Ormsby *et al. Heritage Science* (2024) 12:10
https://doi.org/10.1186/s40494-023-01113-0

Heritage Science

EDITORIAL

Cleaning and conservation: recent successes and challenges

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Introduction

The cleaning of material-based works of art is driven by the preservation of the aesthetic and readability of artworks, as well as the physical and chemical stability of their constituent materials. As straightforward as this may initially seem, these processes pose many and varied challenges to heritage professionals globally. Cleaning generally refers to the removal of unwanted materials from works of art/heritage artefacts. This includes the removal of dust and deposited soil, coatings, overpaint/retouching, previously applied conservation materials, migrated additives/constituents, degraded polymer components, as well as patinas, crusts, scuffs, graffiti, and other marks. These alterations can induce undesirable changes which can affect the integrity, appearance, response to the environment and conservation treatment, as well as the cultural and financial value of works of art. In addition, the complexity of cleaning processes are necessarily underpinned by the requirement to balance the potential aesthetic and preservation gains with any risks to the artwork posed by the treatment itself. The risks in turn are ideally characterised at macro, micro and sub-micron scales which pose numerous scientific challenges; not least of which is determining how any molecular changes elucidated may affect the whole work of art across the short- and longer-terms.

The wider conservation profession has been discussing and investigating the relative merits of various options and reflecting on treatment results for a long time in order to better inform risks associated with treatment and to enhance the range of options available to help address this complex and often artwork specific, conservation challenge. Despite significant and welcome improvements in cleaning system options developed in recent years and decades, there remains a relative lack of rigorously evaluated treatments for specific materials and surfaces, which remain a hindrance to optimal practice. This is reflected to some extent by the range of heritage materials featured in this collection. More recently, the continued use of substances that carry inherent health and safety hazards for the environment and/or users have also precipitated the demand for more sustainable options.

The papers forming this special collection represent a snapshot in the development and/or application of novel cleaning systems as well as scientific techniques developed to help characterise and document cleaning processes and risk. These contributions have arisen from fruitful collaborations between conservators, heritage scientists, academics, and industry and the varied materials, evaluation methodologies and instrumentation included exemplify recent advances in the field. Equally, the collection also underlines the need for continued innovation and cross-discipline endeavours for the continued development of new tools, knowledge, and approaches.

Over the past few decades, heritage conservation has witnessed an acceleration in the development and introduction of aqueous based, gelled, and other novel

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cleaning materials and systems. This has also inspired the development of frameworks for the rigorous design and assessment of the suitability of cleaning materials, as well as the modification and development of instrumentation to better inform risk and cleaning processes. Increasingly, the use of case study artwork conservation treatments in research design methodologies is affording ever stronger connections between research and practice.

This special issue exemplifies current developments through seventeen original papers which feature state-of-the-art research on interconnected aspects of cleaning science. This includes the characterisation of case study objects; the application of existing cleaning systems to specific conservation challenges; the development of new, more sustainable cleaning materials and/or approaches; the design of rigorous evaluation methodologies and the application of novel analytical techniques. As a group, the collection can be roughly divided into two main categories, the development and application of: methods for the removal of unwanted materials, and scientific techniques to assess the impact of cleaning procedures to help characterise and inform risk.

