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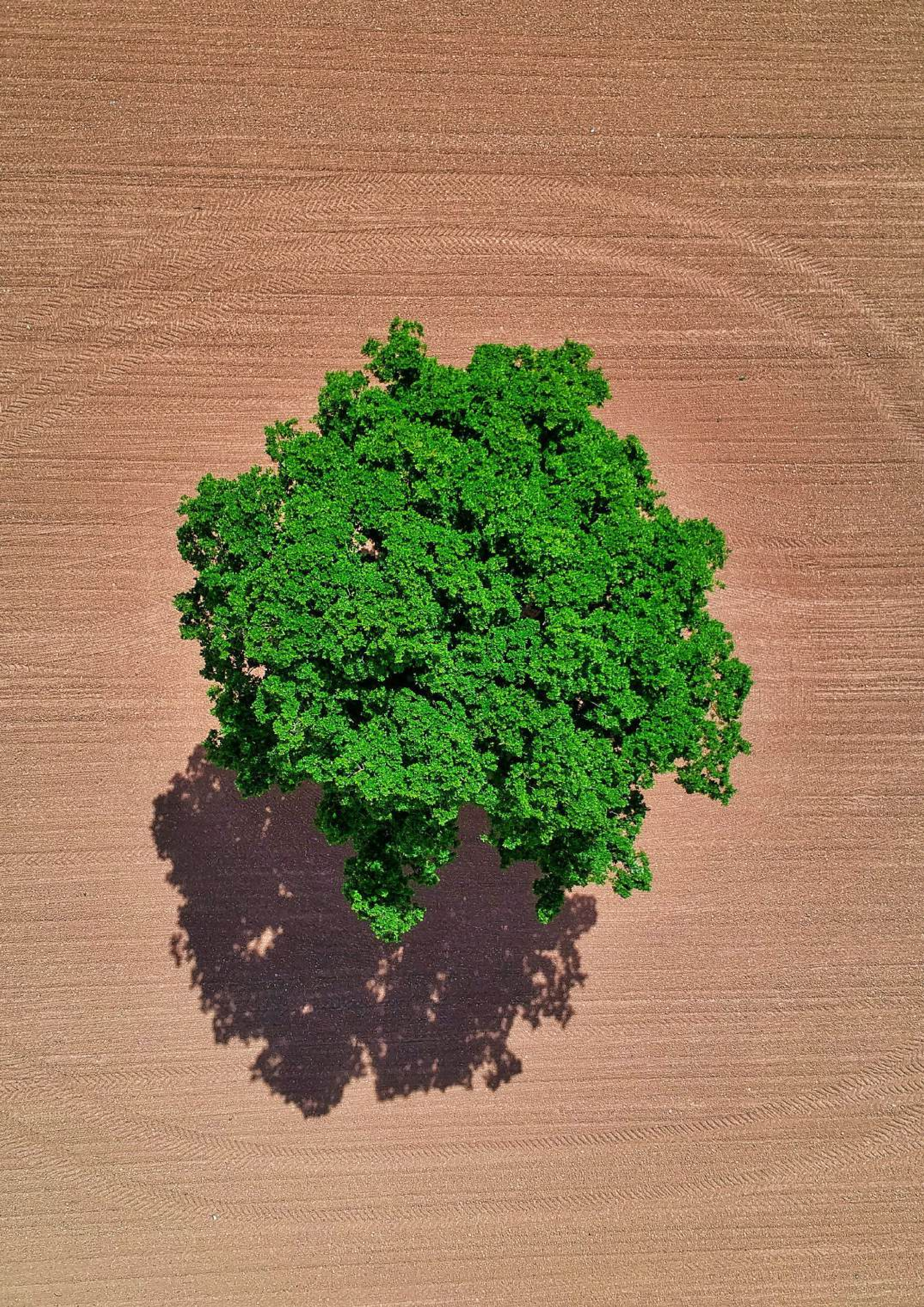

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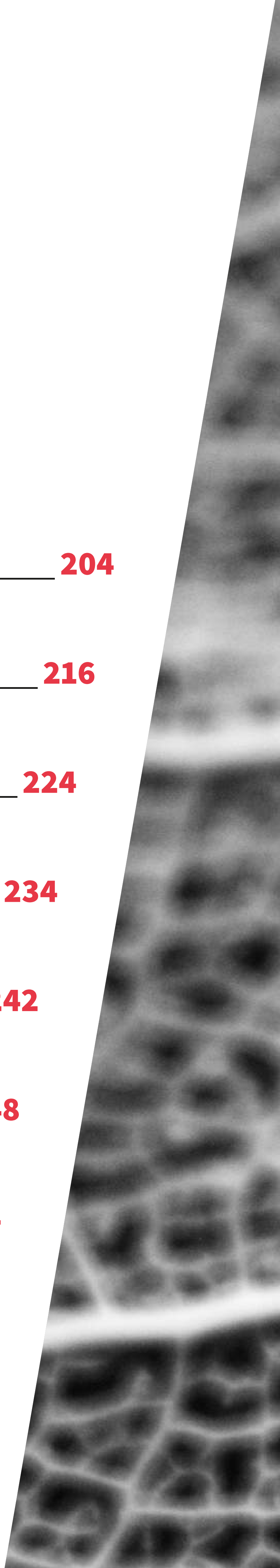


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GREENART

FROM VISION TO PRACTICE

The GREENART Project brings together scientists, conservators and institutions to pioneer sustainable methods for protecting cultural heritage, demonstrating that caring for artworks and monuments must go hand in hand with caring for the planet that sustains them.

The GREENART Project (October 2022-September 2025), funded by the European Union's Horizon Europe programme, emerged from a fundamental question: how can we protect cultural heritage without compromising the planet that sustains it? Responding to this challenge, GREENART brought together a diverse consortium of scientists, conservators, institutions and innovators committed to reimagining the tools and methods of conservation in environmentally responsible ways.

From the outset, GREENART was not simply a scientific endeavour. It was an attempt to build a new ecosystem, one in which materials science, heritage ethics, sustainability, and practical conservation work in concert. It explored how bio-based materials could replace petrochemical ones, how cleaning systems could be both effective and safe, how packaging and consolidation methods could serve both artworks and the environment. But it also addressed a broader transformation: a shift in thinking, where conservation is not only about preserving objects, but about protecting the fragile balance between culture and ecology.

Dissemination was at the heart of this vision. Over three years, 35 articles were published in the AMA Newsletter, each reflecting a key moment in the project's evolution. These texts trace a path from policy debates and conceptual frameworks, through methodological development, to the implementation of GREENART solutions in world-class institutions such as Tate (London), the Metropolitan Museum of Art (New York), LACMA (Los Angeles), the Peggy Guggenheim Collection (Venice), the Hungarian National Museum (Budapest), the Museum of Fine Arts (Houston) and the Italian Ministry of Culture (MiC — Soprintendenza ABAP Chieti-Pescara).

The articles reveal the arc of GREENART's journey: from visionary reflection to measurable results. They highlight not only the technical advances achieved, but also the collaborative spirit that made them possible. Throughout, GREENART has been grounded in dialogue, between disciplines, between generations of professionals, and between the past we inherit and the future we are trying to shape.

Together, these texts offer more than a record of a European research project. They capture a moment of transformation in conservation science, where care for cultural heritage is inseparable from care for the planet — and where the laboratory, the studio and the museum become places not only of preservation, but of environmental responsibility and hope.

— Antonio Mirabile

WIDE ANGLE

Photo Maxim Kotov

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EUROPE FUNDS GREEN AND OPEN RESEARCH FOR ITS HERITAGE

European funding for research and innovation is going green. A complex architecture involving institutional and private actors, notably for the preservation of cultural heritage.

Horizon Europe 2021-2027 is the European Commission's flagship programme for funding research and innovation, supporting a wide range of projects to accompany the social, economic, technological and cultural transformations of the countries of the Union, for them to become "healthier" democracies where cultural values are protected.

"Culture, creativity and inclusive society"

Within this programme, a cluster called Cluster 2 is dedicated to the theme of "Culture, creativity and inclusive society". Coordinated by the European Research Executive Agency, a call for projects was launched last June. With an overall budget of €158m, 51 projects were selected from the 378 applications received following the consultation, which ended on 7 October. The project leaders who just signed their grant agreements with the European Commission are divided into four main thematic families: "Feeding democracy in the face of emerging threats"; "Building a concrete trade policy through supply chains"; "Engaging with cultural actors" and "Protecting European cultural heritage for future generations".

Financing culture and heritage projects

While the first strands focus on protecting the values of democracy and securing trade relations in a post-pandemic world, with war on Europe's doorstep, the last two focuses on culture and heritage. The projects selected for the call "Engaging with cultural actors" are rather monitoring and support missions, intended to make the European funding schemes known to the actors involved. Thus, the ARCHE project will focus on the development of a pan-European framework for European cultural heritage research, while the Net4SocietyHE project will establish transnational networks to advise potential beneficiaries of community funding.

The call, on its part, encompassing the protection of European cultural heritage, was extremely diverse. This subject is at the heart of current European political concerns: it constitutes a crucial societal and economic resource, promoting resilience, inclusion, job creation, etc. It is nonetheless also endangered by the environmental, economic and social risks that Europe is experiencing. Aiming for long- term perspectives so that future generations can seize such heritage issues, the criteria of accessibility — both digital and physical — and of openness prevailed in the selection process. Projects such as IN SITU offers to put these guidelines into practice by studying how to encourage cultural and creative industries in non-urban areas, which have long been forgotten in the field of cultural heritage. Others, such as MuseIT,

— Antonio Mirabile and Carine Claude

PREMIERE and SHIFT focus on the role of technology, virtual reality and artificial intelligence in museums and in the performing arts.

Three innovative projects for green conservation

Heritage implies conservation, preservation and transmission, whether of works, knowledge or sites. Three innovative projects have been selected to support a green transition towards new conservation practices: GoGreen, MOXY and GREENART. Their goal? To develop new materials for the restoration of works of art in an environmentally responsible manner. The three projects aim to test active principles in the development or industrialisation phase, in order to adapt them to more sustainable conservation-restoration goals.

With a budget of €3.272m allocated by Europe, GoGreen is coordinated by the University of Amsterdam and brings together eight participants — professionals, research laboratories such as the CNRS and other universities, the University of Bologna for instance. At the heart of this open research, the methods are inspired by nature and bio-based with green solvents, reagents from nature and ecological delivery systems. The entire chain is engaged, from cleaning to stabilising works of art, including transport and an application to help restorers design ecological preventive and corrective conservation treatments.

On its side, the MOXY programme is based on a sophisticated technology, but simple idea: atomic oxygen to clean the delicate surfaces of works of art, without contact, without risk to health or the environment, without residue or waste. Certainly more environmentally friendly than conventional solvents. The €4m project, coordinated by Ghent University, brings together plasma specialists, environmental scientists and curators from the Netherlands, Lithuania, France, Sweden, Denmark and Italy.

Finally, GREENART — which we will be reporting on in future issues [see box] — is an ambitious international programme that brings together 27 partners — and not just European ones — for a period of 36 months and a budget of €3.8m given by Europe. Its goal? To develop innovative solutions for corrective and preventive conservation while meeting the requirements of the Green Deal, i.e. using low-impact, environmentally friendly materials obtained from renewable natural sources or recycled waste.

GREENART, towards Europe and beyond

Coordinated by the Consorzio Interuniversitario per lo Sviluppo dei Sistemi a Grande Interfase (CSGI), an inter-university consortium based in Florence, GREENART brings together an impressive number of leading European research institutes and universities, as well as professionals in the sector and major international museums such as the Solomon Guggenheim Foundation – Peggy Guggenheim Collection, LACMA, the Tate Gallery and the prestigious Metropolitan Museum of Art (MET). Although the American and British partners are not direct beneficiaries of European funds, they are actively involved in the research initiated by GREENART.

The first aspect of their research involves curative conservation. This entails replacing existing polymers, solvents and surfactants with biological, natural or low-impact materials that are fully sustainable. The second part of the research focuses on systems to replace traditional consolidants, coatings and packaging materials with plant proteins and polysaccharides from renewable resources. For example, protective coatings from cellulose waste or even shellfish, or biodegradable packaging foam, all of which are, of course, non-invasive and reversible.

Launched on 5-6 October in Athens at the Egaleo Park Campus Conference Centre Egaleo Park campus, the first meeting of all 27 GREENART partners was hosted by the CSGI, Piero Baglioni, project coordinator, Antonio Mirabile, dissemination manager and Athina Alexopoulou from the University of West Attica (UNIWA). A moment of exchange and sharing, already bearing fruit thanks to the working groups that have been formed. The first meeting of a long series: the partners will have three years to complete their projects.

All about GREENART with AMA

In many different issues of AMA, people got a chance to go behind the scenes of the GREENART project and discover how academics, curators, engineers and restorers are combining their knowledge and expertise to move heritage research towards a greener future. Exclusive interviews, surveys and reports gave an insider's view of the developments of this innovative European project, which combines heritage science, open research and citizen initiatives. AMA followed GREENART during the three-year programme and will seize the opportunity to go green with subjects devoted to art and ecology, to the green transition of museums, the eco-design of fairs and other initiatives of curators and restorers, currently reinventing their profession through ongoing ecological innovation.

The reversal of a paradigm (2020), Fabrizio Cotognini

Courtesy Fabrizio Cotognini. Antonio Mirabile


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TOWARDS AN INNOVATIVE AND GREEN CONSERVATION-RESTORATION

Under the leadership of the Community Research and Development Information Service (CORDIS), all the collaborators of the Green Endeavour in Art Restoration (GREENART) project gathered in Athens on 5 and 6 October. An opportunity for everyone to get to know each other and discuss their missions.

Scientists and professionals from the world of conservation-restoration are working hand in hand under the aegis of the European Commission, in order to set up greener and more sustainable cleaning, consolidation and protection systems. The 27 partners join their forces to tackle an unprecedented ecological crisis and reduce the environmental impact of their field.

CORDIS is "the European Commission's main source for projects funded by the European Union's Framework Programmes for reflection and innovation, from FP1 to Horizon Europe". It shares the results of cutting-edge surveys with professionals in the field, thus fostering open research and the creation of innovative products and activities. GREENART was born within this initiative, sponsored by Athanasios Gerakis who opened the kick-off meeting on 5 and 6 October in Athens. Under the umbrella name, several programmes get funded by the European Union to develop new, greener tools to restore works of art. The three projects aim to test active principles in their development or industrialisation phase, so they can be adapted to more sustainable conservation and restoration practices for works of art.

Collective efficiency

Orchestrated by the project coordinator Piero Baglioni, these two days of discussions and presentations enabled research laboratories to share their latest advances with the main users of their products such as museums, with Tate or the Metropolitan Museum of Art, for instance, attending the event. Each partner-participant was divided into seven working groups. Before launching the presentations of each branch of GREENART and developing each work package, Athanasios Gerakis presented the general context, emphasising the importance of dissemination and communication of scientific research results. The three projects led by his unit (REA Unit C1) revolve around heritage and its conservation, adapting to the current issues of sustainability and ecology. It is part of a programme whose vocation is to work on culture, creativity and climate — among others — or a more inclusive society. Engineering and technology are put at the service of the planet: GREENART is based on the observation that heritage conservation preserves monuments and works of art while, paradoxically, using toxic and unsustainable materials that degrade the environment. Museums, too, are highly energy-consuming because of their thermal regulation systems… Yet the climate crisis is impacting

— Antonio Mirabile and Jeanne Mathas

material cultural heritage. Hence the project, determined to fighting against its harmful effects through new propositions and adequate alternatives.

Innovate

One of the three projects, GoGreen, promotes preventive and curative conservation practices based on ecological principles, spearheading a green revolution in heritage preservation. How so? By developing, among other things, innovative tools inspired by nature and historical conservation treatments for curative conservation — with a particular focus on innovative cleaning solutions, especially for paints and metals. Another key point lies in the testing and evaluation of materials and formulas using advanced analytical techniques and reference processes.

The second project, MOXY, aims to redefine the paradigm of cleaning methodology through an eco-conscious approach by creating a green, contactless, transformative technology based on atomic oxygen. This technology allows for selective, non-mechanical and liquid-free cleaning, with no health or environmental risks, and no residues or waste.

The third project, GREENART, proposes new solutions based on ecological and sustainable materials and techniques to preserve, conserve and restore: protective coatings from industrial waste materials or plant proteins; foams and packaging equipment or consolidants made with biodegradable or compostable polymers from renewable sources. A toolkit for conservation specialists who want to embrace a more environmentally friendly practice.

Each of these programmes takes a holistic approach and is based on multidisciplinary partnerships, bringing together hard sciences, soft sciences and engineering. Academic centres, innovative industries and SMEs, institutions and professionals in conservation, museums, public bodies and policy-makers, they all work together. The final link, not to be overlooked, resides in the actors who promote training, knowledge sharing and circulation to familiarise potential users with these cutting-edge methods.

A human and scientific adventure

In order to carry out each of these missions, the GREENART global project is organised into work groups, seven in total. Each one focuses on a research, application or expertise area. From scientific and financial management to circulation through effective communication and training, ecological cleaning systems, protective coatings, consolidants and packaging materials, technologies for heritage monitoring; each WP is united under the “green” banner as well as the supervision of the safety of these new materials and their sustainability. Following the introduction by Athanasios Gerakis, the presentations were organised according to the working groups, each one presented by one of its participants, tackling approaches, goals, etc., then developed collectively.

The kick-off meeting brought together different types of partners: Europeans — funded by the European Commission, but also external participants. For the latter, the project stands as a privileged platform for the sharing of technological advances. At the same time, GREENART allows them to have access to and learn about the innovations implemented within the framework of the programme.

Thus, a European project, but with a much broader scope. These presentations were an opportunity for everyone to meet each other. It was also the occasion to get introduced to the structure better and to go into more detail on specific technical points, such as the construction of reports or the conditions attached to funding. A launch day that gave its partners the keys to successful missions; the tools to understand the involvement of each instance in the realisation of this innovative project.

GREENART encompasses all actors, academic and socio-economic, covering the whole chain to ensure a clear impact on conservation-restoration. The project’s unique composition, combined with the integration of professionals’ apprenticeship through modules and courses for conservation training, ensures that the next generation of conservators and conservators is fully prepared to embrace the Green Deal.

This kick-off meeting felt like a convivial gathering. It was an informative and studious reunion in the heart of the Conference Centre of the Egaleo Park campus of the University of West Attica University in Athens. The day provided an opportunity to better understand the roles of each partner and the ecosystem in which everyone has a responsibility to move towards greater sustainability and ecology in conservation-restoration practices. And with the emphasis put in the opening speech on communication, the importance of shared knowledge, GREENART shows its willingness to exchange with citizens, so that they, too, can act and choose to commit, for a greener heritage preservation.

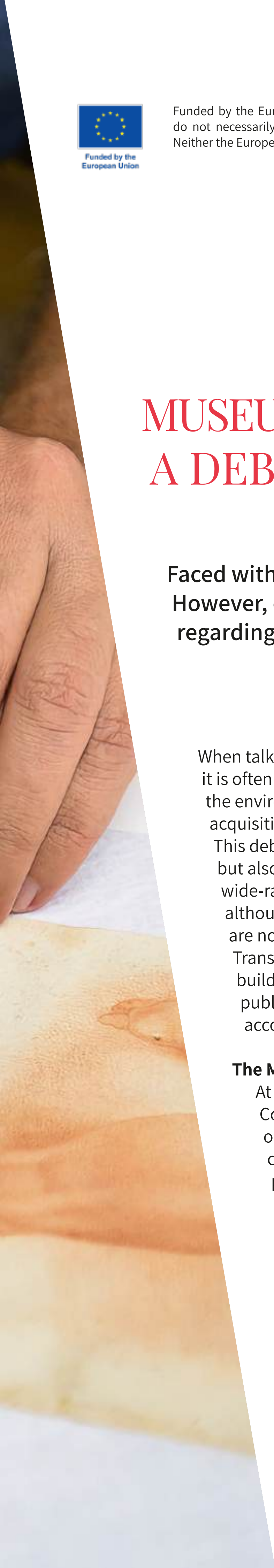
La Tierra de Algallù (*House*, 2019), Sandra Vásquez de la Horra

Kick-off meeting of the GREEART project

Courtesy University of West Attica

FOCUS

Antonio Mirabile



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GREENART

MUSEUMS AND SUSTAINABLE DEVELOPMENT: A DEBATE WITHOUT BORDER

Faced with the climate emergency, museums are adapting to reduce their footprint. However, eco-responsibility and sustainable development raise new issues regarding the design, organisation and management of museums.

When talking about sustainable development in museums, it is often tempting to evoke the antagonism of two missions: the environmental requirements, and the need to develop acquisition and dissemination policies for heritage collections. This debate must be carried by every museum professional, but also by the public and political authorities. It must also be wide-ranging and not only focus on the issue of exhibitions: although this is what is visible to the general public, they are not the only ones concerned by eco-responsibility… Transport, air-conditioning of storerooms, inertia of buildings, conservation, and even movement of the public are all elements that must be taken into account in their carbon footprint.

The Melbourne declaration

At the International Institute for Conservation (IIC) Congress in Hong Kong and the International Council of Museums — Committee for Conservation (ICOM-CC) conference in Melbourne in September 2014, professionals in conservation and heritage science discussed and endorsed the following statement:

Sustainability and Management: The issue of sustainability in museums is much broader than the discussion of environmental standards. It must be a key underlying criterion of future principles. Museums must seek to reduce their carbon footprint and environmental impact in order to mitigate climate change, by reducing their energy consumption and exploring alternative renewable energy sources. Preservation of collections should be achieved in a way that does not involve HVAC (Heating, Ventilation and Air-Conditioning): passive methods, simple and easy-to-maintain technologies, air circulation, and low energy solutions should be considered. Risk management should be integrated into museum management processes.

Museum environment: The environmental requirements of collections and materials are complex, but the task of understanding and explaining these complexities falls to conservators and heritage scientists. Guidelines for environmental conditions for permanent display and storage must be achievable with local human, financial and material resources.

Loans: There is a need to be transparent about the actual environmental conditions achieved in museums to ensure that realistic requirements are made for loan conditions. Most museums around the world do not have climate control systems in their exhibition and storage spaces.

— Antonio Mirabile

For international loans of works, a document would therefore be needed to inform the environmental conditions of display and storage of the collections of any museum. If some museums do not meet the parameters set by the guidelines, a certain amount of flexibility could be allowed in the implementation of these environmental conditions, notably through alternative strategies — the creation of microclimates adapted to the vulnerability of the work of art, for instance.

A necessary but complex adaptation

The recommendations of the Melbourne Declaration remain difficult to adopt. Museums operate with conservation standards established over 40 years ago; the context was very different then. Built and developed around a fossil fuel model, their growth was supported by public investment and justified by employment and economic benefits. Today, museums — as well as companies — need to assess their carbon footprint to design solutions for the immediate future. We need to recognise the work that has been achieved and determine what remains to be done.

For example, a large French museum emits about 9,000 tonnes of CO_2 per year, the equivalent of the footprint of 800 citizens. As a factor of attraction and wealth, culture attracts French and foreign tourists and contributes 2.2% of the gross domestic product. The equation is simple: culture is highly profitable, but it is also a major source of pollution.

Reduce the carbon footprint of conservation, reduce energy consumption, and promote "zero energy" (to heat buildings of heritage interest or manage the climate of new reserves), rethink packaging methods and materials, and find substitutes for plastics wherever possible, evaluate and reduce the risks of pollution due to harmful substances and products, deal with the problem of waste of all kinds (in large and small quantities), rethink the issue of transport, set up "short circuits", integrate protective obligations into public contracts, etc. We also need to review exhibition policies: these temporary events generate income, knowledge, and attractiveness, but the large amount of scenographic material and the travel of the works in air-conditioned boxes devour a great deal of energy.

Questions of method

For some years now, some museums have been applying methods to reduce their carbon footprint, while others have been modifying their exhibition production approaches, and questioning the sometimes contradictory injunctions regarding their mission of opening up to as many people as possible. Museums have a responsibility to inform and convince their visitors and influence their perceptions and behaviour. How can this be integrated into the design of exhibitions and, more generally, into its cultural programming? The debate knows no boundaries: museums for a dense global network, structured for three quarters of a century by ICOM, whose influence could be decisive if efforts converge.

"Thinking about ecology in museums cannot and must not be done from the angle of renunciation," explained Valérie Donzeaud, deputy general administrator of the Musée d'Orsay. On the contrary, it is a cross-cutting issue that must permeate all the museum's thinking. I am working to put in place a strategy whose objective is to answer the question: how does a museum serve society? We therefore start from all the institution's missions to consider how they can respond to objectives in terms of ecology, but also gender equality, accessibility, and social justice. Sustainable development can only be relevant if it involves all the staff, and not if it is just another prerogative in the performance of everyone's duties."

