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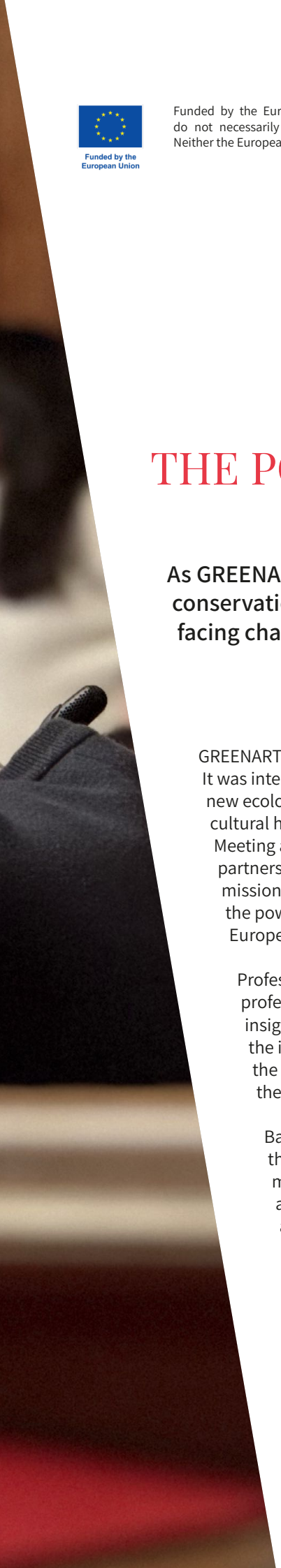

THE POWER OF COLLABORATION

As GREENART, a European project dubbed The future of cultural heritage conservation, enters its third year, partners are making progress, facing challenges and visualising the project's future.

GREENART launched in Athens, Greece, on 5 October 2022. It was intended as a three-year project to develop and promote new ecologically sensitive methods of restoring and conserving cultural heritage. At GREENART's 2nd Annual Consortium Meeting at the University of Ljubljana this past November, partners from across the world shared updates on their mission. According to organisers, the meeting "reinforced the power of collaboration and innovation in safeguarding Europe's cultural heritage while promoting sustainability."

Professor Piero Baglioni, an Italian chemist and University professor at the University of Florence, also offered insights into the project's future. Baglioni stressed the importance of continued collaboration between the project's partners, who are actively engaged in testing the innovations that have come out of the project so far.

Based on the findings presented at the meeting, the past year has produced significant gains towards more environmentally friendly tools, products and methods. Among the many topics addressed at the meeting were green cleaning systems, environmentally safe protective coatings, green consolidants and sustainable packaging materials as well as progress in dissemination, exploitation and communication of GREENART's work.

Green cleaning fluids

A wide variety of green cleaning fluids, hydrogels and microemulsions have been developed by GREENART's project partners. These products are vital for the safe and controlled removal of soil, dust and other detrimental layers from works of art. The goal is to replace existing adopted solvents with natural or bio-fluids. More than 10 new green cleaning fluids, four new hydrogels, and four new organogels were formulated by project partners in year one. Year two saw the development of additional products in all three categories as well as extensive assessment and testing of the products in real world examples.

Testing was conducted by an assortment of museums, collections and institutions collaborating in the project, and was conducted on a range of artefacts including canvas paintings, textiles, and sculptural objects made of stone, metal, ceramic and wood. In case examples involving three specific works — *Equilibrium* (1933-1934) by Jean Helion, *Untitled* (*composition*, 1955) by Tancredi Parmeggiani and *Croaking movement* (1946) by Jackson Pollock — modified PVA hydrogels displayed excellent cleaning capability. Gels with higher tortuosity were also found to perform better.

— Phillip Barcio

Green microemulsions were tested for cleaning efficacy compared to existing products. They were tested on Polaroid film on glass, vinyl polymers, acrylic polymers, natural resins and wax films (beeswax and paraffin) on glass. New PVA/Starch hydrogels were also tested for their ability to clean artworks, including assessments of molar mass variation, branching and solubility.

