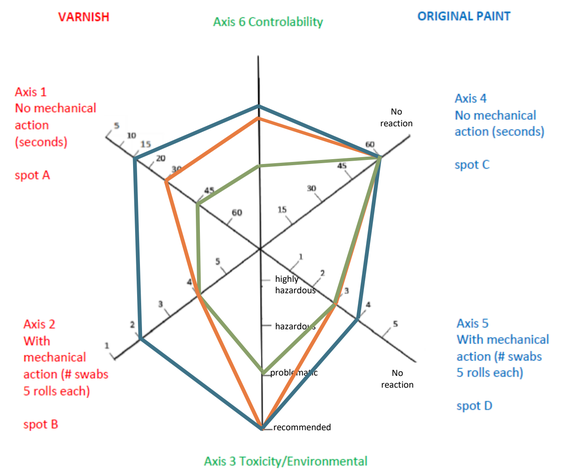
Solvents comparison

“Greener” solvent selection

Solvent	Renewable resources	Green synthesis	CHEM21 (S,H,E)
EtOH	(✓)[1]	(✓)[2]	4, 3, 3
DMC	(✓)[1]	(✓)[2]	4, 1, 3
EL	✓	✓	3, 4, 5

[1] Derived from either renewable or non-renewable resources

[2] Industrially produced by both «green» and «non-green» methods.



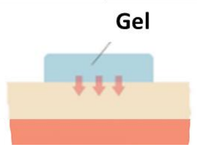
Solvent Star diagrams illustrating the dissolution behaviour of the PVB coating.

- EtOH: highly effective, but pigment loss.
- DMC: moderately effective, less pigment loss than EtOH.
- EL: least effective; slow to act.

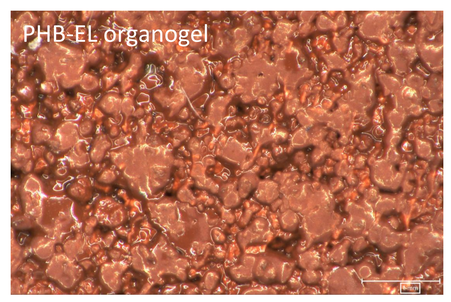
Delivery methods comparison

Cotton swab
- Uneven PVB reduction.
- Pigment loss observed and cotton fibre residues left behind.
- Requires higher solvent volume.

Nonwovens
- Coating swelled and absorbed into the mat.
- Coating peeled away without mechanical action.
- Uniform PVB reduction.
- No pigment pick-up.



PHB-DMC and PHB-EL organogels
- PVB coating swelled in under 5 minutes.
- Swollen layer partially remained, thus requiring a further step.
- Swabbing caused pigment pickup.
- PVB residues left behind.



Hirox microscope images comparing cleaning methods.

Conclusion and future perspectives

- Analytical investigations were crucial for developing representative mock-ups.
- Cotton swab cleaning was least effective and caused pigment loss.
- Both nonwovens and organogels offered “greener” alternatives by reducing solvent use. Nonwovens were most effective: controllable and no pigment pick-up. Organogels showed promise but required an additional removal step.
- Mock-ups provided a controlled experimental set up but do not fully replicate aged, original coatings.
- Solvent-based cleaning should only follow consolidation and secure mounting.

Acknowledgements

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The Courtauld

go green

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