While the issues of conservation of works, scenography, research, and education intersect in the organisation of museums, sustainable development is gradually becoming a new dimension to be taken into account in all fields of human activity. It poses new problems for the design, structure and operation of public institutions. Science museums are already dealing with the climate. Natural history museums are talking about bio and cultural diversity. Fine arts museums are now allowing artists to express their doubts and commitments to environmental issues. Museums have thus begun to include their questions about the relationship between man and nature in their programming. It is not surprising, then, to see them invest in the same way in the issue of sustainable development.

Kinetic Martyrdom (2013), Michael Landy
Courtesy Antonio Mirabile

Photo Ross Sneddon

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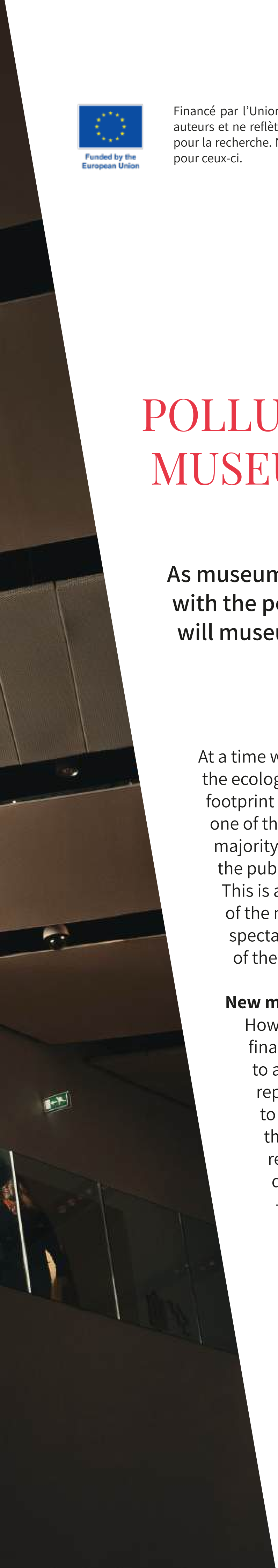

POLLUTING VISITORS: MUSEUMS' HEADACHE

As museum attendance soars, museums are increasingly faced with the pollution generated by their visitors. To be greener, will museums have to become "decreasing"?

At a time when museums are increasing their commitment to the ecological transition, eco-design, waste reduction, carbon footprint and energy consumption, they are coming up against one of their main sources of pollution: visitor travel. The vast majority of greenhouse gas emissions in museums come from the public, in a proportion that can reach 90% for the Louvre. This is a paradox at a time when the communication strategy of the major international museums highlights the ever more spectacular increases in their attendance, particularly that of their foreign visitors.

New models to be invented

How can we reconcile the mission of preserving heritage, financial balance, sustainable objectives and transmission to as many people as possible? In January 2022, representatives of French museums met in Lille to reflect on new development models that take all these parameters into account. "We need to totally rethink the model of the last thirty years," Sylvain Amic, director of the Réunion des musées métropolitains — Rouen Normandie, told France Info. Until now, a successful museum was a museum with infinite growth, which grew richer and larger and had queues of people who came from far away to see paintings that had arrived at great expense from the ends of the earth. Clearly, that model is dying out.

Does this mean that the era of blockbuster exhibitions is over? In Lille, the people in charge of these museums recommend "less spectacular, longer and more intelligent" exhibitions that do not necessarily attract millions of visitors.

In a forthcoming issue on heritage visitors, the social science journal *In Situ* raises the delicate question of the balance between "too much" and "not enough". And how to evaluate it. For museums to be sustainable, do they necessarily need to regulate or reduce the number of visitors?

"The opening of museums to a large public is at the heart of their cultural redefinition," wrote Catherine Ballé, honorary director of research at the CNRS and specialist in the sociology of organisations, in the article "Change, museums and sustainable development" published in *Museums and Sustainable Development* in 2011. "Attendance is becoming a criterion and a measure of success, even if success has a price. In this collective work resulting from a collaboration between France and Quebec, she returned to the transformation of museums in the face of the challenges of sustainable development and its economic consequences." The arrival of a large number of visitors in museums leads to a review of their

— Carine Claude

Photo Alicia Steels

operation and organisation: exhibitions and events, cultural and commercial services, development and multiplication of spaces. The increase and diversification of activities have led to the expansion of functional services: management, administration, organisation, finance and communication. This evolution reinforces the weight of the economic logic that museums obey, or rather do not escape."

Knowing the pollutants, controlling the environment

Faced with a growing number of visitors, the control of the museum environment is an old question. In 1973, Garry Thomson, in his article "How to organise the preservation of our cultural heritage" published in the UNESCO magazine *Museum*, took stock of the pollution linked to museum attendance.

The main enemy of works of art: dust. "Every museum, even if it does not plan to set up a restoration service, must take very seriously the problem of controlling its internal environment, so as to reduce to a minimum, with the means at its disposal, the deterioration of its collections […]. The accession of visitors brings in dusty air, whereas conservation requires the absence of any pollution, of any form of energy (light or heat) that might cause chemical reactions, and of constant conditions."

For a museum is not a watertight box. Whether through the ventilation systems or through the entrance of visitors, atmospheric pollutants settle in and degrade the works. Michel Dubus, a research engineer at the C2RMF, the French museum research and restoration centre, has taken an interest in the nature and pathways of these pollutants inside the museum. Particles and gases which, combined with humidity, can cause rapid and sometimes irreparable damage. For example, dust promotes the corrosion of metals and the development of fungi on graphic documents, while volatile organic compounds discolour photographs. "In museums, pollutants enter the building with the new air (soot, clays, calcite, quartz, exhaust fumes, pollens, spores, insect eggs, marine aerosols) or with visitors (textile fibres, dander, hair, food debris, viruses, bacteria)," he lists in his 2014 article "How to limit pollutants in museums". He adds, "The more complex the tour, the greater the number and agitation of visitors, the greater the dusting."

A balance to be found

Two main strategies can be implemented: limit them before they enter the museum, or try to control them once they are in. As early as 1995, the Quebec Conservation Centre reviewed the harmful effects of pollutants that can enter museums with the constant comings and goings of the public and recommended a number of preventive measures. Compiled in a *Manual of Preventive Conservation in Museums*, these measures are often common sense. These include: providing a vestibule after the entrance of visitors, especially for those with a high frequency of opening to the outside world, to create an airlock before entering the museum itself; placing carpets in the entrance hall to reduce the amount of soil and other large particles - provided it is made of good quality curly fibres and regularly dusted; or fitting ventilation systems with special filters, for example with activated carbon to limit small particles and gaseous pollutants.

These actions reduce the risks, but do not eliminate all the problems. "How can we control the pollutants, the corrosiveness of the air?" asks Michel Dubus. "We have no power over atmospheric pollution, but we can filter the new air, check that the building's operation is in line with its initial design, and adapt the visitors' route to the collections. Inside we have to adapt the decorative materials to the materiality of the collections, filter the return air, control the procedures." A subtle balance to be found between the layout of the premises, public movement and protection of the collections. Or as the Quebec Conservation Centre summarises it: "Make sure to use all available means to filter the pollutants generated outside or inside the building itself. Let's welcome visitors, but let's get rid of the pollutants!"

To limit pollution without sacrificing attendance, the Sistine Chapel had implemented a radical solution: dusting visitors. "The Sistine Chapel was in danger of becoming a victim of its own success," lamented Antonio Paolucci, the former director of the Vatican Museums, in *The Guardian*. For 100 metres before the entrance, a carpet cleans shoes. Inside, vents suck dust from clothes. And the temperature has been lowered to reduce the heat and humidity of the bodies. It doesn't matter how many visitors there are, as long as they are clean.

Photo Grant Ritchie

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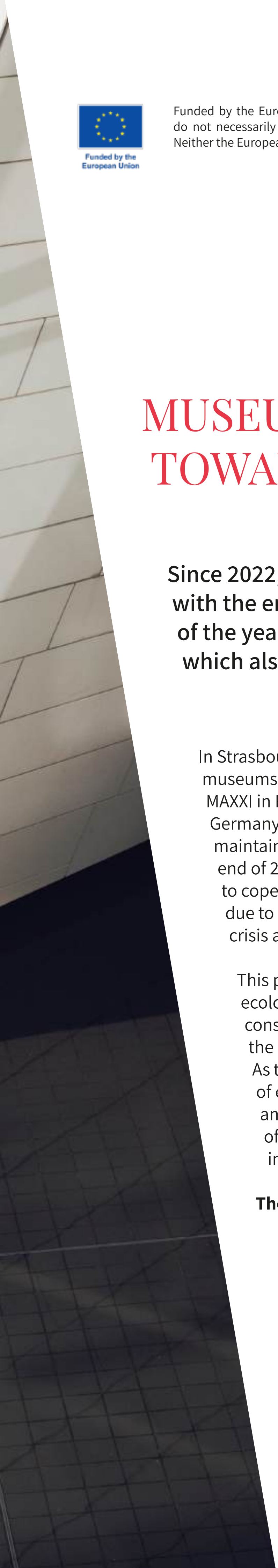
Louis Vuitton Foundation

Courtesy Paul Gaudriault



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MUSEUM ARCHITECTURE: ON THE WAY TOWARDS SUSTAINABLE DEVELOPMENT?

Since 2022, European museums have reported difficulties in dealing with the energy crisis. As the situation has become critical at the beginning of the year, institutions are compelled to scrutinise their expenses, which also reside in the architecture and the very structure of their buildings.

In Strasbourg, the decision last October to close the city's museums two days a week caused quite a stir. In Italy, the MAXXI in Rome reduced its opening hours by two hours, while in Germany, Claudia Roth, Minister of State for Culture, vowed to maintain the country's cultural offerings at all costs. Since the end of 2022, European institutions have had to take measures to cope with the increase in their energy expenses, as much due to intense consumption peaks since the end of the health crisis as to price increases resulting from the war in Ukraine.

This pressure has highlighted the interest in an accelerated ecological transition to reduce costs induced by energy consumption, where the use of renewable sources and the reduction of carbon footprint go hand in hand. As the activities of a museum involve a large number of elements requiring significant and continuous amounts of energy, it is clear that the very architecture of buildings has long neglected to take such issues into account. What about today?

The first museums

It was during the 18th century that the first museums appeared in Europe, built around curiosity cabinets and private collections. By the end of the century, two models emerged: the Pio-Clementino Museum in the Vatican and the Museum Fridericianum in Kassel. They combined functional principles — in the display of works with, for example, paintings associated with rooms and sculptures with galleries — and symbolic principles — embodied by the dome, reflecting the sacred space of knowledge and memory.

In 1802, the ideas of architect and theorist Jean-Nicolas-Louis Durand gave birth to new institutions in Europe and introduced new materials such as iron in their construction. In the mid-19th century, this momentum found its concrete forms in the use of glass, cast iron, or steel. The space and architectural ambition of museums allowed for real revolutions in the urban landscape.

The expansion and gradual diversification of inalienable museum collections raised the issue of storage and conservation space. In the mid-20th century, Le Corbusier offered modern solutions with the concept of the "museum of unlimited growth," the possibilities of internal rearrangements allowing it to adapt to any evolution.

Contemporary museum architecture oscillates between a neutral framework aiming to enhance the collections it contains and the architectural work, like the spiral structure of the Guggenheim in New York, built in 1959. Following

— Diotima Schuck

Guggenheim Bilbao

Photo Pedro Sanz

the same trend, the Guggenheim Bilbao, created in 1997, was designed by Frank Gehry, who has been involved in numerous museum projects where form dissociates from function: the Louis Vuitton Foundation in Paris or the LUMA Foundation in Arles. He is, of course, not the only one. Because the museum also allows its architect to propose a vision, their own. But what place is given to ecology and sustainable development in these projects?

Environmental awareness

In museums, the issue of the environment emerges in the 20th century. Initially presented in the form of scientific knowledge, climate is introduced through its role in the various stages of the planet's transformation. The human impact on it is not yet considered, and knowledge remains limited.

While the environment is present in the themes addressed by the museum, it appears in an informative and educational context. The social role of such an institution truly emerges in the 1960s. It then becomes a place of education, pedagogy, and opens up to ecology, stimulated by the nascent dialogue between the exhibited works and the public.

In 1992, the UNESCO-ICOM Museum Information Centre published a list of works dealing with the subject. The discourse turns towards ecological awareness and awakens to the direct impact of museum practices on the environment. In the United States, the American Alliance of Museums (AAM) created the Committee on Environment and Sustainability in 1994 — which became the Green Alliance in 2008 — and proposed sustainable development standards in good museum practices. The same year, the Association of European Museums (AEM) undertook steps allowing a report on the sustainable museum to be published.

Although museum networks and organisations have committed to reducing their environmental impact and adopting sustainable practices since the 1990s, there remains a gap between widespread awareness and its implementation. It is not until the 2000s, at least, that the ecological impact of museum architecture can begin to be taken into account, as demonstrated by the Pompidou-Metz Centre in France, opened in 2010.

Energy expenses

Initially constrained by the capacity of their reception spaces facing an ever-growing audience and by their storage potential for works of art, museums now also undertake renovation projects to meet the need to develop more sustainable practices. In particular, old buildings represent significant challenges, often requiring costly restructuring.

Building operation and maintenance, lighting and temperature control, artwork transportation… A museum's activities require significant and continuous amounts of energy. From a sustainable development perspective, all these elements need to be analysed and rethought, including the building's thermal performance, heating and air conditioning systems, internal and external human circulation, water and fluid management, waste production… even the products offered for sale in the museum shop or its dining area.

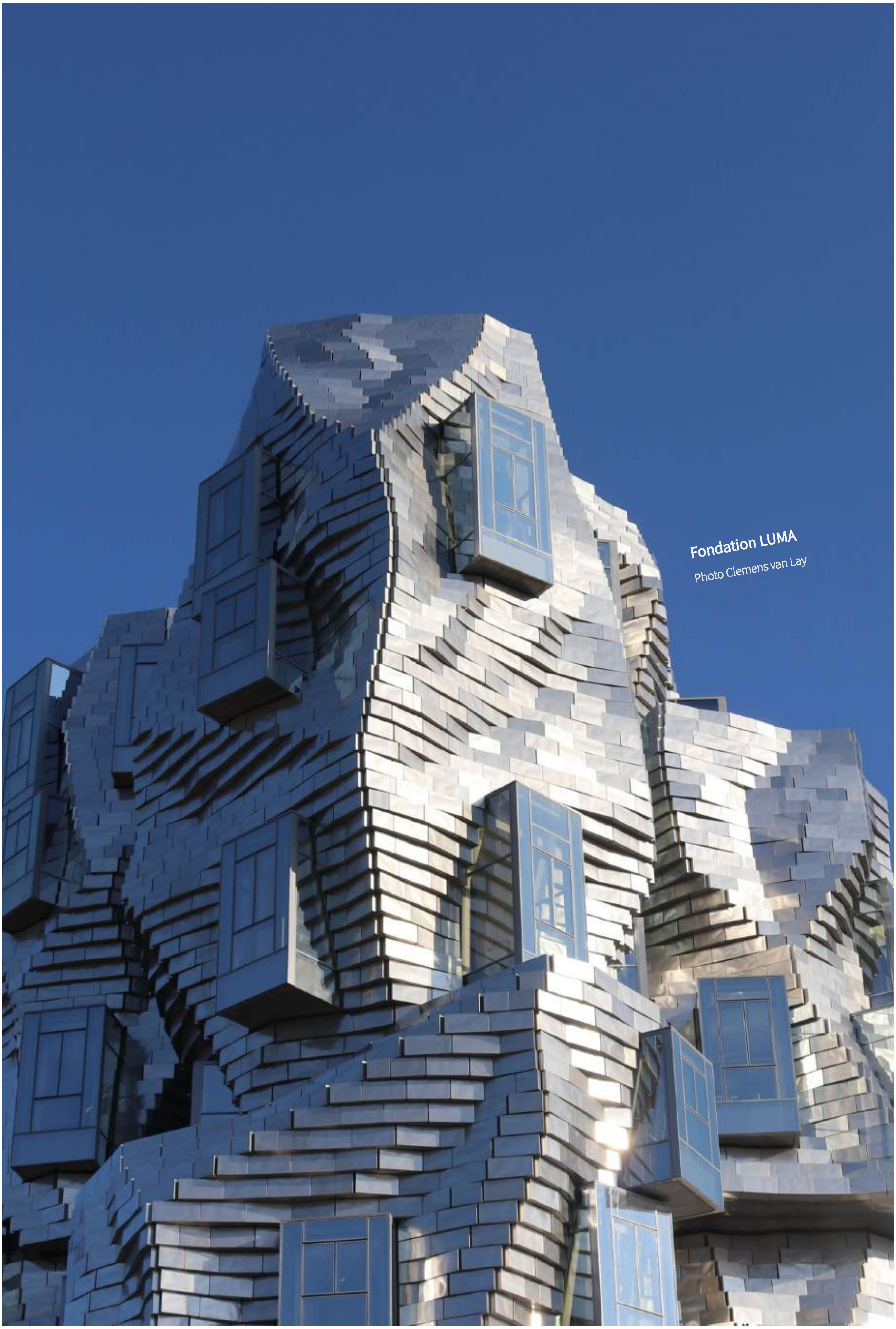
Similarly, artwork conservation raises questions: how can museum architecture take into account the expansion of collections over the long term and their progressive deterioration? Because if it is to be sustainable, the museum's structure must not only provide the most ecological reception space possible but also inevitably take into account the objects it contains.

Sustainable museum

For museums, the concept of sustainable development is closely linked to the implementation of preventive conservation policies. As the purpose of these institutions, the works they contain are heavily dependent on the environment in which they are preserved: it is about taking care of the outside to protect the inside.

First developed by the International Council on Monuments and Sites (ICOMOS) in 1980 within the framework of international conferences on the conservation of cultural heritage, the concept of preventive conservation emphasises measures against deterioration. It is no longer just about limiting conservation to artwork restoration.

To achieve this, a museum's structure can take into account a variety of parameters that allow it to respect the environment while


Fondation LUMA
Photo Clemens van Lay

protecting its collections as best as possible. The architect can optimise the natural terrain use natural ventilation, or install photovoltaic panels. The construction materials generally strike a balance between durability, non-toxicity, recycling, renewability, and low-pollution manufacturing. However, insulation remains a problem, as animal- or plant-based insulators are flammable and attract insects. Finally, the structure's modularity sometimes comes into play in the design to allow for interior rearrangements.

The "High Environmental Quality" (HQE) approach, established in France in the 1990s, facilitates the implementation of such principles in architecture. The initiative has international repercussions, later integrated into the BREEAM environmental certification system for building in the United Kingdom. Today considered a benchmark in sustainable construction, it is often one of the criteria in architectural calls for projects for museums, as was the case for the Quai Branly Museum in Paris.

Many museums around the world have not yet embarked on this transition — notably, the Guggenheim Museum in Abu Dhabi has faced significant criticism for its construction — however, ecological initiatives are increasing, and research for sustainable development is constantly evolving, posing new challenges for architects. Although this awareness is still recent, it is indeed gaining momentum, whether among the public, cultural actors, researchers or engineers, all in search of new solutions.

Solomon R. Guggenheim Museum

Photo Mickaël Pijoubert. © Art Media Agency

Centre Pompidou Metz

Photo Frederic Lo Brutto

WIDE ANGLE

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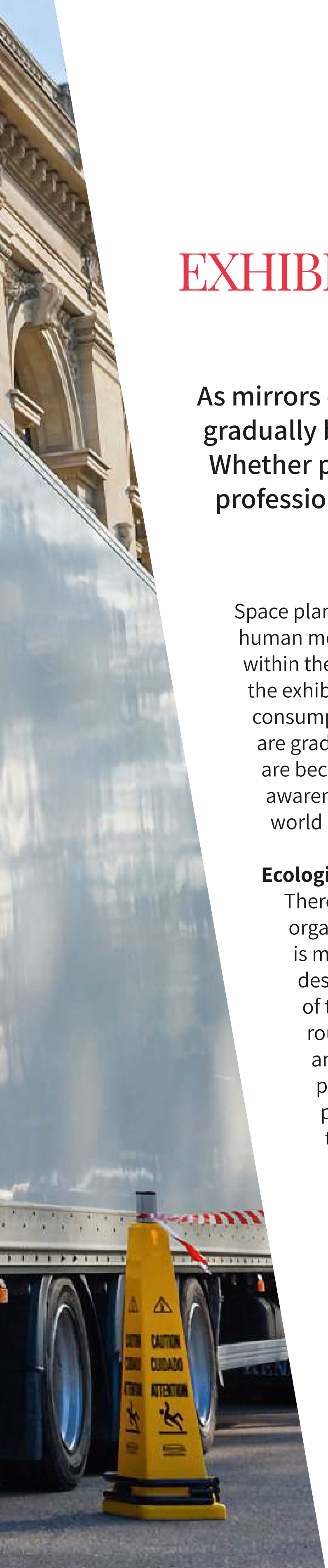
GREENART



EXHIBITIONS: GREEN ISSUES AT EVERY STAGE

As mirrors of the times and the institutions that run them, exhibitions are gradually being examined through the prism of sustainable development. Whether permanent or temporary, they incur variable energy costs that professionals must now take into account, from design to final dismantling.

Space planning and the use of equipment, loans of works, human movements, management of flows and temperature within the space… Among the various functions of the museum, the exhibition is certainly the most visible, but the energy consumption it involves is often overlooked. Professionals are gradually getting to grips with the subject and practices are becoming more aware. In light of this growing ecological awareness, what are institutions and players in the art world doing to design and organise their exhibitions?

Ecological impact

There are a number of stages involved in creating and organising an exhibition, and the ecological impact is multi-layered. On the one hand, it is linked to the design of the event itself, including the production of the materials that will make up the exhibition route — frames, picture rails, panels, labels, etc. — and their use throughout the exhibition opening period — in particular the lighting, sound and video projections. The loan of certain works also needs to be taken into account, and a decision needs to be made about the possibilities for transport — by lorry at best, or by plane — and the costs involved, both financial and in terms of energy.

The exhibition space itself also has an ecological impact. The flow of visitors and their movements will determine the temperature regulation of the infrastructure, both for the comfort of the public and the preservation of the works. Travel outside the exhibition space also needs to be taken into account: journeys to and from the exhibition site, which can take from a few minutes to several hours, involve a considerable amount of transport and expense. They even represent the largest carbon footprint in the balance sheet of temporary exhibitions. The same is true of art fairs, which attract professionals, collectors and art lovers from all over the world.

While the presence of a large audience is a guarantee of success, it also seems to contradict any ecological approach. Blockbuster exhibitions, in particular, are highly publicised and designed to draw in the crowds, like "Munch A poem of life, love and death" at the Musée d'Orsay between September 2022 and January 2023, which attracted more than 700,000 visitors; and the Morozov collection at the Louis Vuitton Foundation, which attracted more than 1.25 million visitors last year, breaking attendance records. So how can we combine the museum's various missions — or those of cultural events — to disseminate its works with an ecological approach?

— Diotima Schuck


EWALT

Responsible exhibitions

In November 2021, the Shift Project, a think tank working to decarbonise the economy, published its latest report, *Decarbonising Culture!* It highlighted a number of points: relocating activities, slowing down travel, reducing the scale of events, and eco-design by documenting the ecological impact of all activities. These are all elements that directly involve the production of an exhibition.

The energy consumed by exhibitions is apparent at every stage: when they are installed, when they are open and when they are dismantled. The fate of equipment produced for specific purposes, for a particular scenography, also raises questions. Exhibition curators and institutions need to take an ecological approach right from the design stage, so that the equipment they use can be reused. Their quality and adaptability to other modes of presentation must be taken into account to limit waste.

Spearheading this movement in France, the Palais des Beaux-Arts in Lille opened "Goya Experience" in February 2022, an exhibition bearing the eco-responsible stamp, using materials that are reusable, low in pollutants and sourced in France. The choice of bio-sourced, recyclable and sometimes recycled materials, responsible manufacturing and short supply chains are all part of a greener approach to creating exhibitions… but they also entail additional financial costs. The "Goya Experience" also proposed an innovative form of exhibition, using new technologies to compensate for the lack of a wide choice of paintings. Immersive and sensory, it focused on two paintings. It was a way of overturning the current exhibition model, which is based on offering a very wide range of works on loan.

To limit the need to transport works of art, digital technology appears to be a possible option. As well as appealing to audiences who are usually far from cultural venues and offering an alternative to loans, digitisation also offers a more immersive experience, accompanying the visitor and enabling them to approach the works in a different way, as close as possible to the details. A relationship that is the very opposite of the traditional museum exhibition, and one that many museums are now embracing in monumental installations such as the Atelier des Lumières in Paris, a site entirely dedicated to this new model.