New and modified cleaning materials

With respect to the development, modification and application of cleaning systems; Giordano et al. provided insights into the physical and mechanical properties of agar when it is atomised in a sol state and applied via spraying, enabling the formation of a homogeneous, thin layer which adheres to three-dimensional substrates [1]. Theodorakopoulos et al. explored the suitability and cleaning efficacy of a surface-attached gel made from a poly(acrylamide) polymer covalently bonded to flexible polyethylene films. These were applied to gypsum plaster mock-ups with different coatings where they exhibited good contact and promoted efficient soil removal [2]. Campos et al. also presented a novel gel, in this case made with chitosan embedded with thiourea dioxide and phosphoric acid to remove manganese-rich black-blue stains on granite or glass artefacts [3]. Fontaine et al. carried out pilot tests with agar gel prepared with potassium nitrate solution which proved suitable for the localised reduction/removal of chlorides from ferrous or copper alloy archaeological objects from a burial environment [4]. Campanella et al. explored the use of proteins (Lactotransferrin and Ovotransferrin) mixed with cellulose pulp to remove iron-based stains from marble surfaces, providing selective and non-invasive chelation of ferric ions without affecting the $CaCO_3$ substrate [5]. Lozano et al. studied the use of deep eutectic solvents to remove gelatine residues from cellulose nitrate cinematographic films where trials showed advantages over traditional approaches [6].

Others involved comparing several cleaning systems to place novel systems within the context of wider practice. Ortega Saez et al. compared the use of gellan gum and polyvinyl acetate-borax gels, with or without a pre-treatment with cyclomethicone (D5) to clean silver gelatine prints [7]. Shah et al. described characterising and removing a lead-rich, efflorescent salt crust from an 18th-century Dutch oil painting after assessing various gels with aqueous solutions and chelators [8]. Stoveland et al. showcased a range of novel techniques such as soft particle blasting, CO_2-snow blasting and hydrogels for the removal of soiling on porous and water-sensitive mock-ups based on Munch's monumental *Aula* oil paintings [9]. Mašková et al. also investigated the effect of high-speed CO_2 snow on smooth and rough paper surfaces compared with nitrogen jet cleaning and dry cleaning using commercial materials. In this case CO_2 snow showed potential for the removal submicron-sized particles ingrained in paper and inaccessible areas of books [10]. Solid-state Nd:YAG lasers (UV, vis, near IR range) and Er:YAG lasers (mid IR) also featured, with Bertasa and Korenberg reporting the first study on cleaning artificially soiled feathers where the Nd:YAG option proved useful for removing dust from feathers, except for those rich in melanin [11].

New analytical and imaging approaches

The use of analytical and imaging techniques to characterise artwork materials and the effects of conservation treatments also featured frequently in this collection, reflecting growing sophistication. Wills et al. carried out multi-instrumental characterisation of the ink used to vandalise Rothko's painting 'Black on Maroon' (Tate, T01170) to comprehensively identify the key ink colourants and to explore the possible effects of residual ink on canvas tensile properties [12]. Salem et al. investigated the impact of oxidative and reductive bleaching on cotton fibres via Atomic Force Microscopy (AFM), demonstrating that the treatment induced swelling, softening and rearrangement of the outermost layers [13]. Wilda et al. described the use of a portable Florescence Lifetime Imaging (FLIM) system to monitor in-situ varnish removal from easel paintings which offers specific discrimination of the varnish fluorescence from the fluorescence of other materials in the painting, as well as greater sensitivity for the detection of the presence and distribution of residual varnish [14]. Baij et al. used portable Fourier Transform Laser Speckle Imaging (FT-LSI) in combination with UV photography to investigate real-time solvent(s)-retention inside paint layers during and after varnish removal using Evolon® CR, highlighting the potential benefits and challenges of using LSI analysis in conservation practice. In addition, this provided insight into the motion of pigment particles induced by varnish removal solvents and helped to determine the optimal use of Evolon for the solvent-based removal of varnish from oil paintings [15]. Kavda et al. used unilateral NMR alongside other techniques to investigate the effects of polar and non-polar solvents on polymethyl methacrylate (PMMA). Although tests were performed using prolonged contact times, all solvents evaluated were found to induce sensitivity to surface abrasion, with ethanol deemed the most problematic [16]. Iwanicka et al. used Optical Coherence Tomography (OCT) and reflection FTIR spectroscopy on a painting by van Gogh to identify the materials and to distinguish between an artist's applied varnish and a non-original coating subsequently added during conservation treatment. This combination of techniques facilitated the fine-tuning of the removal of the later varnish and helped re-establish a balanced appearance to this artwork [17].