In the realm of new organogels, novel Polyester-enriched Castor oil polyurethanes were tested for their hydrophobicity. The organogels were tested on two oil on canvas easel paintings from the 18th and 19th centuries, and a polychrome wood sculpture from the 19th century. The goal of the test was to remove aged varnishes gradually with minimal impact on the paint layer. The test measured the practicality of removing varnish from the surface, the ease of preparation, the number of applications necessary, the ease of removing and rinsing the gels, the ease of application and efficiency of the varnish removal.

Tests showed that systems soaked in polar solvents (such as acetone and ethanol) are unsuitable for safely and precisely removing varnish from surfaces highly sensitive to these solvents. In contrast, organogels are more versatile and they enable a slow release of solvents, which, although softening the varnish layer more slowly than pure solvents, provides greater control and safety.

Tested hydrogels showed a disadvantage, with the varnish migrating poorly into the gel and swelling underneath. Testing on archeological metal objects revealed that cleaning with hydrogels resulted in better results with no residue compared to cleaning with cotton swabs. Less waste was also produced. Hydrogel testing is ongoing on a 19th century sword belt and an 18th century Handstein. When tested on two 20th century, unvarnished oil paintings on canvas, green hydrogels effectively removed surface dirt, but in some cases caused stains to the back of the painting, indicating absorption by the canvas support. In some cases, minute areas of colour were also lifted from the support.

When tested on artworks on paper, micro-emulsions with green gels did not succeed in removing varnish without solubilising. Green cleaning gels and fluids were also tested for their ability to remove adhesives from paper samples without altering or damaging the paper surface, and without leaning residues. In all cases, the removal of the adhesive was minimal. In one case, pure cotton paper had planar distortions due to the moisture of the materials.

Additional testing of GREENART's green cleaning fluids and gels has been done and is still being conducted, on a range of other artefacts, including Tibetan polychrome wood furniture, the door soffit from the *Damascus Room*, a late 15th century Italian velvet panel, the 17th century Torah Ark Curtain, a bronze sculpture by Alberto Giacometti and Antonio Bellucci's *The adoration of the Magi* (c.1682). The action plan for the next six months also includes further testing and assessment by project partners, including the Houston Museum of Fine Arts and the Peggy Guggenheim Collection.

Green protective coatings and consolidants

Protective coatings are added to the surfaces of artwork in order to stop the buildup of detrimental substances, while consolidants are utilised to mend, repair or hold together degraded elements of an artwork. Traditional protective materials are considered poor in terms of their durability and sustainability. The objective of this part of GREENART's project is to develop multifunctional green protective coatings and consolidants to provide long term protection for works of cultural heritage from pollutants, humidity and other degradation or corrosion agents. They should be easy to use, transparent and removable. This will allow conservators to preserve the original appearance of substrates and will ensure the long-term stability of both coatings and protected surfaces.

Year two of the project saw the further development of sustainable protective polymer coatings made from bio-based monomers or waterborne polyurethane (WPU). Among other factors, these coatings are being tested for hardness and adhesion strength. In 2024, synthesis of bio-based WPU was achieved and investigation of its anticorrosive and self-healing properties is now underway. Sustainable protective polymer coatings from renewable polymers are also currently being developed and tested. In 2024, organo-modified chitosan coatings with transparency, hydrophobic phases, anti-corrosion modified-graphene oxide with water resistance, and anti corrosive properties were realised. Filler-based hybrid coatings with anticorrosive properties and nanofillers based on Arginine were also realised.

Real world case studies of these products have been performed on archaeological artefacts, including metal objects and ceramics. Preliminary results indicate that novel biopolymer coatings are easy to apply by brushing, their effect on treated surfaces is satisfying and they do not leave brush strokes while drying. After one year, partners at the Peggy Guggenheim Foundation of Venice found that the passive biopolymer coatings

David Chelazzi

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Photo Eugene Kuznetsov

maintained good stability inside. Results suggest that they can prevent the accumulation of dust and dirt particles on surfaces, however, since some alteration compounds were detected, a corrosion inhibitor may be needed.

Going forward, additional tests of new green protective materials are scheduled to be conducted, including testing of drying time, mechanical properties, VIS and UVL behaviour, SEM/EDS imaging and analysis and measurements of thickness, glossiness and colour.