The health crisis has greatly accelerated this transformation, giving pride of place to digitised art that can be accessed directly from a computer. Many museums have embraced this new approach, going even further and offering online exhibitions as virtual tours, offering an alternative way of reducing the need for visitors to travel and helping to spread art on a global scale — at the risk of undermining the experience of the physical object in the process.

Digitalisation: a viable alternative?

In fact, the possibilities offered by new technologies are double-edged: they make works more accessible to audiences who are socially or physically distant from cultural venues, but at the same time alter the relationship with the object by transforming the experience of the work in favour of the sensational. Between data storage, energy consumption and obsolescence, the carbon footprint of digital technology is also very real. And in an exhibition using such tools, the electricity used over the duration of the opening increases the financial and ecological costs.

Challenges of a sustainable approach

Ecological awareness, precipitated by the health crisis, is a relatively recent phenomenon in the cultural sector. CIMAM, a forum for modern and contemporary art collections and exhibitions, has produced a guide for professionals on how to manage the carbon footprint of an exhibition. The Palais des Beaux-Arts in Lille is offering workshops on the theme of museum sustainability. Generally speaking, the introduction of courses on green issues seems to be a fundamental step towards rethinking exhibitions from the perspective of sustainable development.

However, the cost of the ecological transition remains a major issue for institutions. The Amcsti bulletin on the sustainable approach to exhibitions published in

February 2022 highlighted the lack of financial investment by public authorities to support private sustainable initiatives. The institutions, for their part, "are asking professionals […] to be a driving force in eco-design because they do not have enough in-house resources [and] are lowering […] the remuneration of professionals, which they continue to regard as proportional to the amount of work rather than to the 'time spent'". This is still a delicate situation for the professionals involved in finding solutions, which are still time-consuming and more costly.

In an age of globalisation and constant displacement, those working for sustainable development are also stressing the importance of relocation – a central theme for art today, but also for the economy as a whole. The Shift Project proposed relocating activities to local areas, shortening distances travelled, reducing scales, eco-designing works, integrating mobility issues and … giving up. Dynamics that engage contemporary creators, professionals and audiences alike. And, ultimately, the opening up of other exhibition models to embody new relationships with the world.

In the light of the challenges facing the world of culture today, the green initiatives taken at every stage in the organisation of exhibitions need to be made visible in order to raise awareness among professionals and the public alike of the energy costs involved. At a time when contemporary art is increasingly concerned with the environment, ecology and the relationship between man and the living world, it would seem that institutions too should follow suit and give concrete expression to the works they exhibit.

Photo Elmer Canas

ZOOM

© Alessandro Mosalini. Courtesy Rencontres d'Arles

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GREENART

ECO-RESPONSIBILITY: TIME TO MAKE CHOICES

Welcoming the public, the logistics of works and exhibitions, surveying the area… In the face of the climate emergency, Les Rencontres d'Arles is deploying a whole arsenal of eco-responsible measures infused by the thinking of its photographers and teams. Here's an overview.

How can an international festival like Les Rencontres d'Arles reduce its environmental impact? What social role can it play in its local area? How can we defend the way photographers look at global change? The festival did not wait for the scorching summer of 2022 to question its practices and raise awareness of these issues within the photography ecosystem. Eco-design is, so to speak, part of the DNA of this festival, which was designed from the outset to take place outside its walls. Churches, cloisters, industrial wastelands… all places that have to be rethought and adapted for photographic display every year, without altering their heritage identity. The opposite of a white cube.

Olivier Etcheverry, the historic scenographer of the festival's exhibitions, who sadly passed away on 3 March last year, championed the "fairground", sober and thrifty side of the event. By re-using material from previous exhibitions each year, he was constantly reinventing the way in which the works were read and displayed, long before the virtues of eco-design became common knowledge. "Reusing scenographic material is both a constraint and a desire, he confides. Playing with the ephemeral is part of the festival's genetic make-up. This diversity is also what opens up people's curiosity. The important thing is that they look at the images on the show, not necessarily the spaces." It's an approach based on sensitivity and common sense that he has passed on to Amanda Antunes, who is now in charge of the festival's scenography and to all the production teams.

"The festival is a laboratory that shapes itself according to aesthetic, technical, political and social developments. On the strength of its experience and aware of the road still to travel, the association deals with ecological and societal issues on a daily basis," says Hubert Védrine, President of Rencontres d'Arles. As a result, in March 2022, Les Rencontres d'Arles joined the Collectif des Festivals Éco-responsables et Solidaires (COFEES) and the Festivals in Motion national project, which aims to reduce greenhouse gas emissions linked to festival transport, with 80% of the carbon impact coming from public and staff travel. This year, the management of Les Rencontres d'Arles has set up a working group to implement practical eco-responsible actions before and during the festival

A festival is a complex machinery where environmental impact lurks in the smallest gaps. The works of art are no exception. Frames, inks, paper, prints, wallpapers… Cécile Nédélec, head of the exhibition

— Carine Claude

production, explains: “For the events we produce, we work closely on these issues upstream with our service providers in Arles and Paris to find out what we can and cannot do, or simply to make more eco-responsible choices. We have a very fluid dialogue with them, whether they are photo labs or framing and laminating workshops. For example, Atelier SHL, our service provider in Arles, is very sensitive to these issues. They give us precise information. We know that for a given print run, the paper will be 70% agave fibre and 30% cotton with no optical additives, that for the wallpaper the ink will be a Greenguard-certified HP latex ink made in France, and that the natural wood for the frame mouldings will be oak sourced from a certified forest in France.” For her, traceability becomes more complex when it comes to inks. “It’s not very well documented, even though customers are increasingly asking their suppliers for the origin of their products. We’re never safe from greenwashing…” [see box].

3 questions to... Cécile Nédélec

Cécile Nédélec is the Exhibition Production Manager of the Rencontres d’Arles.

How do you define the festival’s eco-responsible specifications or priorities?

We take a different approach depending on whether we’re producing the exhibition or hosting one that’s already been mounted. As part of our production work, we choose a main focus each year, which can vary depending on the project and our workload, because these are very time-consuming processes. For example, last year we put together an exhibition that calculated its footprint from A to Z. This year, we’ve set ourselves the target of reusing and inventorying frames. Our former art administrator, who now works in CSR, has helped us to think up calculation tools and indicators, including for the transport of works, which we have discussed in our working groups. We haven’t put them in place yet, but that will be the next stage.

What are you doing in terms of scenography?

Since 2021, we’ve done a huge amount of work to switch everything over to wood and stop using plasterboard. For economic reasons, the festival has been designed around a system of reuse, with the construction of modular caissons that make up the picture rails. It’s a rationalised, standardised system that we keep from year to year, on which we place the wood, which is also recovered from year to year from our storage at the Étienne paper mills. We set up a system for storing and packaging the assemblies. The big improvement came in autumn 2019 with the creation of a Filemaker database for inventorying the exhibition furniture — not the picture rails — i.e. the display cases, pedestals, benches, etc. We’re lucky enough to have a team of fitters for the picture rails and a carpentry team for the furniture. This is also one of the special features of the Rencontres, as we have the capacity to build things “made to measure”.

How do you work with artists and other cultural organisations?

This database is very useful for discussing scenographic proposals with the artists. Each piece of furniture has its own identity card, well packaged, with a photo and an inventory number. We also sometimes make loans to museums, like the Musée de la Camargue, for example. We’re very open to this kind of sharing between cultural players.

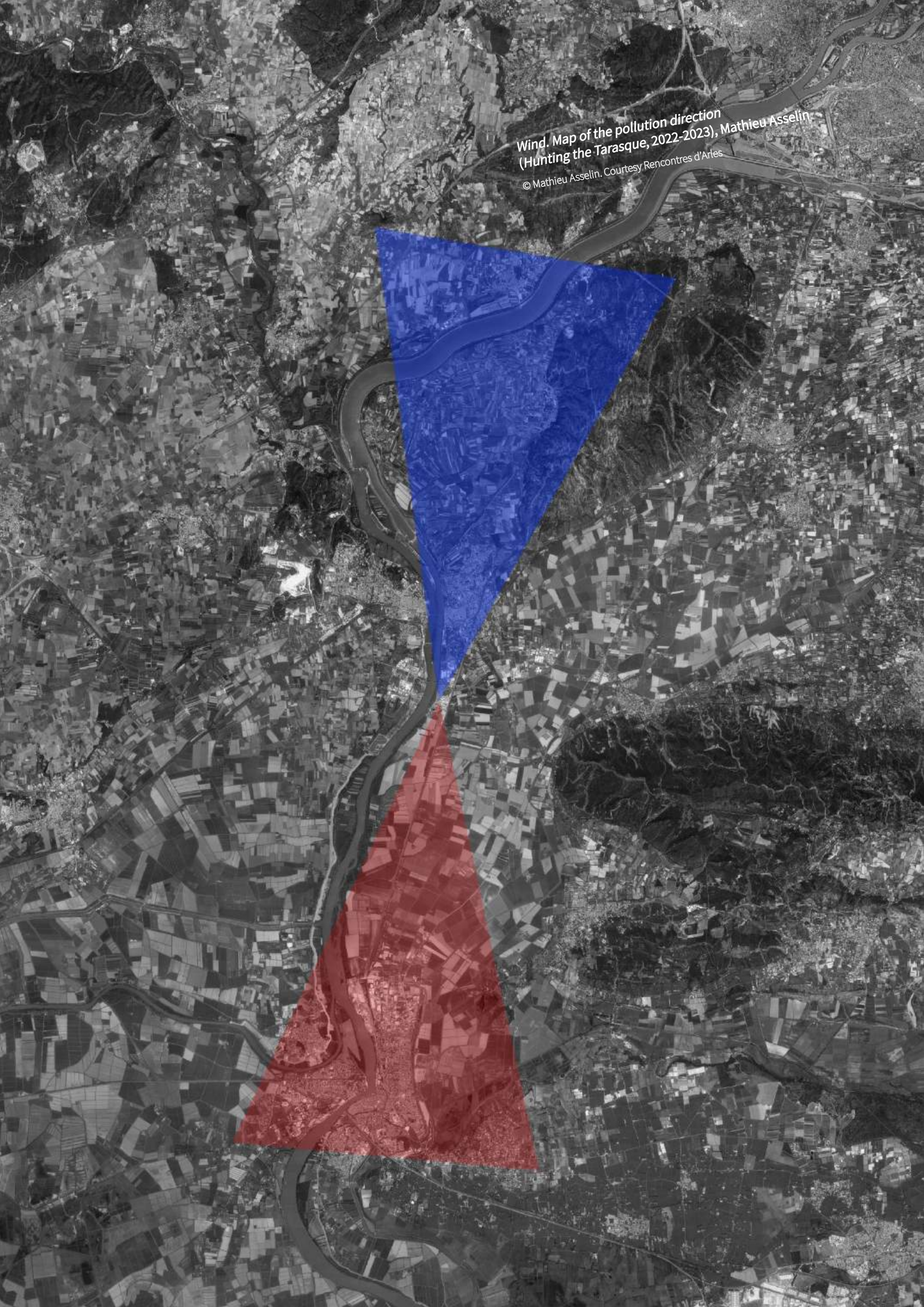
To manage the large stock of frames, the team has developed an optimised inventory and stock system to make it easier and easier to reuse them. “This is especially true for historical exhibitions, which feature classic vintage prints in relatively standardised formats, she continues. We made the CIRCAD workshop in Paris aware of the need to reuse the frames they had produced from one year to the next for the festival. This approach requires more work on our part, because it often takes longer to reuse them than to place an order. But this year, as we have a lot of archive exhibitions, we’ve decided to focus on that: we’re going to reuse more than 200 frames for the classic photos.”

The question of frames is fundamental, and with good reason: the festival receives between 2,500 and 4,000 works each year. And with them, a mountain of bubble wrap. The aim is zero loss: works that arrive already framed are protected and sent back in their original packaging. “We have a fairly strict policy on repackaging frames,” adds Cécile Nédélec. Our technical teams are aware of this issue. It’s one of the tasks of the surveyors, who created a specific inventory system a few years ago to avoid wasting bubble wrap. We also try to share transport between exhibitions and we have grouped shuttles that leave Paris to bring the works. We are dependent on volume, but we already have a number of tools at our disposal for rationalising exhibitions, which we use on a daily basis.”

Field survey

To think about the overall eco-responsibility of a festival like Les Rencontres d’Arles, which welcomes

We exhale (detail, 2022-2023), Tanja Engelberts



Wind. Map of the pollution direction (Hunting the Tarasque, 2022-2023), Mathieu Asselin

> The region is extremely rich, attracting a wide range of photographers to explore its ecosystem. It's a point of convergence: we're questioning Arles, its history, the festival and its commitment to society, artistic proposals, Anthropocene, climate change — environmental concerns are very present in young photography. — *Christoph Wiesner*

more than 120,000 visitors a year, you need to take a certain height of vision. Rooted in a territory that is fragile from both an ecological and a social point of view, the festival cannot simply be a "laboratory" detached from its contextual realities. This is why Rencontres d'Arles has joined forces with the Cité Anthropocène in Lyon to carry out a transdisciplinary study of the Arles area in February 2023. Scientists, researchers, architects and artists looked at the ecosystem of the Rhône delta with, in mind, the idea of making new recommendations for summer habitability for Ground Control, a former railway site and familiar exhibition venue for the Rencontres d'Arles. The site, which had to close last year for a fortnight due to the intense heatwave, is this summer hosting the exhibitions "Grey sun" by Éric Tabuchi and Nelly Monnier and "Special attention" with Jingyu Cao, Raphaël Lods and Iris Millot.

Sentinel territory and mitigation strategies

Ground Control serves as a test area for implementing the solutions devised as a result of the survey. "We put together a heterogeneous group of around fifteen people from very different disciplines — urban geography, biodiversity, agro-ecology, microbiology, etc. — because when we talk about climate change, we need to reorientate the way we do science and the way we see the world, using a variety of approaches," explains Valérie Disdier, Chair of the Cité Anthropocène. For a fortnight, the team carried out a field study in Camargue, meeting local players from users to firefighters, including elected representatives, ENSP students and festival employees. The Rhone delta is a sentinel area, a fragile territory where the acceleration of change is felt even more than elsewhere. "We started from the basic assumption that the heatwave summer of 2022 was not a one-off episode. The second assumption was to come up with recommendations that were not based on hypertechnology, but rather on a form of frugality — for example, what solutions could be found to avoid air conditioning? For example, an already built-up site like Ground Control has its advantages and disadvantages. How can we make the most of it?"

If we were to take this line of reasoning a step further, the recommendations could be extended to the opening hours of exhibitions or the working conditions of reception staff, with, in time, the very temporality of the festival being called into question, which would have a domino effect on the entire local economy. A scenario that is not on the agenda, but which inevitably raises the question of the medium — or long-term viability of major cultural and tourist events in high-risk areas. "The myth of summer as we have known it since the 1950s is not working. Arles is almost a seaside town from an economic point of view, notes Valérie Disdier. Environmental awareness is undeniable, including among elected representatives. But, as is the case everywhere, you often have to hit the economic wall to get people to react. Let's not forget that simple, sustainable solutions already exist."

A look at the impact of the Anthropocene

At Monoprix, the "Here near" exhibition presents three projects dealing with the nuisances that threaten the ecological balance of Arles and the surrounding area. Mathieu Asselin, Tanja Engelberts and Sheng-Wen Lo have been carrying out field research since 2022. Industry, transport, animal life, water distribution networks… the Anthropocene is having a major impact on natural ecosystems. "In the context in which we live today, it is essential to look around us, to observe our place in the environment and in space, our relationships with human and non-human living things. And to realise the extent to which all these elements and beings are interconnected," says Dutch curator Daria Tuminas. "In this exhibition, I'm looking to create connections between spaces. It's not just about Arles, but also Camargue, Switzerland, where the Rhône comes from, Indonesia, where the Tarascon paper mill is based, and so on. Everything is interconnected. This interconnection between all forms of life and all regions is one of the keys."

"Here near"
Until 24 September
Monoprix. Place Lamartine. Arles
www.rencontres-arles.com

Courtesy Rencontres d'Arles


MIKA SPERLING

Photo Sonika Agarwal

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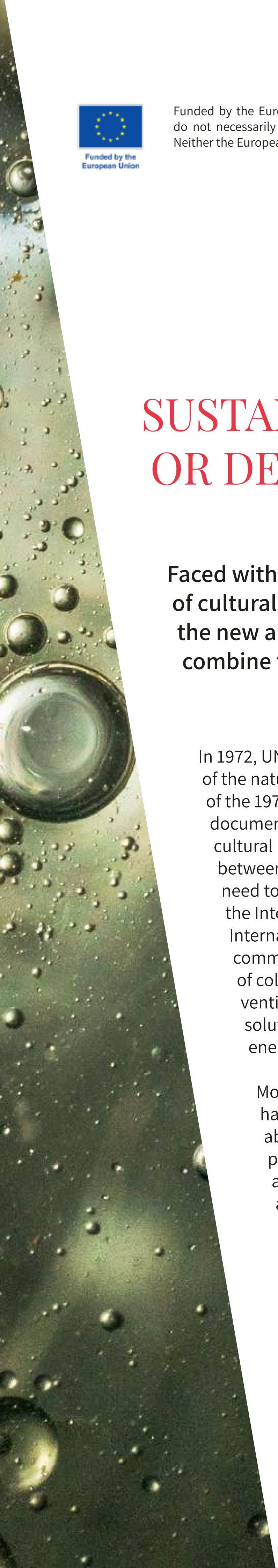


SUSTAINABLE DEVELOPMENT OR DEGROWTH

Faced with an ecological emergency, the world of conservation restoration of cultural property is at a crossroads. Between the UNESCO conventions and the new approaches to sustainable development, how can heritage professionals combine the preservation of works of art with environmental protection?

In 1972, UNESCO signed a convention for the protection of the natural and cultural heritage. The most original feature of the 1972 Convention is that it brings together in a single document the concepts of protecting nature and preserving cultural property. The Convention recognises the interaction between human beings and nature and the fundamental need to preserve the balance between the two. In 2014, the International Council of Museums (ICOM) and the International Institute for Conservation (IIC) agreed on common environmental guidelines: the conservation of collections should be carried out without heating, ventilation or air conditioning (HVAC), with passive solutions that are easy to maintain and low in energy consumption.

More recently, the term sustainable development has been opposed by terms such as degrowth, frugal abundance, prosperity without growth, convivialism, post-growth, etc., which propose a project for an alternative society involving the transition from a growth society to a post-growth society and a fundamental change in values summarised by the virtuous circle of the 8 Rs (re-evaluate, re-conceptualise, restructure, relocate, redistribute, reduce, reuse, recycle). It is from this virtuous circle of the 8 R's that the 3 R's rule (reduce, reuse, recycle) is extracted, sometimes used in conservation-restoration. This strategy has a more detailed variant, the 5 Rs rule, which forms one of the foundations of the zero waste approach.

It is in this somewhat contradictory context that the growing awareness of ecological issues is beginning to shake up professionals in all sectors of cultural heritage. They are calling behaviour into question and conditioning new public policies. What is the situation in the specific field of conservation and restoration of cultural property? How can heritage preservation be combined with environmental protection? How can practices be adapted to better meet the pressing need for sustainable development? The majority of French conservator-restorers (75%) are self-employed, working in preventive, curative and restoration conservation. Like everyone else, they consume energy and resources and generate a certain amount of pollution and waste. But what is the environmental impact of conservation and restoration work, and what can be done to become eco-responsible? What is the world of conservation of cultural property in general and restorers in particular doing? It is still impossible to answer the first question.

— Antonio Mirabile

The workshop of the conservator-restorer

The integration of eco-responsibility is an essential stage in the life of a conservation-restoration workshop whether institutional or private. It must be taken into account right from the architectural design stage of the building, so that work processes, the choice of equipment and the provision of collective protection can be adapted as effectively as possible. Retrofitting workspaces is never easy.

Reducing energy consumption can be achieved through major building renovation, but other levers for action can also be mobilised. These include adapting premises and raising occupants' awareness of energy savings, working on the building envelope, installing efficient heating and ventilation equipment and optimising equipment operation. Purchasing energy-efficient laboratory equipment to reduce electricity consumption is also a good strategy. The issue of programmed obsolescence must also be taken into account, and since January 2021 there has been a repairability index, which applies to certain equipment, the aim being to buy durable and repairable.

As far as lighting is concerned, however, improvements have already been made, as follows incandescent lamps have been banned since 2012, followed by fluorescent lamps in 2017 and halogen lamps in 2018. All that remains are compact or low-energy fluorescent bulbs and light-emitting diodes, which are highly energy-efficient. Also of great interest is the research carried out by the American aeronautics industry into air purification, which has identified the decontamination properties of certain plants that absorb formaldehyde, toluene, ammonia and benzene vapours.

Commitment and training

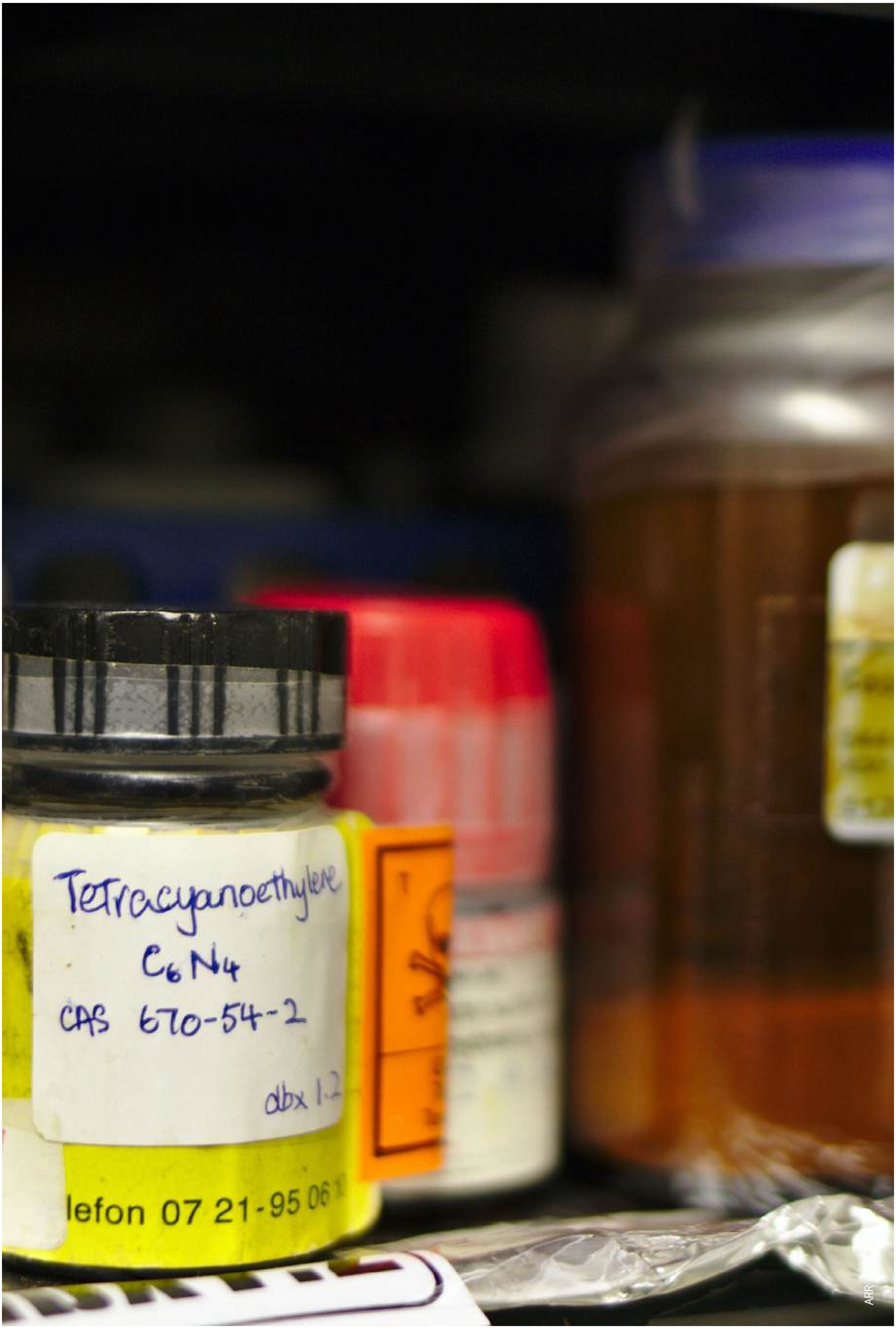
According to the results of a survey on professional commitment to the environment conducted in 2019 of 64 conservators and restorers, more than one in two respondents already consider themselves to be committed to adopting environmentally friendly practices, and they also feel that they waste and harm the environment in their professional practice. Still more than one in two respondents said they had already looked for or implemented alternatives to the two materials considered the most polluting, namely plastics and solvents. One of the difficulties in this field is the lack of information on ecologically responsible methods or materials directly applicable to the professional practice of conservation. References are often scattered and searches using key words often lead to nature, town planning and architecture. What we have here, then, is a group of professionals who are aware of the potential impact of their activity on the environment, but who need to develop their knowledge and skills on subjects related to the ecological transition and how this relates to the practice of their profession.