Wider context: the climate emergency

The collection expertly covers a range of heritage materials, cleaning systems and evaluation/characterisation tools and thus represents a snapshot of current foci in cleaning science. There have been (and continue to be) a range of welcome recent developments which help inform conservators re aspects of treatment design and execution such as solvent selection, enhanced control of cleaning action though gels and non-contact methods, enhanced cleaning efficacy and providing insight into the immediate (in-situ) and longer-term impacts of cleaning systems and processes. In addition, within the context of the climate emergency, sustainability and environmentally friendly practices have recently begun to underpin the development and modification of conservation materials, particularly around cleaning, as frequently featured in this collection. Alongside others, over the next few years, three European projects funded through the Horizon Europe Framework Programme—GreenArt (www.greenart-project.eu), GoGreen (https://courtauld.ac.uk/research/gogreen-project/) and MOXY (www.moxyproject.eu) will be contributing further to cleaning science and practice through developing, assessing and evaluating green cleaning systems across a range of conservation challenges. These projects at least in part focus on either developing new cleaning materials using renewable sources such as bio-based solvents and gel systems or recycled waste (Greenart, GoGreen), or for the MOXY project, avoiding the use of solvents and gels through exploring the potential of atomic oxygen for removing organic accretions, soot, and biological materials. The concept of 'green thinking' within daily conservation practice is central to these projects, particularly within the GoGreen project alongside the Sustainability in Conservation initiative.[1]

Sustainability in collaboration

This collection also illustrates the benefits and inherent potential within collaborations between industrial and academic scientists, museum and heritage scientists and conservators. This blend of skills, contexts, requirements, and perspectives can however be difficult to align to deliver both effective and impactful research, as well as practicability in conservation. However, it is important to remind ourselves that many of the tools and methodologies we use across the widest realms of conservation emerged from similar conversations between professionals with different training, skills, ideas, and new technologies; this collection contributes to that dialogue.

Communication within collaborations can still be challenged by fundamental tensions between the need to control and reduce variables for accuracy and rigour within scientific pursuits and the need to embrace, respect and represent complexity within conservation treatment and practice. However, more recently, the growing range of novel and modified systems available and the inclusion of conservators in primarily science-driven research has resulted in the effective uptake of novel cleaning systems, greater representation of case study treatments and advances in approaches. In addition, exploring the impact and efficacy of cleaning systems is becoming increasingly scientific as we continue to strive to understand these processes and interactions at the molecular scale as well as in-situ during treatment. It is also increasingly evident that alongside the development of new cleaning options and scientific tools, research falling within the realms of *conservation treatment* fundamentally requires conservation perspectives and inclusion to achieve the most effective and impactful collaborative outcomes.

As a final note, the editorial team are immensely grateful to and sincerely thank every author who contributed to this special collection for their time, expertise, knowledge, and unique research; we remain enthused by your contributions and future research directions. We are also grateful to the teams of paper reviewers, the editor-in-chief Richard Brereton, and Heritage Science for the invitation and opportunity to create this collection which we hope will inspire more collaborative research, new cleaning materials, instrumentation developments and applications and of course, successful conservation treatments.

[1] https://www.siconserve.org/greener-solvents/greener-solvents-handbook/. Accessed 9.11.23.

Author contributions
BAO lead the editorial team for the Cleaning and Conservation special collection; all authors contributed to the design of and invitations to contribute to the special collection, and liaised with primary authors; BAO lead the editorial paper; BAO, AB and KJvdB contributed text and all authors edited, read and agreed to the final version. All authors read and approved the final manuscript.

Declarations

Competing interests
Bronwyn Ormsby (Tate) is a current partner in the GreenArt project and Klaas Jan van den Berg (University of Amsterdam) is a current partner in the MOXY project. All other authors declare no competing interests.

Published online: 03 January 2024

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