In the area of consolidants, natural adhesives such as animal glue, wax, starch and resin have historically been used for consolidation in paintings, but are noted for their poor stability and performance. Synthetic adhesives can form a coating layer that can damage artworks. Their incompatibility with the original substrates can also result in poor outcomes including deterioration of the artwork. GREENART's objective is to develop green consolidants to strengthen fragile works of art and their supports. In years one and two, several families of consolidants with promising results for paint layer and support, including frames, stretchers and panels, have been developed, and a selection process identifying the best candidates is ongoing.

Green packaging materials

Conventional packaging materials for storing and transporting artefacts are unsustainable, hydrolysable, non-recyclable and have been found to insufficiently protect the objects. GREENART's objective is to develop green packing materials or foams for the safe storage and transport of these artefacts. In years one and two, several new packaging materials, multifunctional foams and enhanced replacement materials have been realised and selection of the best candidates is ongoing. A wide and fully comprehensive set of case studies was identified in year two and artworks made from textile, metal, wood, stone and plastic are currently being evaluated.

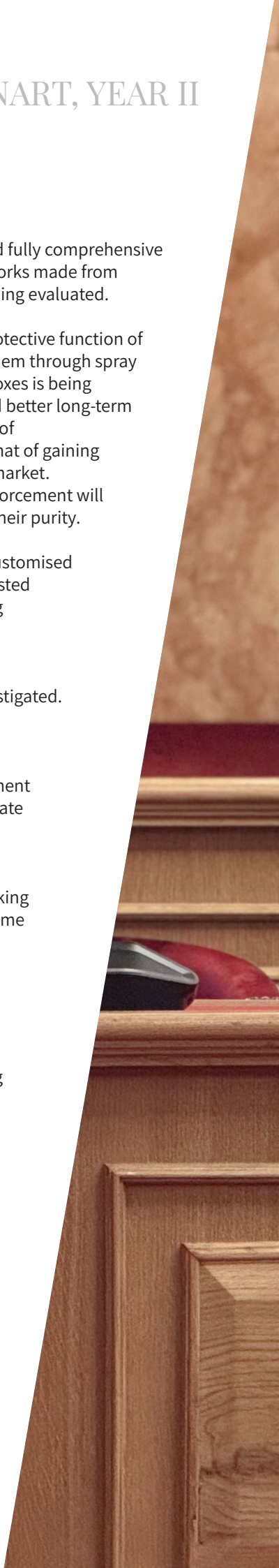
Work was also performed in year two to extend the protective function of naturally aged archive boxes, including refurbishing them through spray deacidification. Virgin wood fibre content in archive boxes is being reduced, as materials with higher moisture barrier and better long-term stability and no VOC absorption are being tested. One of the challenges identified in this area in year two was that of gaining acceptance of new products within the conservation market. Acceptance will require high marketing efforts and enforcement will also be required to regulate bio-based materials and their purity.

Among the specific sustainable and multifunctional customised packaging solutions currently being developed and tested by the project is one to realise a customised packaging solution for *Box in a valise* (1941) by Marcel Duchamp. Scans of the object have been concluded to realise a packaging solution through 3D printing. Advanced Metal-Organic Frameworks (MOFs) are also being investigated.

Dissemination, exploitation and communication

It was noted at the meeting that GREENART's success is dependent on the project partners' ability to implement effective exploitation of innovations and to communicate and disseminate information and knowledge about the project's progress. That plan includes publications of scientific papers, dissemination of information to journalistic outlets and taking advantage of networking opportunities with other groups. As more parties become aware of the project, increased exploitation becomes possible as new partners innovate other possible uses for the project's technologies.

Under the supervision of Antonio Mirabile, whose role as the primary link between heritage institutions and scientific research has been instrumental in enhancing the project's impact and dissemination, year two saw tremendous growth in this area. GREENART project results were presented in 16 international conferences and 19 sectoral meetings, 20 dissemination articles focusing on topics related to the GREENART project were presented, 17 training events were organised during which the GREENART project was presented, 17 scientific publications have been produced and 6 others were submitted for publication. GREENART partners participated in multiple networking clusters with other like-minded groups of citizens, and a project video was created. Additional dissemination goals going forward include continued work on the project website, activations on the project's social media channels, participation in European and international conferences, and the publication of additional articles in various publications.



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