As far as conservator-restorers are concerned, the principle of respect for the environment is not yet an integral part of the code of ethics. Nor is it really yet part of the training process, but in fact the same applies to other conservation professionals.

Plastics, cellulose and gloves

Before looking at the materials used in conservation-restoration, we need to talk briefly about life cycle analysis, which is a method whose main objective is to measure the impact of a material on the environment, in other words, to assess the environmental cost of a product. The cycle takes place from the search for raw materials to the end of the material's useful life. It covers extraction of the raw material, transport, manufacture, installation, maintenance, demolition (if applicable) and recycling. The intertwining of these processes often makes it difficult to determine the sources and destinations of the flows.
This is particularly the case for multifunctional processes where a single process will generate several products, or where a product has a large number of components and there is opposition to manufacturers withholding information.

Paper, cardboard, plastics and gloves are materials widely used in restoration activities, they are used in the temporary or long-term packaging of works of art or for personal protection, they are all recyclable, but the production of cellulose involves high costs for wood, water and energy,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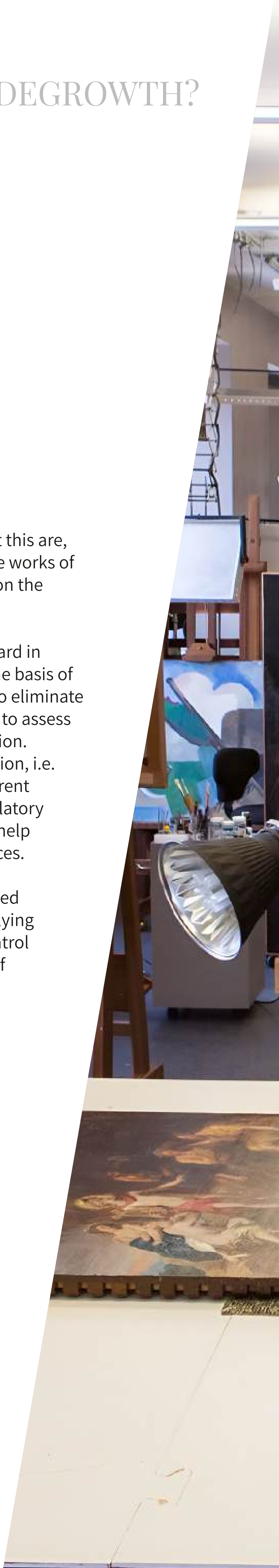

generating chlorinated and sulphurous pollutants. As for cotton, which is used every day, growing it requires massive water consumption and the use of toxic fertilisers and insecticides. All these materials, including gloves and plastics, can very often be recycled, but it is not possible to reuse and recycle everything indefinitely, because the material inevitably degrades. And let's not forget that the raw material for plastics is oil, derived from non-renewable sources that are slowly running out.

Solvents

Since the 1960s, conservation-restoration practices have become increasingly professional, and there has been a significant increase in the use of organic solvents, with toxicological and ecotoxic risks that are often poorly assessed and managed. Unfortunately, the precautions taken to treat works of art are not without effect on health and the environment. Many of these solvents affect the nervous, endocrine and reproductive systems, and can also affect organs such as the liver and kidneys. To date, polychrome restorers are the most exposed, despite a fairly recent rise in awareness to which new methods and products are attempting to respond. Replacing a solvent normally used in the profession with another is encountering a great deal of reluctance on the part of professionals. The two main arguments against this are, on the one hand, that we do not know the effect on the works of the replacement solvents that may be proposed and, on the other hand, that we are not used to using them.

The European REACH programme is a major step forward in this area, aiming to assess over 30,000 chemicals on the basis of their toxicity to health and the environment, in order to eliminate the most dangerous. But there is a shortage of experts to assess chemicals, and a lack of resources to pass on information. The implementation of developments through legislation, i.e. regulations on exposure limits, is even slower, and current standards often lag behind scientific knowledge. Regulatory limit values are therefore indicative: they are a tool to help assess risks, but must be supplemented by other sources.

Some green methods have nevertheless been developed in conservation restoration. One of these involves applying charged solvents in a gel, which not only increases control of the cleaning process, but also reduces the volume of solvents used and the amount evaporated. There has also been research into the use of essential oils as a preventive air treatment or as a biocide.

What's next?

It is possible to become a more eco-responsible conservation-restoration professional after a radical change in behaviour and lifestyle. This change must first take place at a personal level before it can be professional. Without persuasion in personal life, it won't work in professional life. There are many obstacles to change: human inertia, the lack of research into alternative products, the very status of conservator-restorers, who in France are independent professionals, dispersed units outside the institutions for which they work. Ecology must be included as an additional reference in the profession's Code of Ethics. Today, researching, collecting, conserving, restoring, interpreting, exhibiting and transmitting tangible and intangible cultural heritage must be an ecological, accessible and inclusive process.


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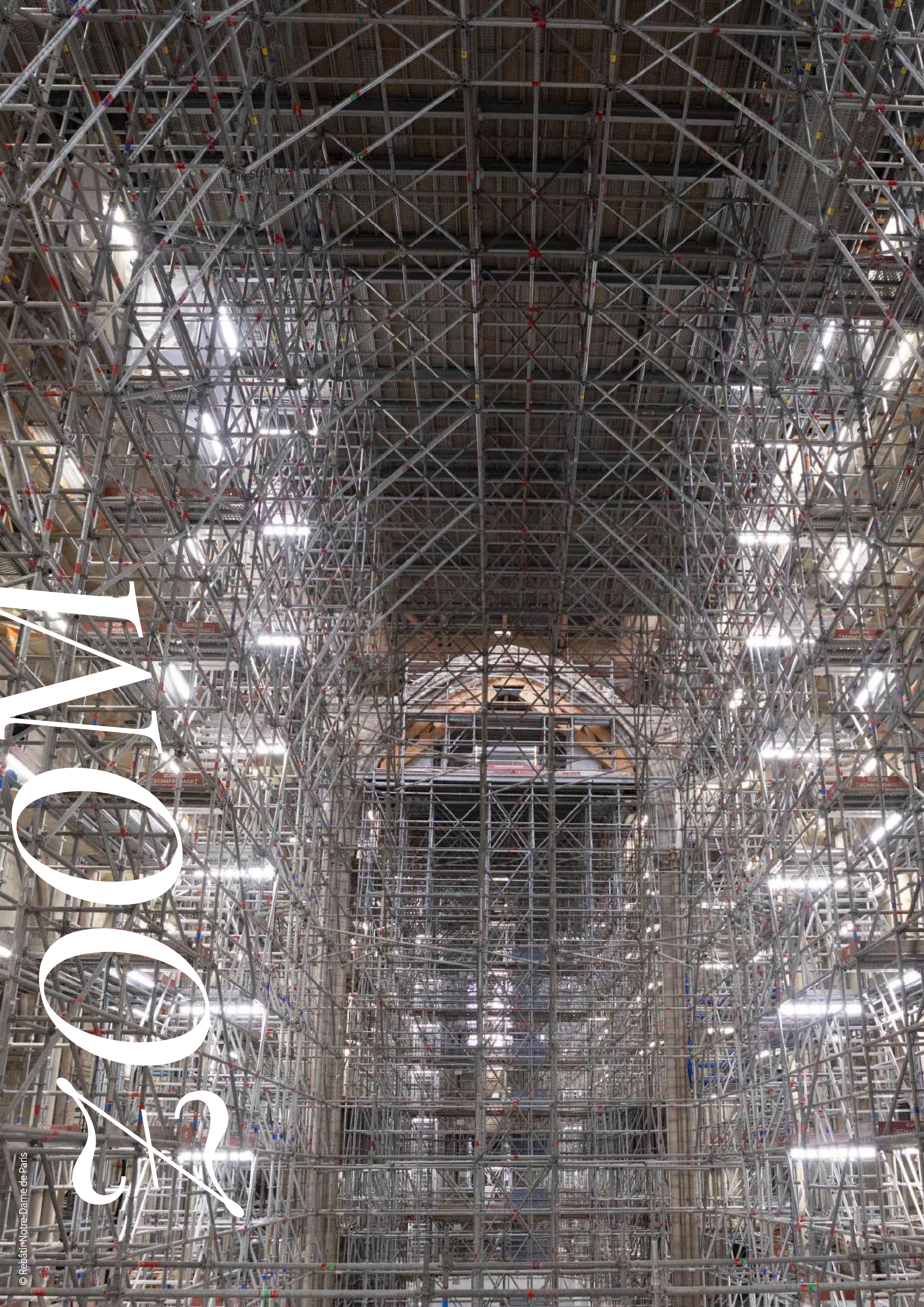

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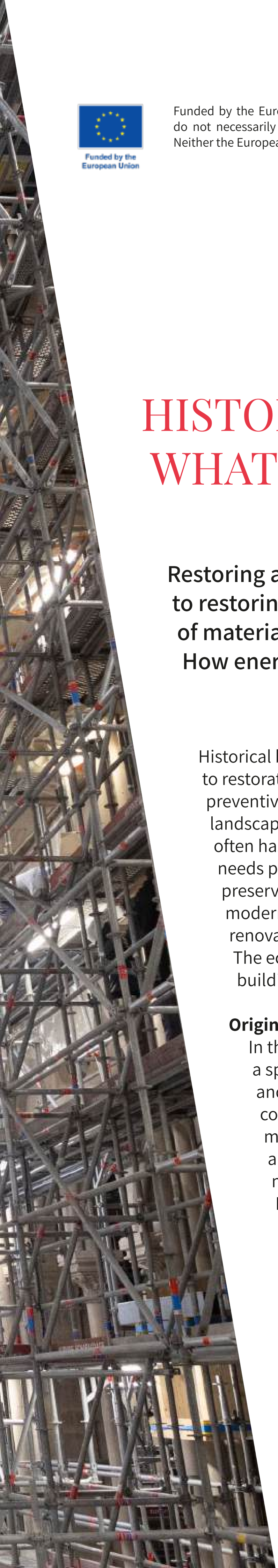
GREENART



HISTORICAL MONUMENT RESTORATION: WHAT ECOLOGICAL IMPACT?

Restoring a historical monument is a vastly different undertaking compared to restoring a piece of art. It demands more resources, larger quantities of materials to extract and transport, and produces more waste. How energy expenditures are controlled in this process?

Historical buildings hold a unique status when it comes to restoration practices. They are central to concerns of preventive conservation and restoration. Integral to a country's landscape and distinctive character, architectural heritage often has both historical and artistic significance that needs protection. However, is it possible to balance the preservation of sometimes centuries-old buildings with modern environmental concerns? Do current monument renovations always incorporate sustainable practices? The ecological focus seems to vary depending on the building's purpose and restoration objectives.

Origins of monument preservation

In the realm of artistic restoration, monuments hold a special place. They are subject to varying legislations and protections depending on their location and country. Generally in Europe, the concept of "historical monuments" emerged in the 19th century, with a focus on restoring the original styles of medieval monuments. In France, the position of General Inspector of Historical Monuments was established in 1830, followed by the Commission of Historical Monuments in 1837. From then on, restoration works on buildings deemed of artistic or historical interest were regulated.

Throughout the 20th century, the boundaries of monument restoration became clearer, thanks to International Congresses of Architects and Technicians of Historical Monuments — in 1931 in Athens, 1964 in Venice, and 2000 in Krakow. The primary goal was to find the best means to preserve a building's identity, often incurring substantial costs in manpower, materials and finances.

Expensive projects?

In 2019, Notre-Dame de Paris suffered a fire, destroying its spire and timber framework. The subsequent restoration project spanned across France. New vaults were made from stones extracted in Oise; the spire and transept from wood sourced from a thousand oaks sent to 45 different sawmills. The scale of the project was unprecedented. By 2022, the Cour des comptes revealed a budget of €151 million for building conservation and an additional €552 million for the overall restoration.

From material extraction to assembly, from facade cleaning to interior work, this "rescue" showcased the vast scale of monument restoration, far surpassing that of any art pieces. On a smaller scale, such restorations often involve multiple companies and workshops, as well

— Diotima Schuck

as various trades. However, restorers tend to prefer traditional, local materials, reducing transport costs and promoting specialised skills and jobs, aligning with principles of ecological sustainability.

Ecological benefits

Compared to building demolition, restoration is more eco-friendly. Replacing a building consumes energy and produces waste, while restoration allows for material recovery and preservation of their original "substance" — a requirement for historical monuments. Preferring preservation and original materials, natural substances like stone and wood are more suitable and environmentally sustainable.

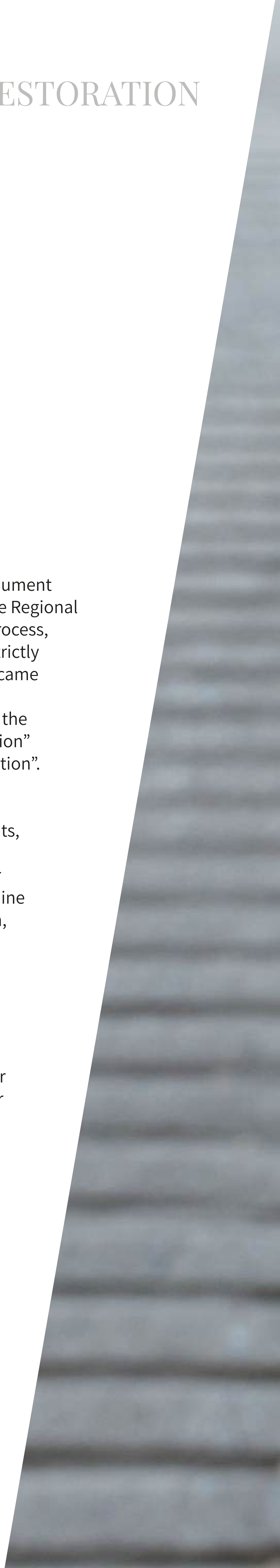
Wood, in particular, is apt for renovating historical monuments and older buildings. In terms of heritage preservation, using wood also maintains a building's identity since many older structures primarily used this material. From an ecological standpoint, wood absorbs CO_2, offsetting the energy used in its harvesting and processing. However, modern materials, like concrete, are sometimes preferred for their manageability, impermeability and strength, even though their environmental impact is often greater than wood's.

In France, any renovation of a classified historical monument requires approval from the Ministry of Culture, with the Regional Directorate of Cultural Affairs (DRAC) overseeing the process, often with public subsidies. While these projects are strictly regulated, tracking their energy costs only recently became a focus with the "Climate and Resilience" law from 22 August 2021. This law introduced two definitions in the construction code: "high-performance energy renovation" and "comprehensive high-performance energy renovation".

Monitoring and sustainable architecture

However, there are exceptions for historical monuments, as the Energy Performance Diagnosis (DPE) is deemed unsuitable for older buildings, not accounting for their original materials and ecosystem. While there's a genuine ambition to improve ecological impact in construction, heritage preservation and ecological transition sometimes seem contradictory.

Preserving historical monuments can be challenging, especially as many are tourist attractions. Their restoration, however, remains essential. Unlike art pieces, the materials used for their restoration can be natural and are often preferred over modern alternatives, which are less polluting due to their lower energy production costs. Despite the scale and costs of these projects, the practice can be sustainable. Yet, this doesn't seem to be a priority for heritage buildings. The focus is more on preserving their history, identity and culture. Exempt from modern ecological standards and energy measurement tools, they require in-depth studies and solutions tailored to their unique characteristics. In terms of restoration the challenge remains: how to incorporate equipment aligned with ecological sustainability principles while preserving their identity?



WIDE ANGLE

Photo Caitlin Cunningham. Courtesy Harvard Art Museums

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HERITAGE, SCIENCE AND TECHNOLOGY

Heritage sciences are also facing new ecological challenges. Knowledge transfer, preservation of cultural objects, technological equipment, energy consumption. What are the options within the scientific community? Here are some avenues for reflection.

Heritage sciences constitute an interdisciplinary research field for the scientific study of cultural and natural heritage. Drawing from diverse disciplines of humanities, sciences, digital technology, and engineering, "heritage sciences" is a generic term that encompasses all forms of scientific research on human creations, and the combined works of nature and humans, which hold value for individuals. They aim to enhance the understanding, maintenance, sustainable use, and management of both tangible and intangible heritage. The heritage sciences sector has rapidly evolved over recent years. The number of scientific publications produced each year has significantly increased over the last twenty years, with over a third resulting from international collaborations. Heritage scientists predominantly work in heritage, academic, or research institutions, and their work ranges from fundamental research to more applied studies with the ambition to improve the understanding of cultural heritage and develop new ways to ensure its preservation, appreciation, and transmission, while aligning with the eco-responsibility perspective since December 2019 (the launch date of the European Green Deal). Like everyone else, they consume energy and resources, generate pollution, and produce waste. But what is the environmental impact of their work and how can they act to become eco-responsible?

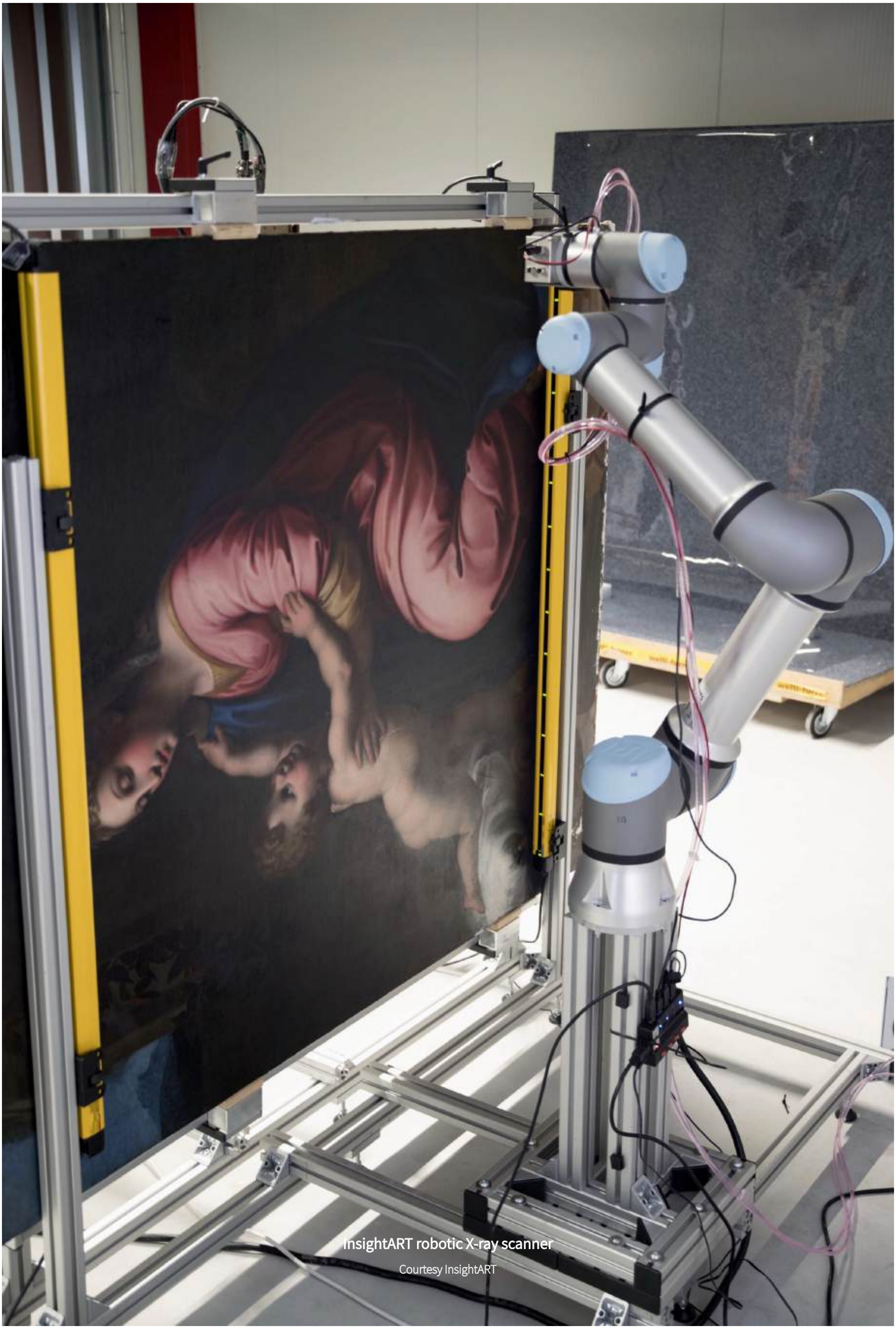
Open access

Open science is a broad topic covering various issues. In July 2018, the French Ministry of Higher Education, Research, and Innovation published the National Plan for "open access to scientific research results, without barriers, delay, or payment". This principle of openness is gradually being adopted by all institutions. It allows the author of a scientific paper to publish it in open access, so that the entire text is freely accessible to any reader. The APCs ("Article Processing Charges" or publication fees) are financially covered by the author or, more often, by their affiliated institution. The economic model is thus that of the "author-payer". The establishment of open-access text repositories has indeed caused the number of research studies on the internet to skyrocket. Internet users are rarely aware, but their wanderings in the virtual world have a real energy cost. According to Alex Wissner-Gross, a physicist at Harvard University, two Google searches would consume as much carbon as a hot cup of tea and generate 14 grams of carbon emissions, almost the footprint of an electric kettle (15 g).

Invasive, non-invasive, fixed or portable

The artworks that have reached us are precious and must be studied with the utmost caution. This is why the use of chemical methods

— Antonio Mirabile



InsightART robotic X-ray scanner

Courtesy InsightART

requiring samples is becoming increasingly rare: removing material, even in very small quantities, is no longer acceptable on heritage objects. Moreover, the sample is not always representative of the complete work, as it is often localised on the edges or in already damaged areas, around gaps. Hence, numerous new non-invasive analysis methods have been developed over the past twenty years. But it is primarily the new portable instruments designed for in situ analysis that offer the most advantages for research on artistic productions. Fixed analysis instrumentation requires the relocation of the artwork; it is the museum that is going to the lab! Beyond the carbon footprint associated with the manufacturing of a crate used only once with all the plastic cushioning systems inside and an air or other transport, heritage objects are subjected, during their transport, to conditions that promote various types of deterioration and damage. The most common dangers include handling effects, shocks, vibrations, and variations in relative humidity and temperature. It should not be forgotten that some deteriorations occur gradually and are not necessarily detectable immediately.

Instrumentation and obsolescence

The term "obsolescence", stemming from the Latin *obsolescere* meaning to lose value, was used by the Romans to denote an object that wouldn't be useful for long. Obsolescence is typically defined as a set of mechanisms encouraging consumers to frequently renew their purchasing act. Planned obsolescence, characterised by manufacturers' intent to shorten product lifespan, is one of the most controversial forms of obsolescence due to the perceived manipulation of consumers to meet companies' growing sales objectives. Regardless of its form, obsolescence is problematic from a sustainable development perspective. It leads to accelerated acquisition and disposal cycles of goods, whose primary consequence is a skyrocketing growth of waste. The obsolescence phenomenon is particularly evident in the electrical and electronic sector, where users tend to frequently change devices to keep up with rapid innovations. Each year, 20 to 50 million tons of electrical and electronic equipment waste is generated. It's essential to know that in all sectors and among all scientific instrumentation manufacturers, factories only provide spare parts for about ten years following the last marketing.

However, it's worth noting that these cutting-edge instruments like mass spectrometers or scanning electron microscopes demand a lot of effort to acquire and are often very costly (hundreds of thousands or even several million euros). Grant applications allowing the acquisition of these instruments are often lengthy, thus, support personnel put a lot of effort into keeping them operational as long as possible. Smaller common instruments like pH meters or balances with shorter lifespans are recycled with small electronic equipment. But just like a well-maintained car, scientific instruments can be useful for about ten years. In some cases, the instrument simply isn't performant enough for research needs anymore.

In rapidly evolving scientific fields, equipment transitions from a development phase to a routine operation stage. The obsolescence rate of knowledge is high and the evolution of instrumentation towards rapid commercial exploitation is notable. It then becomes essential to think about organising research laboratories in a reactive, flexible, and networked manner.

Scientific imaging

The last category of common analysis methods concerns imaging applied to works. This can be used either to preserve a record of the work's state at a given moment or within an investigative framework. When talking about recording, photography comes to mind. However, other two-dimensional (2D) full-field imaging techniques besides photography exist. Staying within a domain close to visible radiation, UV photographs allow imaging of restored areas, while infrared ones provide a different distinction between closely coloured pigments. Infrared reflectography enables visualisation of underlying drawings made with carbon. Moving further in frequency, X-rays allow the object's transmission radiography, accounting for its density differences. These imaging techniques can be modified to render the three-dimensional (3D) structure of the object, like with X-ray tomography. It's also worth noting that several presented techniques can also be used to image objects, with the final image realisation in a "point by point" mode. The complexity of heritage materials is such that simultaneous recourse to various aforementioned techniques is often necessary to correlate results and extract sought-after information. Likewise, the development of multispectral cameras is encouraged to analyse works simultaneously across a large portion of the electromagnetic spectrum (especially UV, visible and infrared). But, what will remain of these digitally born images in twenty years? What fraction of this work will be transmitted in the future? Probably quite little. As recently shown by a joint report from the Academy of Sciences and Technologies, the spontaneous aging of supports leads to constant migrations for digital information conservation (copying from an old to a new support). The operation is costly due to necessary handling and equipment; storing information on hard disks running day and night entails a real environmental impact (electrical consumption and air conditioning).

Energy consumption

The energy crisis, currently impacting the world and having strong effects on all of society (individuals, companies, research, administration…), does not spare SOLEIL, which had to renew its electricity supply contract for 2023 in 2022. SOLEIL, a particle accelerator (electrons) produces synchrotron radiation, an extremely bright light allowing the exploration of inert or living matter. In consultation with its supervisory bodies CEA (Atomic Energy Commission) and CNRS (National Center for Scientific Research), it had to take the very difficult decision to cease operating the accelerators and the 29 light lines during the so-called Run 1 period, from 18 January to 27 February 2023. This choice also aligns with the need to participate in the national effort to reduce electricity consumption during the winter period, which could prove critical for electricity supply.

Scientific research and eco-responsibility

Scientific research has always been subject to strategic orientations, being influenced by policies and subsidies from various government levels and societal evolution. For several years, certain scientific circles have been advocating for research to contribute more to establishing a genuinely sustainable society. However, many researchers work on topics that, they believe, have no connection with eco-responsibility themes, even though this concerns us all. Through their knowledge, scientists have a privileged position to implement sustainable and effective solutions. They have an exceptional ability to innovate within their research work. There's no doubt they will be capable of integrating the challenges. The shift towards a viable society thus necessitates a renewal of how we view scientific research a more globalising vision, which includes long-term, interconnected, and transdisciplinary solutions-focused approaches.

Courtesy National Galleries of Scotland

Photo Drew Hays

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GREENART

A METHODOLOGY FOR ENVIRONMENTAL SUSTAINABILITY

Life-cycle assessment measures the environmental impacts of a product or service. This tool is used to evaluate the new green products for art conservation and restoration developed by GREENART researchers.

The GREENART project — or Green Endeavor in Art Restoration — was launched on 1st October 2022. Financed by the European Union, it brings together researchers working towards sustainable cultural heritage by developing new environmentally friendly restoration and conservation products in art. To rethink existing systems and formulate new ones, researchers rely on various methodologies to assess their efficiency, environmental impact, and health risks. One of these methodologies, life-cycle assessment (LCA), is crucial. What are its principles?

A standard framework for LCA

Life-cycle assessment is standardised according to ISO 14040:2021 and 14044:2021. These standards belong to a broader system assigned to environmental management, providing a framework for organisations and companies to harmonise their ecological approach through shared measurement tools and standards. After decades of methodological development and practical application, LCA has been adopted by the European framework for the assessment of "Safe and Sustainable by Design chemicals and materials" (EC SSbD), established in December 2022 by the Joint Research Centre, the scientific and technical research laboratory of the European Union. This framework works towards defining criteria and evaluation procedures for chemicals and materials, while advocating a hierarchical approach.

This approach guides GREENART researchers in developing new conservation and restoration products. Elena Semenzin is an associate professor in environmental chemistry; she assesses environmental risks and impacts related to traditional and emerging pollutants. Alex Zabeo, one of the founders of GreenDecision, is an expert in computer science and software development for decision support, including LCA. Involved in the safe and sustainable design of products developed by GREENART, they explain: "The first three steps of the EC SSbD framework primarily consider security aspects, covered by hazard and risk assessment approaches. The environmental aspect, the fourth step, must be assessed through the measurement of environmental sustainability covering the entire life cycle of the products." This is where they use the LCA method, conducted on their innovative products.

The fifth step of the EC SSbD approach includes the evaluation of socio-economic aspects related to the production of chemicals and materials, aided by the methodologies of social life-cycle assessment (LCA-S) and life-cycle costing (LCC).

— Diotima Schuck

Analysing the life cycle of a product

Analysing the life cycle of a product is necessarily done from an environmental perspective. It involves understanding each stage of its life, from the extraction of raw materials — which can be minerals, metals, fossil fuels, wood, etc. — to its production phase. But this analysis doesn't stop there because it also considers distribution, use, maintenance, and repair until the end of the product's life. The product then becomes waste that can be reused, recycled, or disposed of depending on the possibility it offers. And in a life-cycle assessment, all these stages are taken into account, each with factors that must be distinguished, analysed, and interpreted.

To conduct this analysis, researchers proceed in four phases, standardised by ISO 14040:2021 and 14044:2021 standards. The first involves defining the objective and scope of the study. For GREENART, it is about comparing new conservation and restoration products to those used today to verify whether they are characterised by reduced environmental impacts. The inventory comes next, meaning recording the inputs and outputs of each elementary process of the system (meaning, the study object delimited for analysis, here the innovative products of GREENART). Inputs include resources, raw materials, or energies, i.e., each element entering the system during one of the life cycle stages. Outputs are the results or waste generated by the system, manifested through atmospheric emissions, solid waste, or water discharges. This inventory of flows is then translated into environmental impacts. Finally, the results obtained are interpreted in the last phase of analysis, with the aim of identifying potential further improvements.

Through these steps, the environmental impact of the product will be evaluated and quantified, taking into consideration various elements. The two researchers explain: "A life-cycle assessment allows for the calculation of several impact categories, such as climate change, acidification, eutrophication, or toxicity to human health. This calculation is based on data collected in the environment, including the presence of oil or chemicals, energy or water consumption, and the emission of greenhouse gases or other substances into the air, water and soil." They add: "We use relevant references to establish our goals for reducing environmental impacts."

Environmental Footprint (EF) method

In the context of the life-cycle assessment of GREENART's new products, researchers use a specific life-cycle impact assessment (LCIA) method proposed by the European Union, the Environmental Footprint (EF) method. "It is the most reliable, comparable, and verifiable method for measuring environmental performance," explain Elena Semenzin and Alex Zabeo.
"The use of EF method is already planned within the framework of EU policies and legislation, such as the Taxonomy Regulation. The EF method considers sixteen impact categories that cover a broad range of relevant environmental issues and are related to several policy objectives such as protection of human and ecosystems health."

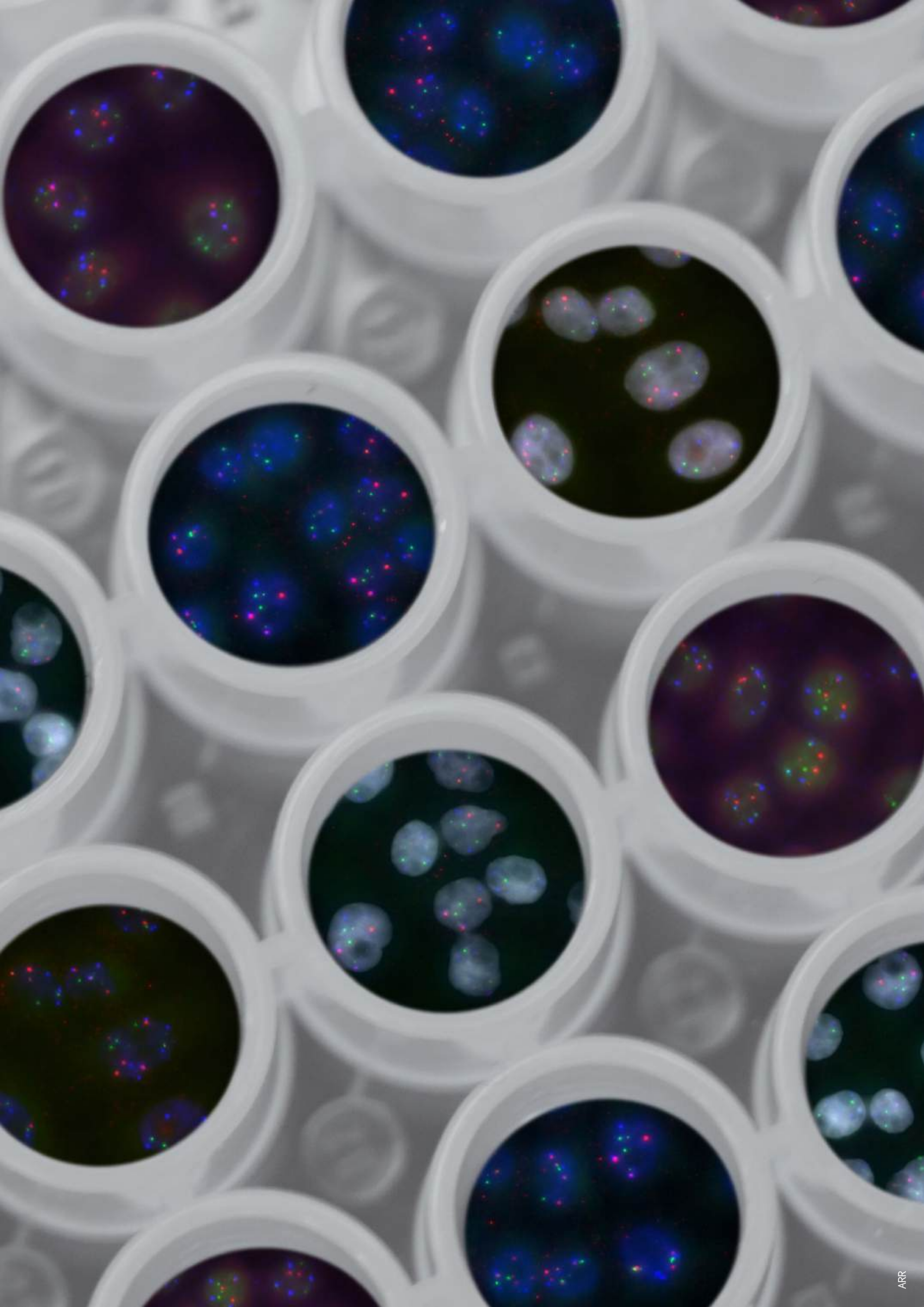
Are there relevant differences among different LCIA methods? The researchers clarify: "Different life-cycle assessment methodologies include different impact categories calculated using specific algorithms. The use of different methods makes it difficult to compare between different studies. For this reason, at the European level, there has been a significant effort towards harmonisation. The EF method is the main result of these efforts. Additionally, alongside this method, an EF database has been developed."

Beyond the evaluation of new products, it is also about measuring the impact of products in use today. Indeed, LCA measures and allows communication on the environmental performance of products developed by organisations through comparative studies. Companies can thus establish comparisons between similar products. "The identification and evaluation of benchmarks are crucial because life-cycle assessment is a comparative tool. And in the EC SSbD methodology, these benchmarks are necessary to establish goals for reducing environmental impact for different impact categories," explain the GREENART researchers, who will work on establishing these benchmark data targeting existing conservation-restoration products in the third year of the project, "alongside the life-cycle assessment of innovative GREENART products."

Methodological limits?

In the EC SSbD methodology, the fifth step, which evaluates the socio-economic impact of chemicals and materials, contains the most uncertainties. Fundamental components of the sustainability concept, social and economic dimensions are "less frequently integrated into the practical application of sustainability assessment", expose the researchers. Unlike life-cycle assessment, social life-cycle assessment (S-LCA) and life-cycle costing (LCC) are not yet standardised internationally. "For this reason, the analysis is characterised by more assumptions. Moreover, during the phase of designing new products, there is generally a lack of data at the industrial scale, so the analysis will necessarily be a preliminary analysis and should be iterated as soon as more complete datasets and information become available."

However, these limitations and needs for iterative application also affect LCA due to the complexity of accurately collecting all the incoming and outgoing flows of a product's life cycle.



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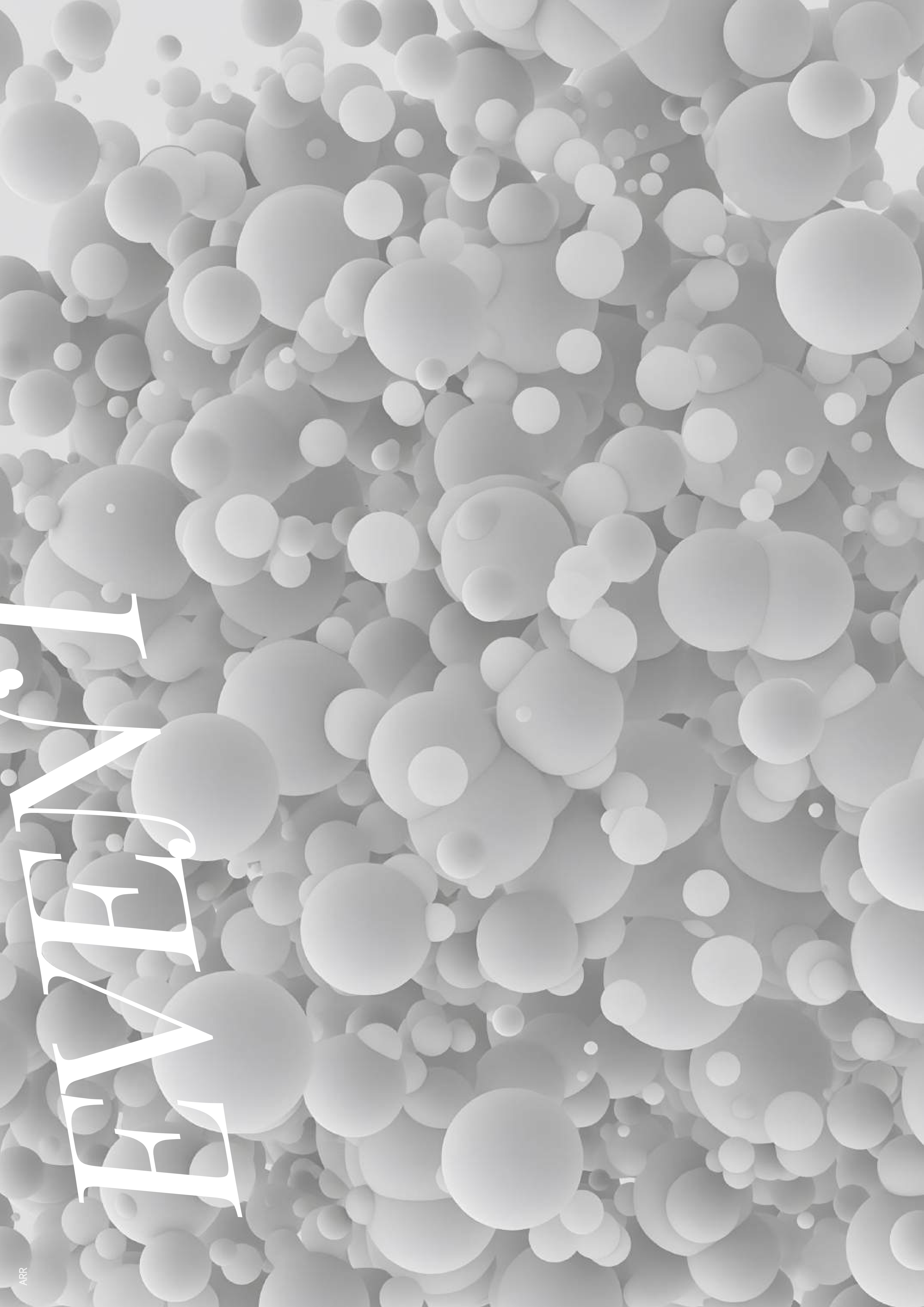
"Life-cycle inventory data — collected in the second step of life-cycle assessment — represent the backbone of LCA because they transform a product system into unit processes and quantifiable input and output flows to assess their environmental impacts. And the evaluation of the quality of this data is crucial," comment Elena Semenzin and Alex Zabeo. "Another limitation is associated with the comparability of life-cycle assessment studies. This is due to the high degree of subjectivity inherent in life-cycle assessment, mainly arising from the wide range of choices and assumptions that the practitioner must make when modelling the studied system, as well as the vast variety of available databases and calculation methods. For this reason, the main efforts are directed towards the harmonisation of the methodology."

As a relative method, life-cycle assessment can primarily establish whether the impacts of the evaluated product are above or below a selected reference. Thus, the GREENART researchers explain: "Ongoing efforts are focused on absolute life-cycle assessment, which, based on planetary boundaries, aims to provide environmental impact scores that are objective and absolute."

For now, GREENART implemented the first step of the EC SSbD framework by conducting evaluations of the human health, environmental and physical hazards of products under development. "We are currently working to finalise the safety aspects evaluation, and it is only in the final year, for the most promising products that are positively evaluated in the preceding stages, that we will proceed with life-cycle assessment, life-cycle costing and social life-cycle assessment," conclude the researchers.


Photo Marvin von Hagen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GREENART: INITIAL GOALS ACHIEVED

It's been more than a year since the GREENART project kicked off! In Naples, on the 14 and 15 December, its members convened to share progress on the development of new restoration products.

Officially launched 15 months ago, GREENART is committed to promoting sustainable conservation and restoration of cultural heritage by developing new, environmentally-friendly tools and seeking alternatives to harmful components in currently marketed products. This involves a complete rethinking of restorers' practices. Engrossed in their tasks, the Works packages — various teams associated with the project, from researchers to museum restorers — gathered to discuss their advancements. Cleaning, protective coatings, consolidation, and packaging materials: every step was meticulously examined.

Cleaning

Dedicated to green cleaning, the first Works package team aims to develop cleaning fluids in the form of microemulsions and gels by July 2025, ensuring safe and controlled cleaning of artworks — that is, the removal of aged, unwanted or deteriorating layers.

As of 30 September 2023, the first phase is complete: developing cleaning fluids with components that can replace today's solvents and market-available surfactants, making them green. These have been selected using a rating scale from 1 to 6, categorising surfactants from "recommended" to "very dangerous". Currently, at least three surfactants in use fall into this latter category.

However, GREENART is innovating. Among the newly developed products, water and oil-based fluids have been created without traditional surfactants, adding a hydrotrope… an interesting solution for researchers, as hydrotropes are generally more environmentally sustainable than conventional surfactants. The latter, being synthetic and derived from petrochemistry, cause more allergies and skin reactions Not very biodegradable, they release chemical compounds that can be even more toxic upon decomposition. Thus, these surfactant-free microemulsions represent a greener alternative, with a broader range of possible applications. So far, experiments seem to prove the interest and effectiveness of this new type of mixture.

Since 1st October, the second phase has commenced and will continue until March 2024, focusing on the study of gels created from biological, natural, or low-toxicity polymers. These gels will confine the cleaning fluids and solvents developed by the research team for controlled cleaning. They must also be synthesised through low-energy consumption processes, including recycling. Several hydrogel

— Pierre Naquin and Diotima Schuck

solutions have £been tested, and the researchers have achieved a relatively effective positive result after several testing phases. The goal now is to further improve their mechanical and cleaning properties and optimise formulations, particularly by replacing animal-derived polymers with those derived from wheat gluten.

Protection

Regarding the work package dedicated to developing coatings to protect artworks, by 30 June 2025, the team aims to have mastered various key elements: developing passive and active coatings with multifunctional, multilayered, and/or composite protective barriers to prevent various forms of degradation — pollution, humidity, corrosive agents, etc. Naturally, the research is bounded by the use of biological monomers and polymers sourced from sustainable or renewable products and natural waste, as well as by the aspiration to develop solutions enabling the self-repair of artworks.

Currently, researchers involved in the GREENART project face the challenge of the ecological durability of traditional protective products. IPCB and Specific Polymers, two project partners, are working to identify green components that can produce multifunctional coatings. A second group is exploring self-healing capabilities of coatings, while a third is tasked with developing products with anti-corrosion, plasticising, and anti-fouling properties. As of December 2022, the researchers have successfully formulated the base components of new coatings and assessed their durability. Some, though derived from non-biological sources, remain durable in application due to their self-healing properties. However, the researchers aim to go further by exploring these same possibilities with biological products.

Next steps include enhancing the uniformity and protective effects of coatings, both passive and active, and refining their structure and layers. This involves ensuring multiple functionalities in a single product, such as acting simultaneously as an anti-corrosion protection, a barrier against degrading agents or UV rays and possessing hydrophobic and antifungal properties. These new products have been tested on various metals after accelerated ageing and they demonstrated efficacy, particularly on silver and bronze alloys.

There are challenges in the testing phases, depending on the chosen material, type of object, and the conditions and location of its conservation. By 31 January 2024, the first phase of research should conclude with the development of new passive coatings. Institutions like the Peggy Guggenheim Collection in Venice have offered objects with specific conservation needs for testing with GREENART products. While passive coatings are nearing completion, active coatings are expected to be ready by 30 September 2024.

Consolidants: strengthening artworks

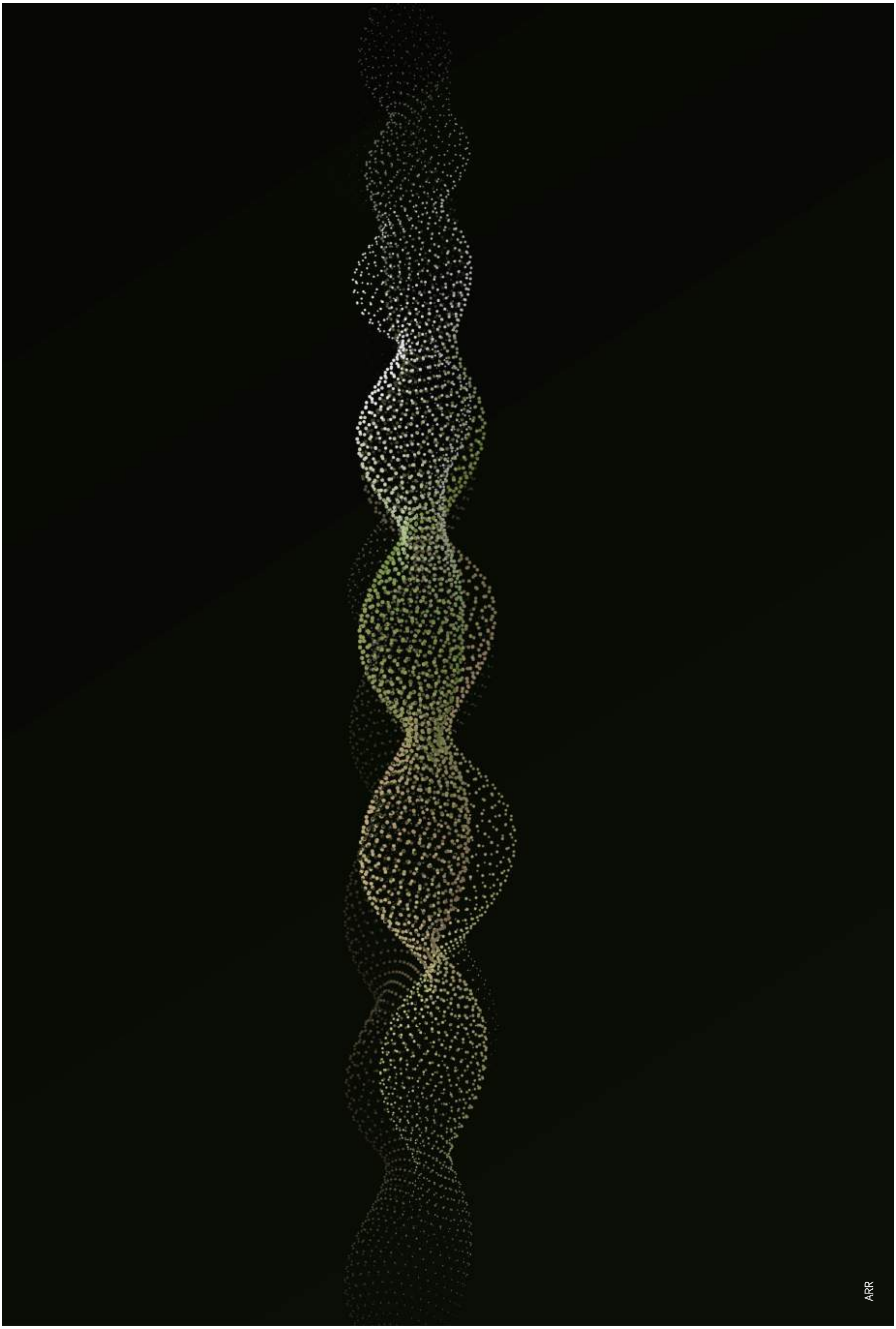
Consolidants, though less visible, are crucial in art conservation. The team dedicated to consolidants aims to develop tools to support and reinforce fragile artworks, as well as packaging materials and foams for their storage and transport. This Works package directly influences preventive conservation methods, seeking sustainable solutions aligned with long-term conservation goals. It involves both material consolidation and structural support (frames and panels).

What tools are involved? Consolidants address issues like fragile paint layers, flaking or crumbling pigments and textiles. These issues arise from industrial paint formulations rich in additives and artistic material experimentation. Improper storage and handling also contribute. Research is also focused on fibre reinforcement in artworks, using biological processes like silk fibroin, a natural protein from silkworms and spiders known for its high mechanical strength. The aim is also to control the gelation and aggregation of products on the artworks.

Regarding the development of consolidating adhesives, researchers are striving to create products that are compatible, sufficiently strong, and avoid potential new deteriorations while making the application as simple and feasible as possible. Currently, they have managed to create dispersions — used in adhesives and as binders in paints — that can consolidate encaustic paint. These will soon be evaluated on test objects.

Consolidants: strengthening structures

When artworks deteriorate, so do their structures. Physical, biological, and environmental factors cause deformations or flaking of paints. Typically, wooden supports or various systems are used to hold the object in place, but GREENART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is looking to propose walls or panels made of custom mechanical properties natural fibres, more resistant to ageing, while optimising their stability. By 30 September, the packaging materials and foams should address issues related to surrounding humidity and pollution, with an appropriate lifespan and usage — or reuse. For instance, paper fibre boxes have been studied for alternatives: by deacidifying them or replacing their components with different materials. Further research on the composition of these solutions will complete the data collected so far.

The current market products for artwork packaging are not at all durable or recyclable. If researchers are addressing these issues, improving these tools will also involve modifying their components to reduce their thermo mechanical properties, eliminating risks of shocks or vibrations during transport. GREENART also envisages custom packaging, produced using digitisation of the artwork, followed by 3D printing. For surrounding temperature and humidity, researchers recommend designing a new sensor made of bioplastics and sustainable materials.

Currently developed foams offer significant advantages: they are non-toxic, green, easy to handle, light yet strong, and can be easily produced in desired shapes and sizes. Notably, they change colour when exposed to organic acids or aldehydes, can absorb acids and gases, and resist the growth of fungi, mould, and bacteria. However, their production is costly and still consumes too much energy for GREENART standards…

Studies have already been conducted on various test objects: papers, paintings, textiles — from aged faux leather handbags to mineralised or non-mineralised archaeological fabrics. The different problems presented by each fabric, wool, cotton, linen are being identified to propose the most adequate treatments possible.

Monitoring technologies

The team dedicated to new green technologies must devise devices made from recycled materials or waste, which will be evaluated by museums and art galleries later. Naturally, these new devices must be as or more efficient than those currently available.

After selecting materials for sensor manufacturing, the challenge was to create compounds that function effectively for real environment testing. The researchers' results are positive but need optimisation, especially in sensor fabrication. Soon, other alternative materials will be studied for their humidity and temperature change detection properties.

Seeking to improve existing tool capabilities, GREENART also proposes reducing the size of some tools, like the transponders used by sensors. While some tests have been positive, others require more research, particularly regarding new natural materials proposed, which still poorly respond to temperature changes and humidity, leading to premature degradation of the object.

In summary, further studies will provide more insights into the limitations of these new green technologies: response time, detection limits, accuracy, etc.

The task of finding the best combinations and the most suitable application for each artwork, object, and material is complex. It requires numerous experiments and research, as well as the development of suitable chemical solutions. So far, the researchers of the GREENART project have met the objectives set for the first year, and some of the Works packages are already able to propose products more effective than those available on the market for art restoration. While some still require optimisation, they will soon enter the testing phase on artworks, in collaboration with conservators and institutions.

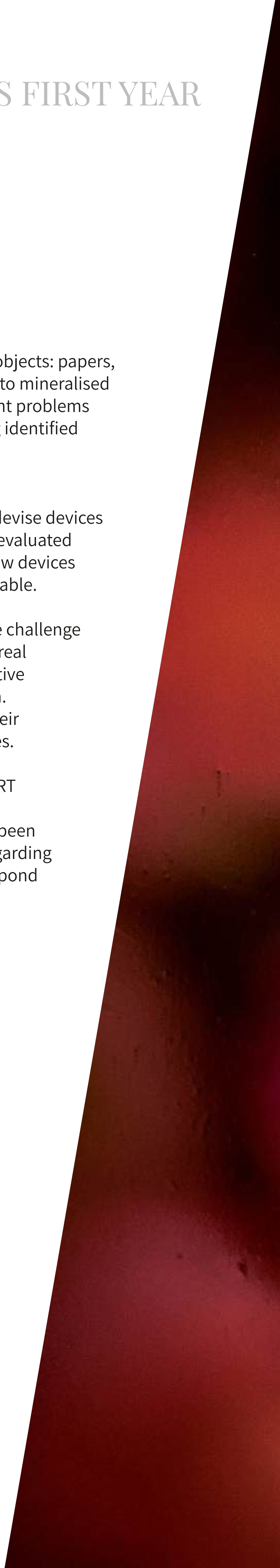

Photo Arnold Landon

DISCUSSION

Photo Antoine Merlet. © C2RMF

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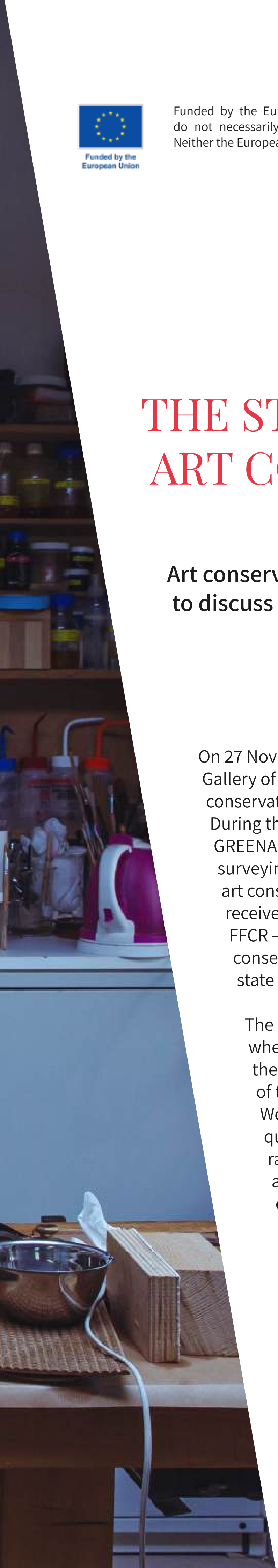
GREENART



THE STATE OF GREEN ART CONSERVATION

Art conservation professionals recently met in Slovenia to discuss sustainable practices within their field.

On 27 November, a public event was held at Ljubijana's Gallery of Modern Art, Cankarjeva, to discuss green conservation practices in museums, libraries and archives. During the event, Antonio Mirabile, a valued partner of the GREENART Project, shared the results of a questionnaire surveying hundreds of professionals within the French art conservation field. The results included 193 responses received from individuals represented by AFROA, APrévU and FFCR — three professional associations in the collections conservation area — and offered insights into the current state of ecologically sustainable practices within the sector.

The survey emerged out of a moment at the end of 2023 when members of AFROA, APrévU and FFCR questioned the adequacy of their professional practices in the face of the challenges posed by the climate emergency. Working in partnership, they established the questionnaire in order to take stock of the entire range of professional practices in which they are involved, including packaging, transport, conservation and climate and waste management. Of the 193 respondents, 48 percent were conservators; 36 percent were registrars; 15 percent were preventers; and one percent worked in other areas. Fifty-six percent were employees of an institution involved in art conservation; 46 percent were freelance.

The first round of questions measured the current level of commitment to sustainable practices within the industry. When asked about their personal level of action in their daily professional life, 1.6% responded that it was non-existent, 35.8% said it was weak, 53.4% said it was average and 9.3% said it was excellent. Similar levels were reported when asked how committed the respondents' workplaces are to responsible ecology, with 6.2% responding not at all, 34.7% saying their workplaces do almost nothing, 47.7% saying they do a little and 11.4% saying their workplaces are very committed to sustainable practices.

Respondents were asked what they believe the obstacles to change are. The most significant obstacles listed were doctrine or the weight of habit, lack of time, lack of proper equipment, difficulties related to administrative functioning, lack of financial means; and realities associated with their current building or facilities. Other answers included a general lack of competencies and difficulties related to hierarchical management structures.

The survey measured the number of loans made by museums and institutions each year and whether the institutions assessed the

— Phillip Barcio

environmental impact of those loans. Of the 93 respondents to these questions, more than half made between zero and 50 loans per year, with 14.6% making more than 500. Ninety-two percent of respondents reported that they were not currently working on reducing loans and 90% responded that they did not currently do anything to assess the environmental impact of their loan process. About half of the respondents said that they take environmental issues into account when engaging in the public procurement process.

In two thirds of cases, respondents reported that the institutions they work with send people to personally accompany loaned objects either “often”, “very often”, or “systematically”. The measures currently being taken by those institutions to limit the carbon footprint of such convoys include transportation sharing, traveling by train, virtual accompaniment, utilising hybrid vehicles and limiting the use of air conditioning in the vehicles.

In general, travel of service providers is considered an area of potential ecological reform in the sector. When asked if they knew the environmental impact of their business and professional travels, 70% of 193 respondents said no. When asked how they felt they could reduce the environmental impact of their travel, the most common responses were utilising low carbon transport, limiting travel, carpooling and choosing methods of mobility that do not consume fossil fuels.

The use of packaging crates is another area identified for potential ecological consideration. These crates are predominantly used for the internal movement of objects and for loans. Of 77 respondents to a question about acclimatisation of insulated crates: 18% said they acclimatise empty crates, 46% said they employ acclimatisation of 24h, 20% said they employ acclimatisation of 48h and 16% said they employ no acclimatisation. Eighty-eight percent of respondents said they do not get their crates painted. More than half of respondents reported that their institution does not maintain an internal storage area for packaging crates. Of those who do maintain an internal crate storage area, 44.2% say that storage area is smaller than 10 m^2 and 38.5% say it is smaller than 50 m^2. In 62% of the cases, there is an individual who has a dedicated responsibility to these storage areas. In most cases that person’s job title is registrar.

The next round of questions related to energy consumption within cultural heritage institutions. The first question addressed the imposition of energy restrictions. Although about a third of respondents reported that their institution is not subject to any energy restrictions following the increase in energy prices, two thirds reported that they are subject to restrictions when the temperature drops and nearly half are subject to restrictions in the summer. Of 113 respondents, 84% responded that they do not currently know how much energy their institution consumes, although 39.4% actively carry out assessments to obtain data about energy consumption and 15.2% delegate such assessments to a service provider.

Eight out of 106 respondents reported that a climate control specialist was in charge of prescribing climate guidelines within their institutions. That responsibility mostly falls on registrars, conservators, curators and preventers. Around two-thirds of respondents reported that their institution does not propose microclimate management systems. Nearly 70% of respondents said that they do not have enough information to support more sustainable climate prescriptions, while 73% said they do not currently seek advice from a national institution to validate their prescriptions. Asked if they would be willing to give up control over their own climate systems in order to achieve different results, an equal number (16%) said either yes or no unconditionally; one third said yes, conditionally, such as when the institution is closed; another third said they do not know.

The next round of questions assessed the concerns and actions of freelancers within the field. Of the freelancers who responded, the majority reported that their interest in ecological sustainability began after 2016. Their current efforts included conducting survey analyses, going on consultancy missions, site monitoring, supplying equipment, observation, diagnosis, health assessment after leaks and ensuring the proper management of collections according to the climate recorded.

The freelancers reported that in most cases they had to do their own

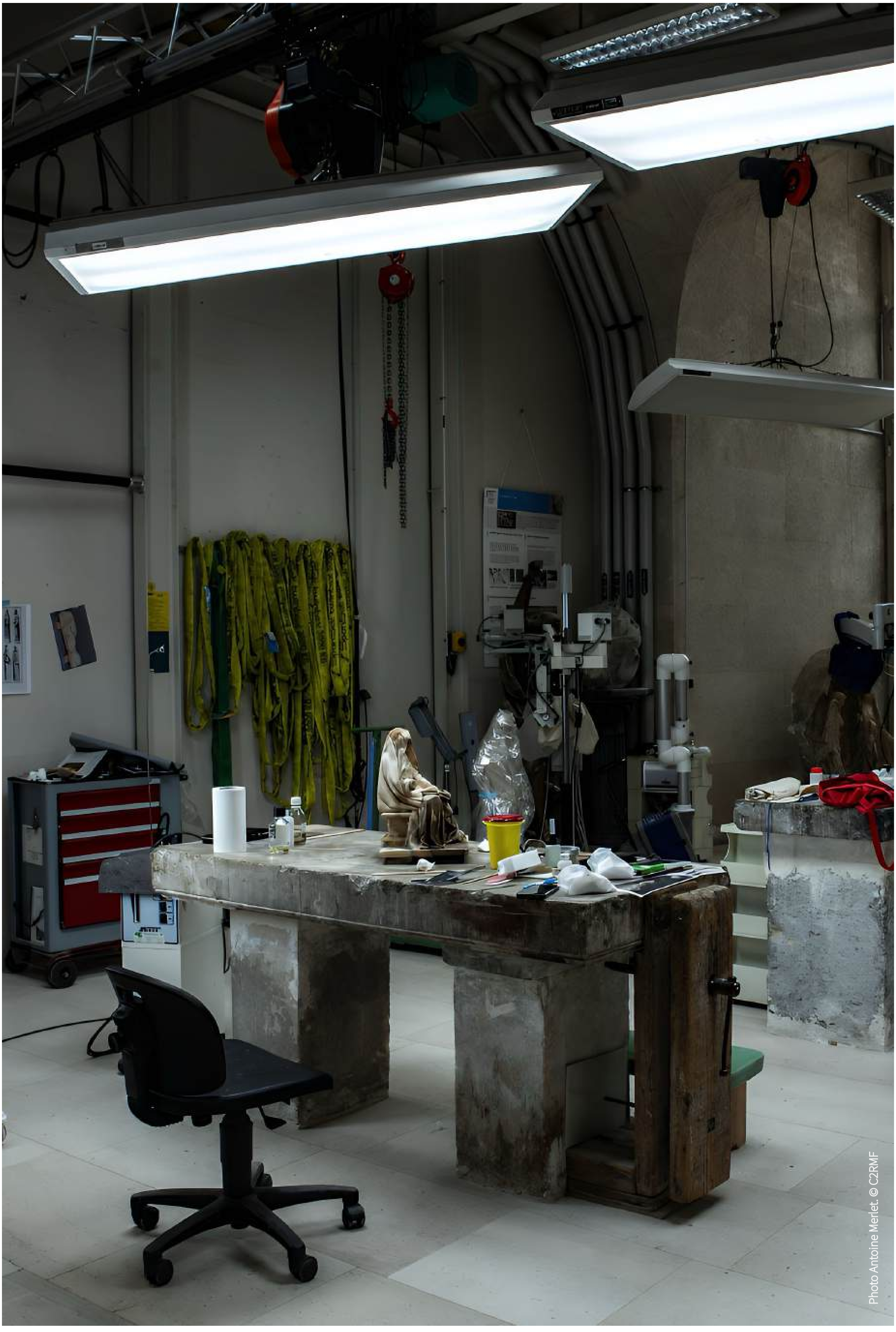


Photo Vanessa Fournier. © C2RMF

climate measurements, without the help of institutional surveys. In two-thirds of the cases, they reported that their efforts to convince the institutions they do work for to adopt ecologically responsible practices in terms of climate management have failed. Similarly to individuals employed by institutions, the vast majority, 88%, of freelancers reported that they did not consider their knowledge of sustainable development regarding climate to be sufficient. When faced with questions, 61% of freelancers report that they consult experts in the field, including experts from national institutions and climatic specialists.

Waste management was a major area of concern for many respondents. Many reported that they have reduced the use of certain materials due to their environmental impact. The top materials listed as having been reduced were plastic materials and solvents. Other materials listed were synthetic paints, adhesives, resins, cotton, fillers and biocide. However, 77% of respondents reported that they do not know how much waste they produce.

When asked whether they would be prepared not to carry out certain interventions because of their environmental impact, 74% of respondents said yes, but 63% said they have never actually defended that position with a client or partnering institution. When asked if they would be willing to increase their fee in order to be able to implement eco-responsible approaches that generate an additional cost, 79% said yes.

In terms of energy consumption, the most common areas where consumption reduction currently takes place in the sector are electricity, air conditioning and water. Electricity reduction is mostly achieved through low-energy light bulbs, replacing neon lights with LEDs, turning off lights when not needed, installing motion-detecting lights and unplugging unused appliances. Reduction in air conditioning, ventilation and heating is mostly achieved by lowering the ambient temperature (heating), conducting administrative work at home where less air conditioning is needed, using programmable thermostats, regulation of relative humidity and management of sunlight. Reduction in water use is mostly achieved through recycling wastewater, checking tap leaks, using rainwater and recovering water from dehumidifiers.

The top materials respondents reported recycling were cardboard, paper, plastic, wood, metal, solvents, PPE and cotton. Those same materials were reported as being reused, in addition to glass and water. The systems most often reported as being used to recycle waste were municipal sorting bins, waste collection centres and external service providers. Respondents also reported a number of materials that they use in large quantities for which they do not currently have a recycling solution. Those materials include pallets, wooden crates, impregnated cottons, certain plastics such as bubble, film, polystyrene and polyethylene, mylar and tyvek, film and anoxic absorbers, plastic syringes, nitrile or latex pants, contaminated water from stabilisation treatment, oxygen absorbers, canvas scraps, adhesive leftovers, epoxy resin residue, solvent and resin-soiled hand towels, acids and bases, solvents, lime grout and screed, certain PPE, damaged art frames and lighting.

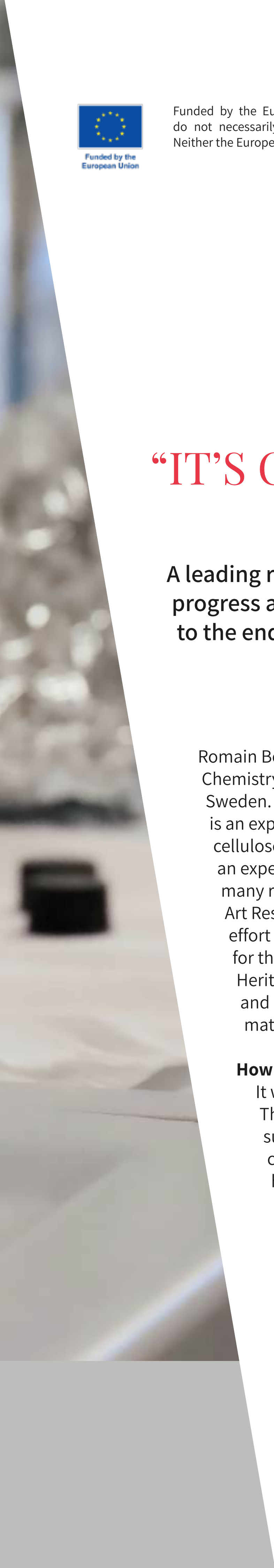
Most respondents replied that they have changed their purchase habits in response to concerns about eco sensibility. The most popular changes include making purchases from local suppliers, purchasing more sustainable materials even if the cost is higher, making group orders, requesting delivery to a relay point if possible and purchasing materials in bulk.

In conclusion, respondents were asked the overarching question of whether they considered their own professional practices to be in line with their personal commitment. Of 193 respondents, 13% said “not at all”, 33.7% said an unqualified “yes” and 50.8% said “a little.” All respondents felt that they could use more training, especially in the areas of climate management and eco-responsibility, waste management, carbon footprint and green solvents.

Photo Antoine Merlet. © C2RMF

INTERVIEW

Photo Mickaël Pijoubert. © Art Media Agency



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GREENART

"IT'S CONCEPTS, THEN IT'S DANCING"

A leading researcher on the GREENART project discusses the project's progress and challenges, and highlights its importance to the endurance of Europe's cultural heritage.

Romain Bordes is leading a researcher in the division of Applied Chemistry at Chalmers University of Technology, Gothenburg, Sweden. With a background in surfactant chemistry, Bordes is an expert on surface-active materials, including nano-cellulose, advanced colloidal systems. He has also become an expert on cultural heritage preservation. Bordes is one of many researchers working closely with the Green Endeavor in Art Restoration (GREENART) Research Project, a three-year effort to develop sustainable products and procedures for the preservation and restoration of European Cultural Heritage. His work bridges fundamental research and real-world applications in surface chemistry, material science and environmental technologies.

How did you come to get involved in art conservation?

It was not originally my thing. I am a surface chemist. That means my job was to look at how to treat surfaces. I did my thesis on polymerisable sub-active compounds. It is very complicated, very research heavy. Then I was introduced to Professor Piero Baglioni. He makes formulations to clean art. Cleaning art is surface chemistry. It is the same thing. A substrate that is extremely fragile, like the face of a man or a woman, or a painting, is the same. You have to make sure to remove what you want to remove, without damaging what is underneath. We made formulations, we mixed, did tests. And the formulas worked. They were used to clean frescoes in a church and we had a magnificent result. They removed the varnish that was on the surface and they revived the colours. The cleaning was effective. That was ten years ago.

Then you were invited on board EU projects?

Yes, and I was working with lots of other things in parallel, notably cellulose nanoparticles and silica nanoparticles. And we saw we could use that to consolidate the support material of cotton canvas, because the materials are similar. So we got the money and we started doing nano-research. That is how I discovered European projects, how they worked. I also saw the evolution of how the European Union manages projects, how it puts pressure so that people deliver. They structure the projects with deliverables. You have a framework. If we went into a project, we had to be pretty sure that what we were going to do was going to work more or less. So we did not start with purely esoteric questions. We did applied research. And it was super-interesting. We did work at the Tate and the Pompidou. We were there when there was no one else there. This kind of museum, when you can be alone, it is exceptional and it allows you to have another view of art. My dad studied fine arts and then he did advertising for a time

— Pierre Naquin and Phillip Barcio

and then he did architecture, things like that. There was always a taste for beauty, a taste for aesthetics, in which I was bathed as a child. So for me it was important to preserve art, because art is culture. It is a societal value. A society without art is a society that has lost something.

Now with GREENART you work on conservation, restoration, cleaning, coatings, consolidants…

So this is where you enter an extremely grey area and you have to be relatively technically advanced, because the ingredients we use can be used in certain things and we can call it a coating, because you mix them, you put them on a surface, it dries and it forms a film. We can take exactly the same quantity of polymer, but instead of using it as much in concentrate, we dilute it and there is no longer enough to form a film, or the film would be so thin that it has no practical value, but we will use it in other formulations, to do other things. So one of the qualities of people who work in formulation, coatings and things like that is that we are often used to mixing things that are not intended for a particular function, but we tell ourselves that it has the right property to do the function we want, and we adapt it. And that is where it is interesting. For example, to make gels that we apply to clean, we use a molecule which is often called PVA. PVA is something they are trying to move away from, because it is not bio-based. But the fact is that we also use it in other applications, in cosmetics for example, to control viscosity. PVA is in the plastic packaging that is in the tablets that you put in the dishwasher, which will dissolve. The only difference is the way in which it is made. The manufacturing of the molecule is the same in absolute terms. This is where it is fascinating to understand the physics behind it and the physico-chemistry behind it. Because starting from the same molecule, you do two things which are orthogonal in terms of application.

What is the difference between varnishes and a consolidants?

A consolidant does not protect but stabilises. A varnish will cover the entire surface to create a barrier to the outside world. So you are going to make a film, very thin, preferably invisible. You do not want to mess up the artwork underneath, but you want, for example, the oxygen not to get to the surface to oxidise it. It is as if you are adding material, but it is not the same material. And the material that you are going to add, you want it to be as close as possible to the material of the object. But it cannot be the same thing. So all that, it comes from chemistry. But it is complicated. Think about paper, for example. Thirty years ago we were making paper at 300 meters per minute. Today, it is 2,000 meters per minute. We multiplied the speed by more than six by better understanding fibres. We can remove the water more quickly, maintain the structure and send it to dry. That is the chemistry of surface colloids. The use of silica particles, with a polymer, allowed this acceleration. We managed to increase the speed of what is called “dewatering” of the paper, because we understood how these interactions took place. Something that did not happen 40 years ago was when you cut paper, your scissors did not get dull. Today, if you cut paper, scissors eventually become dull. The reason being that there are between 10 and 30% silica particles in the paper, and silica is abrasive. But adding silica allows the production speed to be increased. With things like this, we realised that in the conservation of art, they could make a mess, because, for example, maybe products could emit new atmospheric pollutants which can damage the object that you put in a box. It is in a box, it is well protected… yet maybe it is the box that ruins your life. The box can ruin you, but there is also the object which can self-degrade, because it ages. And you have locked it in a box, so it will emit its pollutants in the box. So you increase the quantity of pollutants locally, whereas if it were placed on a shelf, the problem would not arise, but there would be other problems. It would be sensitive to light, things like that. So the question that we are trying to address is to develop solutions which are, for example, anticipatory of these problems.

With GREENART, you are looking at prevention but also the environmental side…

We said to ourselves that the volumes that we are going to have to use and produce, the environmental impact is going to be important. So we have to produce solutions to the problem. And that is what the project is working on. Another challenge is the definition itself of something being “green”? We discussed that a lot with the sustainability group. And even to them, it is complicated. When you work, for example, on cleaning solutions, you can say, “Ah, reusing garbage is green. We are doing circularity.’ But if you start

Romain Bordes

Photo Pierre Naquin. © Art Media Agency

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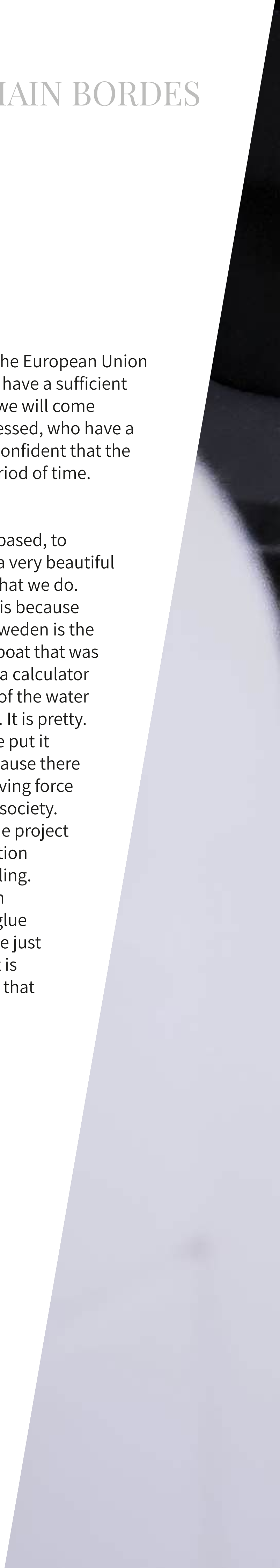
to look in detail, you can also rightfully say, “I need 10 grams of this product to achieve such a result and it is circular. But I put in so much energy. What if I use 0.1 grams of this other product, which is disgusting, but on the other hand it is in the right place, at the right time.” There is no right or wrong in our world. Sometimes we have done something that is super green, only we cannot put it into the formulation we want. Sometimes you realise that by putting 5% of a product that is not green, you manage to define a formulation as 95% green. Well… it is better than 0%. Because it is pushing in the right direction. Overall, I think we are getting pretty green. And there are several speeds in the project — that is what is important to understand. Maturity is a long-term topic. With consolidants, products on the market are disgusting, they are not organic, they are not biodegradable or anything.
It is terrible. Understandably… they were not developed for that. So we set out to create green solutions, but we started from scratch, we had nothing on the table. So it takes time. There is also the question of reversibility, which becomes philosophical. When you put paint into paint, does it stay painted? Is it still the original paint? Is it still the original surface? Philosophically, is it better to risk losing the object, or to give it a second life and consolidate it? Restoration, strictly speaking, means returning to the original properties of the material. So you are at 100%, then it has deteriorated, it has gone down to 30%, and you add a material which brings it back to 100. It is mechanical stable. We will be able to do what we need to do with it — not carry it on your back and go to the beach, but expose it, make it visible to the public and give it back its cultural aspect. Ultimately, the European Union will only evaluate what we do if we deliver results that have a sufficient quality. The next time we apply for funds and money, we will come across as people who have delivered, who have progressed, who have a good springboard to create the next generation. I am confident that the solutions we develop can have value over a certain period of time.

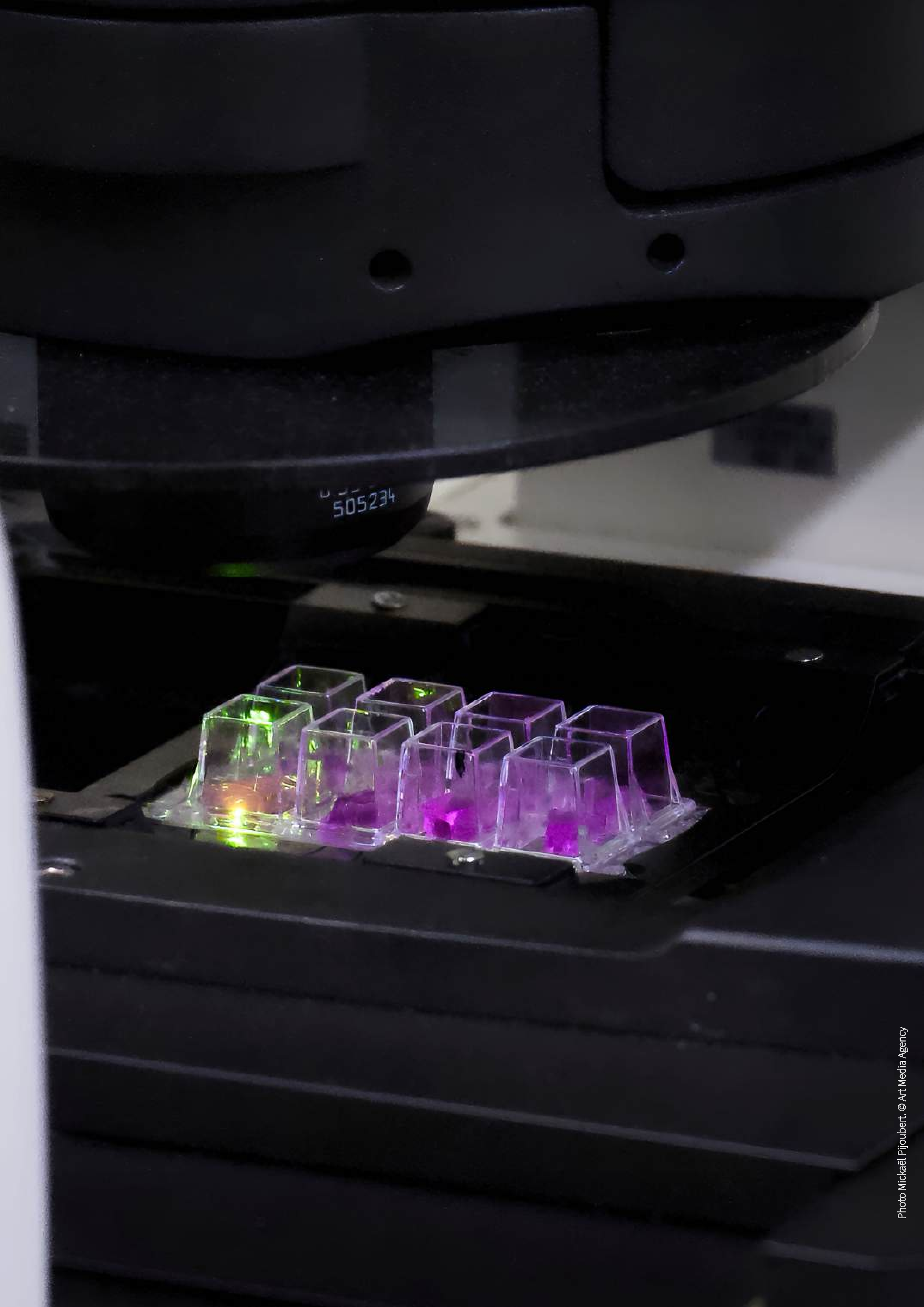
What is next after GREENART?

I would like us to continue with everything that is bio-based, to continue to integrate this component. I think that it is a very beautiful showcase of technology on a European scale and of what we do. Because, what are we doing it for? People come to Paris because there are museums. The biggest attraction to visit in Sweden is the Vasa Museum. It is the museum where there is the big boat that was taken out of the water, built by guys who did not have a calculator at hand. It sank in the port, it remained at the bottom of the water for hundreds of years, but it was refloated in the 1960s. It is pretty. But it is getting worse now that it is outside. Should we put it back in the water? No, we will try to do something, because there are a lot of tourists who come to see it. This kind of driving force which is ultimately commercial also has an impact on society. And art is a good showcase for testing. For example, the project we are working on with the Peggy Guggenheim Collection in Venice, they have this encaustic painting that is peeling. The substrate is wood. What comes off is beeswax with pigments in it. What they used was a kind of polymer glue that stuck together, and that is not great. So we said we just need to find a way to use wax, but in such a way that it is micronised somewhere and formulate it in such a way that it is in water. So for that, we used nano-cellulose and, in parallel, cellulose derivatives which are used today to control the viscosity of paints. And if we apply this correctly, we can restore the mechanical properties while removing the sensitivity to humidity, because that is what is causing us the problem. It is by thinking around these concepts that we develop formulations.

Are questions of art conservation always so specific?

It is up to us as developers to find a generalisation and it is our personal curiosity which opens the parasol a little. But we generalise by doing, by using concepts. Concepts of chemistry and interaction, hydrophilic, hydrophobic concepts, these are big houses and you know that you are going to make bridges between these houses. And this is where it gets interesting. Sometimes you see bridges forming. It is very difficult to explain it in detail without getting into something that will be very chemical and very boring. But we work on concepts, then it is dancing. There you go.

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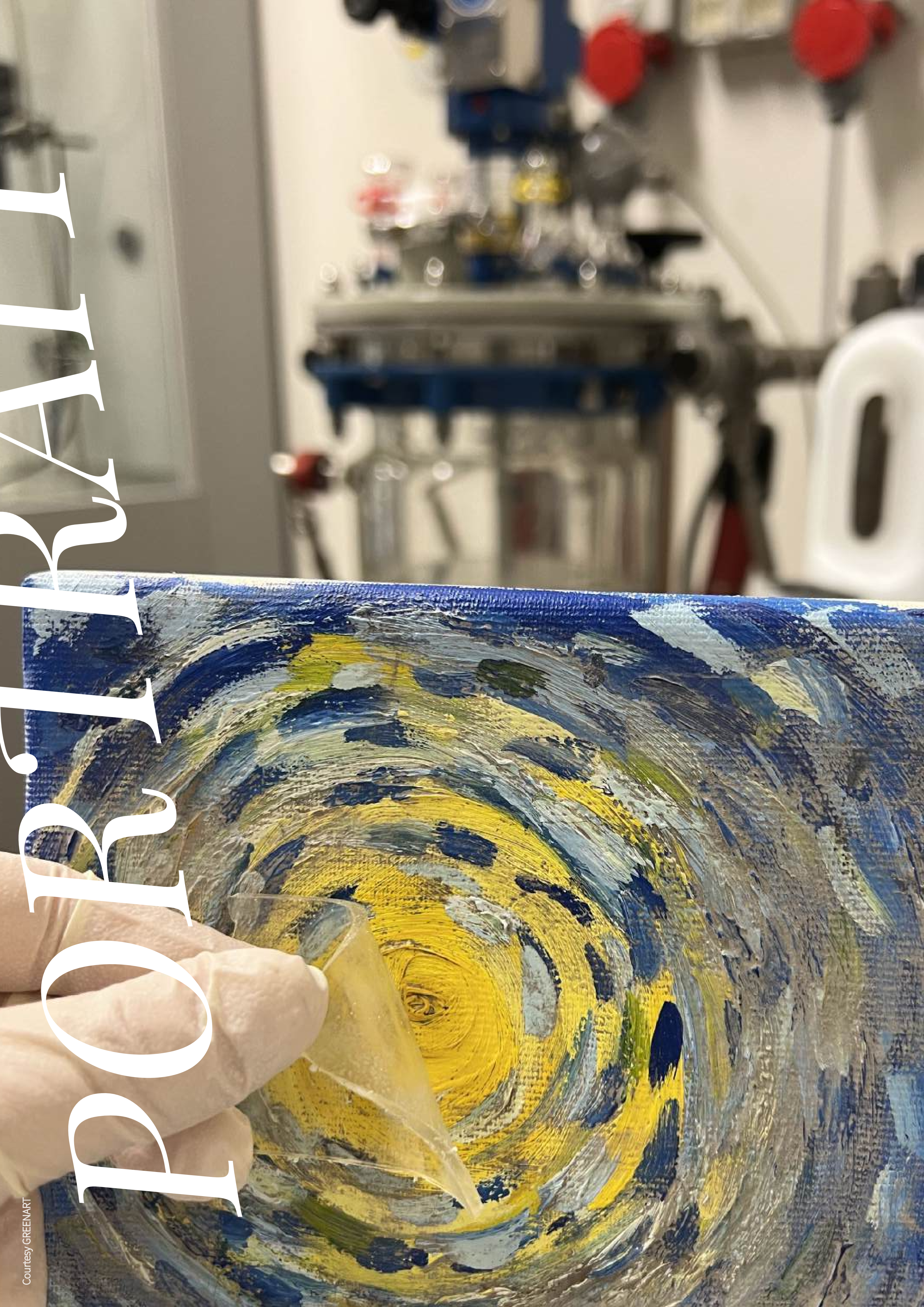
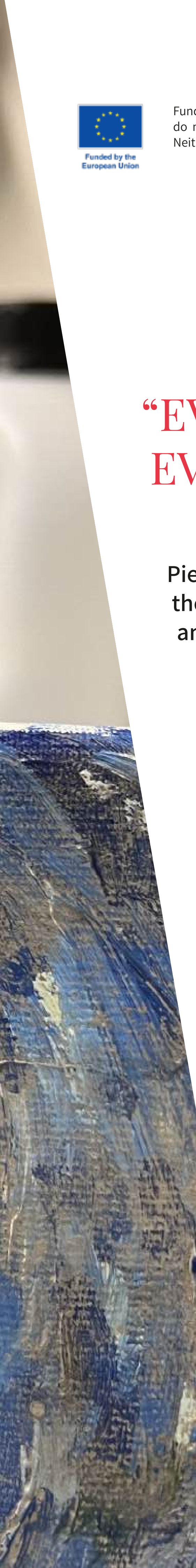


Courtesy GREENART



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GREENART

"EVERY ARTIST HAS HIS OWN RECIPE, EVERY PAINTING HAS ITS OWN STORY"

Piero Baglioni is a professor of chemistry at the University of Florence and manages the European GREENART project to develop new ecological systems and green materials for the restoration of works of art.

A renowned chemist, Piero Baglioni teaches at the University of Florence. A specialist in inorganic and organic colloids, his sensitivity to art has led him since his early years of study to take an interest in the conservation restoration of cultural heritage and works of art, although his research has led him to a multitude of fields, from medicine to industry. Winner of the 2003 European Grand Prize for Innovation, he is the author of many patents and publications. He is involved in the European GREENART project, which aims to develop innovative solutions for preventive conservation and heritage restoration using environmentally friendly materials obtained from renewable natural sources.

How did you come to link art and chemistry?
When I was in my third year of university in Italy, I was taking a physics and chemistry course. The professor was an art enthusiast who saved the frescoes in the churches of Florence, which were badly damaged during the 1966 floods. He was quite fascinating and I decided to do my thesis with him. In the meantime, he became president of the university. It was with him that I discovered the challenges of remedial and preventive conservation.

Are you interested in the materials that make up works of art to understand how they degrade?
We try to model degradation reactions to prevent them from occurring. In the case of frescoes, with my former mentor, we found a way to anticipate these degradation reactions. In other cases, it is not possible, we can only delay the process. If you take the components of paints, it's extremely complex, for example. In practice, if you want to understand the degradation of these materials, you have to use a very specific scientific framework. My professor was a professor of colloid and surface chemistry and I myself became a professor of colloid and surface chemistry. This is a field that has evolved considerably over the last thirty years. In the case of works of art, degradation is mainly on the surface, for example, paintings that lose their colours or pigments, etc. When you have a good knowledge of the science of colloids and surfaces, you can try to understand degradation. This is all part of what we call nano-science.

How many different materials do you study? What are your methods?
Oh, there are many! It all depends on the artefacts. For example, if you study paintings, they use complex components, organic or inorganic materials. You analyse and build your diagnosis, you classify the degradation. And once you have done this classification, you try to find methods to reverse, stop or slow down the degradation reaction. It is even possible, in specific cases, to go backwards!

— *Pierre Naquin*

> Once the classification is done, you try to find methods to reverse, stop or slow down the degradation reaction. It is even possible, in specific cases, to go backwards! In fresco paints for example, you can reverse the degradation caused by the calcium carbonate turning into calcium sulphate. — *Piero Baglioni*

Do you also study the medium?

For example, for paper, the degradation reaction comes from two main systems: acidity and oxidation. The long cellulose fibres are the constituents of paper. In an acidic environment, a chemical reaction reduces their molecular weight, and therefore the length of this chain, to decrease. The paper then becomes fragile and breaks. The oxidation of the fibres is caused by oxygen in the presence of impurities such as iron or copper. So the oxidation at the end acts in the same way as the acidity by breaking this long chain, which results in the paper losing its mechanical properties. In fresco paints, you can reverse the degradation caused by the calcium carbonate turning into calcium sulphate. During this chemical reaction, you have an expansion of the volume, which makes the painting very fragile. You risk losing the colour, the pigments. But the calcium sulphate can easily be converted back into calcium carbonate. You chemically transform the calcium back into calcium carbonate and you can protect the painting for another 1,000 years, because frescoes are the most stable paintings over time.

Do your research concern ancient works or are you also interested in contemporary works?

We already know most of the materials used in different periods. From the 13th to the 17th century, artists were very good technically and used quality materials that were made to last. If you look at contemporary art, it's very different because artists are mixing materials, using what they have at hand, experimenting. You have a palette of colours, which is extremely wide compared to the classical palette, but at the end of the day, you have a system that is quite unstable from a chemical point of view. For contemporary art, the actions to be taken are mainly preventive actions. Each artist has his own recipe. They all use a different binder, in different quantities, colours that are emulsified or not, and so on. So each painting has a different story.

You have been involved in other European projects before GREENART, how do they interact with each other?

Often projects improve on each other. In the case of GREENART, it is very much related to the previous project, which is called Nano Restart, where we developed multiple methods for cleaning contemporary and modern art. The idea of GREENART is to rewrite the systems, to see things differently. In the case of cleaning, chemistry is the only possibility we have to avoid pollution — I know a lot of people think that chemistry produces pollution, but that's not true, chemistry doesn't pollute if it is used properly. So we decided to use the same cleaning system, but rewrite the whole system in a green chemistry way, by changing, for example, the solvent. In GREENART we also use materials and systems that come from another project called Apache dedicated to preventive conservation to prevent the degradation of artworks. Some of these processes that we find effective will be rewritten into a fully green system in GREENART. We are looking at raw materials that need to be fully green, from a biological source or a renewable source that does not interact with the food chain. A simple example is castor oil. We use castor oil because castor oil is not edible, it is produced for a green industrial application. And so we can use it freely.

Do you have any targets in terms of the number of materials or methods to be developed?

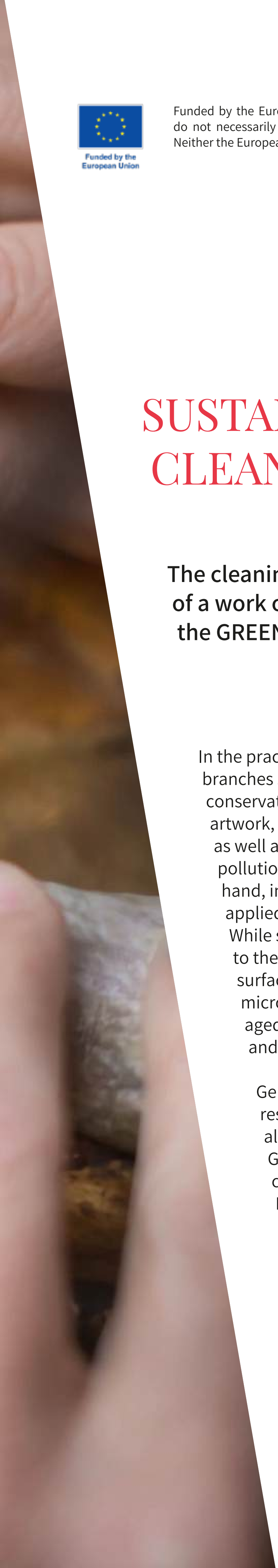
Developing new materials is always a calculated risk. We don't have precise quantitative targets, but the aim is to develop as many as possible under EU classification 9, which means that they will be ready for the market, i.e. that conservators will be able to buy these materials. Let's say that at the end of the project, the objective would be that half of the green materials developed are ready for the market.

What kinds of partnerships need to be put in place to commercialise these materials?

Three groups of actors are involved at different levels. The social sciences with curators and museums; industry, which — ideally — should produce molecules and materials classified as green; and finally those who develop complex systems from the raw materials. The GREENART program actually has four components: the industrial field; research into new ecological intermediates and molecules used to build new systems with specific properties adapted to conservation specialists; application and finally dissemination, because the aim is that people can use our methods, otherwise it is just a game, a purely intellectual satisfaction.

Courtesy GREENART


ZOOM



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SUSTAINABLE INNOVATIONS IN ARTWORK CLEANING AND RESTORATION

The cleaning of artworks is a fundamental pillar in the restoration process of a work of art. It involves the use of products that researchers from the GREENART project are working to transform to make them sustainable.

In the practices of art conservation and restoration, two branches stand out: preventive conservation and remedial conservation. The former targets elements external to the artwork, such as its containers, display cases, crates, or boxes, as well as the surrounding air, which can be treated against pollution for instance. Remedial conservation, on the other hand, involves direct contact with the object using materials applied to the artwork to clean, strengthen, or protect it. While strengthening and protective actions add materials to the object, cleaning involves removing layers from its surface. Dust, dirt, biopollution, or patinas from microorganisms are thus eliminated, as well as sometimes aged varnishes or adhesives that can harm the artwork and its appearance when they degrade.

Gels, emulsions, and foams are products used by restorers to carry out cleaning effectively. These are also the focus of efforts by researchers from the GREENART project, involved in the issue of artwork cleaning and restoration, coordinated by Prof. Piero Baglioni and his team at CSGI (Center for Colloid and Surface Science). Among them, David Chelazzi, expert in chemistry and doctor in cultural heritage conservation at the University of Florence and CSGI, explains: “We want to make them green, using green materials, green methodologies. They must become sustainable in all aspects, with non-toxic raw materials and energy- efficient production.” At the core of the entire project, the use of ecological materials involves considering all stages of production of the newly developed products.

Production stages

To successfully develop their products, researchers follow several steps. They must first select and provide basic components: “This is when we select the best non-toxic and affordable materials,” comments David Chelazzi. Afterwards gels, nanoparticles, films, polymer dispersions are assembled and evaluated in the laboratory, and then with restorers to measure their effectiveness. Then, the team at CSGI, accompanied by Elena Semezin, a doctor in environmental sciences at the Ca’ Foscari University of Venice, and her team, ensures in a new examination the consideration of product requirements at all stages of its life, integrating them with the information produced by all GREENART partners.

Researchers have two paths for manufacturing their products. The first involves taking the best materials manufactured in recent decades and rewriting them using more environmentally friendly components. The second involves

— Diotima Schuck

creating entirely new systems. "There are many materials available. Waste too, or natural and biological compounds that we can give a new life to," the researcher reveals. "In reality, the most challenging aspect is to rethink and recombine these materials, with certain chemical or physical manipulations, which is at the very core of our work." In the development of these products, each step counts, and their formulation is decisive to achieve effective results.

Green and effective

The criterion of effectiveness is a major element for GREENART researchers, as their new products must surpass what is currently available on the market. This effectiveness depends on both the sensitivity of the surface of the objects to be treated and the versatility of the prepared materials. David Chelazzi explains: "When we use gels to clean artworks, we want to be sure that they can remove dirt or aged varnishes without altering the original pigments and different layers." Traditional solvent blends can cause the paint to swell or dull the colours; thus, they may require a step-by-step check of dirt removal. On the contrary, the innovative gels developed by GREENART allow for selectivity in removing dirt between the gel and the paint: "It's a safer and faster process because there is no need to constantly check what we are doing," comments the researcher.

Traditional methods, in fact, use poorly confined organic solvents, which contain inherent toxicity and are often derived from petroleum-based compounds. Composed of natural, waste-derived or "green" synthetic polymers, the gels developed by GREENART are less toxic. They can also be applied better controlled: "Improving efficiency is not only about the quantity of elements removed from the surface of an object but also about the safety with which they are removed," notes David Chelazzi. The GREENART gels and cleaning liquids allow for detaching varnishes from the surface rather than completely dissolving them, as traditional methods do today.

GREENART's new materials are greener and more effective. Here, the requirement for sustainability does not compromise its effectiveness; on the contrary, GREENART's ecological approach goes hand in hand with the proper conservation of cultural heritage: a sustainable conservation over time, environmentally friendly but also respectful of the treated objects. Similarly, the emulsions developed by researchers use water, aiming to maximise cleaning effects while minimising waste.

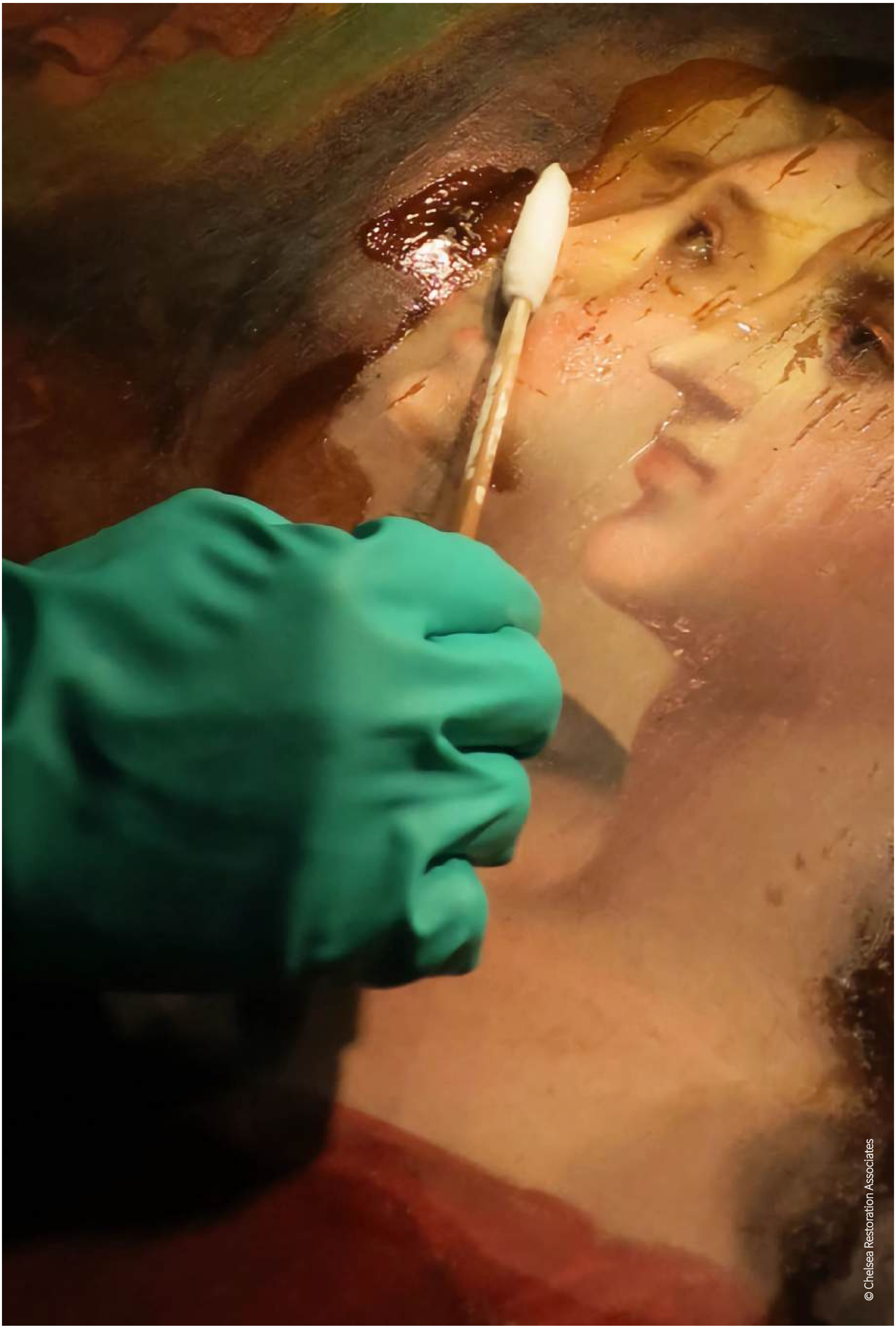
Durable products

As for the sustainability criteria of a product, they extend to its entire life cycle. "They must also be safe in their application and use by restorers, conservators, and all possible users," explains David Chelazzi. "We not only want to use innovative and effective materials but also make them, as far as possible, affordable for users. And in general, offer a quality significantly superior to reference products on the market for the same price." Beyond an obvious ecological dimension, GREENART's new products must also meet safety standards, providing non-toxic formulations, as well as financial criteria by being affordable. For them to be sustainable, their prices should not be too high. "Or, they must be justified by a very high quality of the material and long-lasting effectiveness, over fifty, a hundred years," comments the researcher.

Cross-cutting benefits

If the world of art conservation and restoration seems limited compared to the scope of the project, it's because the efforts made by researchers are not confined to this single domain. Here, it is also a matter of social well-being, preserving the identity of a society through its material goods, and facilitating future generations' access to artworks, endowing the sustainable approach advocated by GREENART with symbolic value. And in a more concrete perspective, the solutions provided by the scientists could extend to other scientific and technological fields.

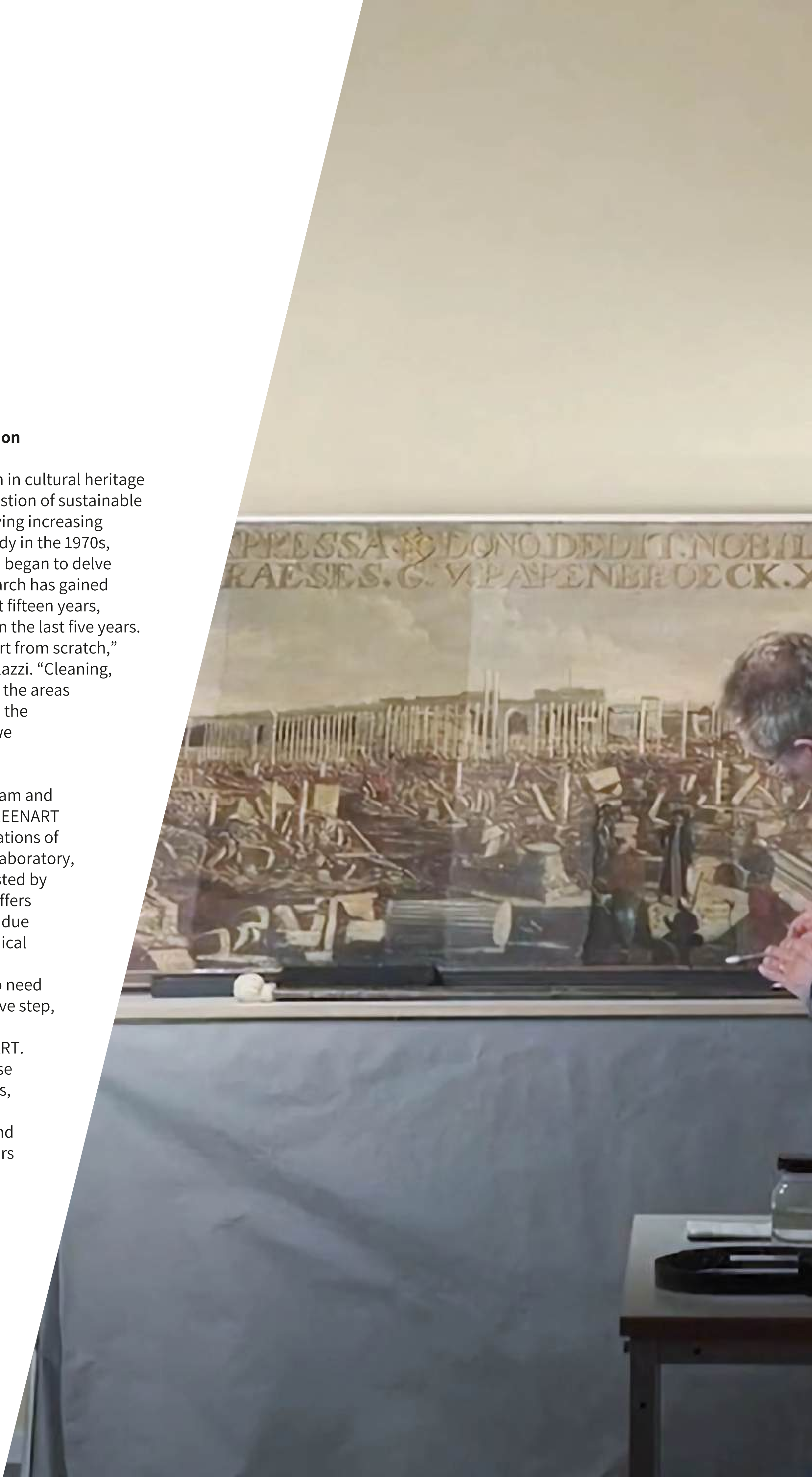
If the developed materials can be transferred to other sectors, the same applies to the methodology followed by GREENART. The development of the life-cycle assessment method, in particular, allows for harmonising green standards: "The scientific framework we are developing and the ecological methodology we are following can be used for the food, pharmaceutical or cosmetic industries," notes David Chelazzi. The scope of research for the green conservation and restoration of artworks thus goes far beyond this single field.



Towards the transmission of the green approach

In the field of research in cultural heritage conservation, the question of sustainable development is receiving increasing attention. While already in the 1970s, a handful of scientists began to delve into the subject, research has gained momentum in the last fifteen years, with an acceleration in the last five years. “We didn’t exactly start from scratch,” comments David Chelazzi. “Cleaning, in particular, is one of the areas in which the CSGI had the most experience, so we are well advanced.”

Currently, the CSGI team and research groups in GREENART are completing evaluations of their products in the laboratory, which will soon be tested by restorers. Their use differs from traditional tools due to their physico-chemical mechanisms; hence, professionals will also need to be trained. A decisive step, which also poses a challenge for GREENART. As not all users of these products are scientists, it will also involve offering workshops and meetings with restorers to raise awareness of these new products. “And for people to trust us, we also have to show that what we are currently developing really does work,” concludes David Chelazzi.



INTERVIEW

Photo Miguel Sousa

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GREENART

DIVING INTO GREEN CLEANING AT TATE

Associated with the GREENART project, the Tate overlooks discussions and collaborations around the assessment of the green cleaning products that are being elaborated. The team's director Bronwyn Ormsby sheds a brighter light on its role and objectives.

Acting as Principal Conservation Scientist at Tate — a position she has been holding since her nomination in 2016 —, Bronwyn Ormsby graduated with a PhD in Heritage Science from Northumbria University in Newcastle in 2002. This is where her collaboration with the institution initially started. Since, she has worked in various roles in Conservation Science and today leads and manages the Conservation Science and Preventive Conservation teams. She also supervises PhD students, oversees and devises scientific research, while providing scientific support for the Conservation Department. Hence her important position within the GREENART project, where she is responsible for Tate's project design, content, and delivery with a team comprising Conservation Science, Paintings Conservation, as well as support from the Collection Care, Curatorial and Research and Interpretation. She further reveals what her role and Tate's are about.

What is your role in the GREENART project?

Tate is an Associate Partner in the GREENART project. Our involvement is funded by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee grant. We were partner in another EU-funded project, NANORESTART, from 2015 to 2018 so I was familiar with the inter-university research consortium (CSGI). As the Principal Investigator for Tate's contribution to GREENART, I designed Tate's project accordingly. Research is primary to Tate's mission and every proposal must be accepted by a range of internal and external stakeholders. The project must be aligned with institutional values, relevant to the Collection and needs to address urgent research and/or practice-based questions. We have a substantial body of research into modern painted works of art and cleaning science to draw from, as well as ongoing programmes around sustainability, so we were well-placed to join GREENART. Tate is the leader for Work Package 2 (WP2) Task 2.3: we co-ordinate discussion and facilitate collaboration around the assessment of the green cleaning materials produced as part of WP2. We meet monthly on Zoom to discuss a range of topics from ethics to the new GREENART materials and beyond. This role is particularly important as well as being enjoyable, where we meet with colleagues from across the globe on a regular basis to learn from each other's experience and research.

In simple words, can you tell us what is involved in cleaning a work of art? What is removed?

Cleaning a work of art is never simple, it depends on the context of the situation, on what you are trying

— Antonio Mirabile

to remove, or how materially complex the work of art is. And it also depends on the time and resources available. One key task is to determine whether something is unwanted and why. Sometimes it is a dirt layer, a coating — or both —, or a retouching. It can also be a graffiti, a range of accidental marks… On occasion it can be the artwork materials themselves degrading and forming obscuring layers on the surface. Once the primary query has been explored, the next step is to assess any risks that might be associated with the cleaning processes. This involves exploring the artwork materials as well as the possible cleaning systems that you may want to use in depth, which leads to consideration of the benefits and risks of each option. When this has been completed (with a whole lot of accompanying due diligence and documentation) the cleaning process, usually slow and meticulous, may then proceed with caution and a regular assessment of progress. Sometimes, however, it may still be advantageous to choose not to clean as we may not know enough about the materials involved, or the artwork may be simply too fragile. Equally, choosing not to clean may bring its own risks, such as the embedding of soiling layers, which generally become harder to remove with time.

What exactly is an assessment of a green cleaning fluid?

GREENART aims to produce cleaning materials that are "green" — i.e., they should have low environmental and human impact — in the form of various gels and liquids called microemulsions or nano-structured fluids. Before they can be used on works of art, they need assessment across a range of parameters. All the GREENART WP2 materials involve direct application to works of art; hence they need to be risk-benefit assessed with diligence regarding their impact on the materials to be removed as well as the works of art. Assessments involve characterising the cleaning system properties such as porosity, stiffness, and liquid retention/release capacity which is conducted by the work package leaders (CSGI) at the pre-production stage. Once the materials are with the heritage partners, other types of assessment also become relevant, including how the materials handle, their cleaning efficacy, ease of use, capacity for re-use, adaptability to various conservation challenges, potential for cleaning system residues remaining on artwork surfaces, safety and disposal protocols, amongst others. This is conducted through collaboration between the material manufacturers, conservation/heritage scientists and conservators and is often focused on case study works of art that have been noted as requiring conservation treatment.

Assessment tools range from the unaided human eye to multi- light-wavelength imaging and photography, increasingly sophisticated microscopy, as well as a range of scientific assessments from the macro to the sub-micron level and beyond. The tools used will vary with the cleaning material type, the artwork materials, shape and size, the availability of instrumentation and expertise, as well as people and financial resources. One of the benefits of working within a large collaboration such as GREENART is that we can approach others within the consortium to discuss, offer and share ideas and skills, as well as the results of these assessments across a range of works of art, from ancient stone to contemporary art.

Is it a methodology that can be adapted to all cultural property materials?

There are established and modified conservation research and examination methodologies that have been used for these types of assessments for decades which can be used for most materials-based works of art (and can also be improved along the way). Most start off with exploring the cleaning materials and artworks separately, followed by an assessment of the effects of the cleaning systems applied to what we call mock-ups, or if super lucky, using some archival material sourced through the artist/other colleagues/institutions which is close if not identical to the artwork in composition and age, such as a preparatory piece. These types of materials are hugely valuable and hard to come by. This process, particularly when research time is funded well, leads to the narrowing down of options and the lowering of inherent risk as the need to test options on the work of art is reduced. The use of mock-ups also facilitates the development of knowledge about how these novel materials handle, behave and can be optimised to the specific cleaning challenge.

Will you also assess the eco-sustainability of the novel material?

Tate will not be assessing the eco-sustainability of any of these materials directly, though we will be exploring the constituents carefully and looking to the life cycle assessments conducted in WP8 with keen interest!

Are you also planning to make a comparative analysis with more traditional methods?

Yes, we always include comparative studies within our cleaning research as it offers better quality and less biased information to the wider

Dr Morana Novak and Dr Angelica Bartoletti carrying out X-Ray Fluorescence (XRF) analysis of Bridget Riley's *Fall* to help identify the pigments present

Photo Dr Bronwyn Ormsby. Courtesy Tate.

field and adds necessary rigour to our risk assessment process. We never guarantee to use novel systems on Tate works — we always devise, rigorously assess, and choose the best option for the work of art in question whether it is a novel system, or not. We will at the very least be using several similar materials, including established systems such as agar that have been used in conservation for at least two decades as well as the NANORESTART materials which we now have considerable experience in using. Our exact mix of materials has yet to be finalised it is one of the several questions we are currently thinking through.

How does a new product make its way from the research laboratory to the restoration studios?

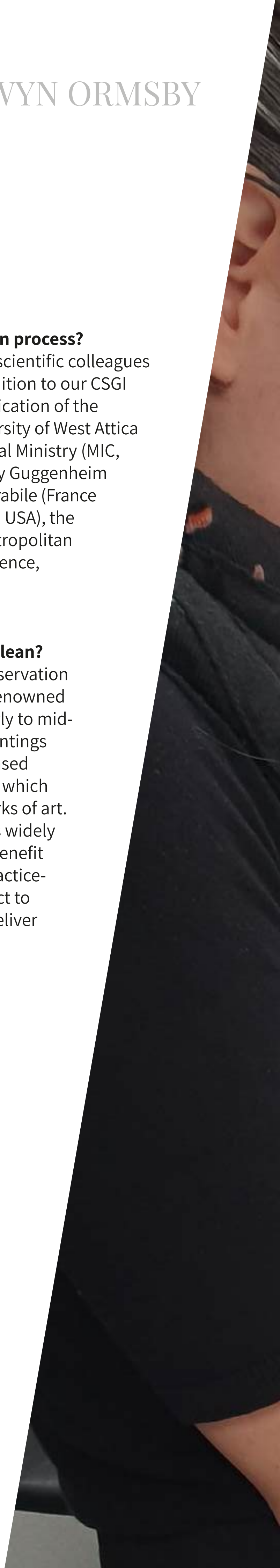
It depends. With GREENART, this process is embedded within the project and is relatively formalised through technology readiness level outputs (TRL). Outside of multi-year funded research, this is done on a smaller scale through focused collaborations between industry/ academia and heritage professionals or by heritage professionals themselves with a specific problem to resolve. In GREENART, as the heritage partners move into the assessment phase using rigorous methodologies and carrying out case study treatments, particular products will begin to rise above others as being most suited. This in turn will mean that the preferred options will receive further finessing and development. The products that meet all the required criteria and show promise across a range of conservation cleaning challenges are most likely to be included in a commercial production phase towards the end of the project.

Which other institutions are involved in this validation process?

In WP2 the team at Tate works with conservation and scientific colleagues from a range of institutions and private practice in addition to our CSGI colleagues to contribute to the assessment and modification of the WP2 novel cleaning materials. This includes the University of West Attica (UNIWA, Greece); Ministero Della Cultura Italian Cultural Ministry (MIC, Italy); The Solomon R. Guggenheim Foundation (Peggy Guggenheim Collection Venice, Italy and New York, USA), Antonio Mirabile (France and Brazil), Los Angeles County Museum of Art (LACMA, USA), the Hungarian National Museum, (HNM, Hungary); the Metropolitan Museum of Art, New York, USA; Tokyo University of Science, Japan; the University of Ljubljana, Slovenia; and the Museum of Fine Arts Houston (MFAH, USA).

Which works from Tate's collection do you intend to clean?

Tate is delighted that our case study research and conservation treatments will focus on two important paintings by renowned British artist Bridget Riley (b. 1931) dating from the early to mid-1960s, called Hesitate (1964) and Fall (1963). These paintings have delicate, unvarnished polyvinyl acetate (PVAc) based painted surfaces, with accumulated soiling and marks which can detract from the impact of these ever-popular works of art. This paint type has had relatively little attention and is widely represented in Tate's collection. These paintings will benefit enormously from the careful, rigorous, and diligent practice-based research afforded through the GREENART project to underpin decision- making and treatment design to deliver optimal, appropriate outcomes. For these artworks, the primary risks include working with inherently water-sensitive paints and burnishing the surface from even the lightest applied pressure, which could result in unacceptable, permanent change. We are currently carrying out further in-depth examination and analysis of the paintings, exploring Bridget Riley's working processes, making mock-ups based on the painting materials and structures while researching into PVAc paints. Soon, we will start trialling comparative treatment options on these mock-ups. As we acquire knowledge over the course of the research, if any of the GREENART materials prove able to afford low-risk, appropriate and sustainable cleaning outcomes the conservation treatment of Hesitate will proceed first, followed by Fall. This will be supported by a full evaluation of the treatments themselves as well as research into GREENART cleaning system residues and the characterisation of any impact of their use on PVAc paints which we also hope will be of use to heritage professionals globally.



Dr Morana Novak carrying out colour measurements on soiling materials used for mock ups of Bridget Riley's *Hesitate*

Photo: Tate Photography. Courtesy Tate Gallery

Dr Bronwyn Ormsby, Katey Twitchett-Young, Anna Cooper and Dr Morana Novak in front of Bridget Riley's *Hesitate*

DISCUSSION

Starch Nanoparticle

ARR

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GREENART

ABOUT CONSOLIDANTS...

Within GREENART, Giovanna Poggi is part of the CSGI team, dedicated to coordination, overseeing the project and assessing the progress of research. Here, the researcher shares insights into the role of Work Package 4 and the development of consolidants.

Launched in October 2022, GREENART is an international project initiated by the European Union, bringing together researchers, conservators, and institutions from art conservation and restoration. Together, they collaborate to develop new, green, and sustainable restoration products such as cleaners, protective varnishes, consolidants, and monitoring technologies. No aspect of their development is overlooked. Through its various working groups — referred to as "Work Packages" — GREENART shares its progress.

Giovanna Poggi initially pursued studies in conservation-restoration at university but quickly shifted her focus towards chemistry within the cultural heritage domain during her bachelor's and master's degrees. She then embarked on a PhD focused on the development of innovative treatments for the preservation of cellulosic materials under the guidance of Professor Piero Baglioni — who is also involved in the GREENART project. Today, Giovanna Poggi holds a position as a researcher in physical chemistry at the Chemistry Department of the University of Florence. She has also participated in several projects at the Center for Colloid and Surface Science (CSGI): FP7 NANOFORART, H2020 NANORESTART, and now GREENART. There, she works with the CSGI coordination team, managing the scientific aspects of the project and evaluating the research progress.

Among the Work Packages of GREENART, Work Package 4 is dedicated to the development of new ecological consolidants. Giovanna Poggi elaborates on the role of consolidants in conservation/restoration and introduces the new products currently under development.

You are working on two classes of materials for the consolidation of cultural assets. Could you tell us more about this?

Work Package 4 (WP4) is specifically focused on the development of environmentally friendly consolidants and packaging materials. It involves various partners such as universities, research centres, and companies, as well as end-users. Regarding ecological consolidants, the CSGI, in collaboration with other developers, is concentrating on two categories of products: fibroin-based consolidants and starch nanoparticle- based consolidants.

Do they apply to the artwork's surface or the substrate?

Fibroin-based consolidants are optimised for strengthening silk textile materials, providing comprehensive reinforcement across the entire substrate. Conversely, starch nanoparticle-

— Antonio Mirabile

based consolidants are designed to enhance the cohesion of the artwork's surface.

Compared to existing materials, in what way are they innovative?

Current consolidation systems used to reinforce substrates and restore the middle layers of artworks often consist of synthetic polymer solutions or dispersions. Although these materials exhibit high consolidating power, they frequently lack other essential qualities required for restoration materials. The ones we are developing are based on biopolymers, ensuring high compatibility with the original materials constituting the artwork. Moreover, due to their nanometric or submicrometric nature, our materials exhibit properties and performance that bulk materials could never achieve.

How are fibroin dispersions obtained? How do they work?

The development of this material stems from the need to create an effective system for consolidating silk while being compatible with this precious and traditional textile. In line with the Green Deal principles, we opted to use residual materials, specifically undyed silk remnants, from which we can extract fibroin, the main protein component of silk, through a relatively simple procedure. The fibroin, obtained in aqueous dispersion form, can then be applied to the original silk intended for consolidation, restoring its mechanical properties. Essentially, we are giving surplus silk a new purpose by using it as a basis to strengthen and preserve significant historical and artistic objects, thus creating a circular economy process. We are collaborating with our partners at the Universidad Estadual de Campinas (UNICAMP) in Brazil and exploring the possibilities of adding other biopolymers derived from agricultural waste — nanocelluloses — to the fibroin-based systems. Preliminary tests have shown that incorporating this material improves the consolidating efficiency of the fibroin-based product. This enhancement is particularly significant, especially considering the often precarious conditions of some silk fabrics.

What about the starch nanoparticles?

Synthetic polymers, known to form a thin, cohesive layer, can significantly alter the visual appearance of an artwork when used to reinforce the middle layer. This is particularly problematic for matte, porous, and weakly bound paint layers, often found in modern and contemporary artworks. To overcome the limitations of conventional methods, we chose to focus on synthesising starch nanoparticles, specifically derived from Jin Shofu starch, a traditional restoration product known for its excellent adhesive properties. The use of starch nanoparticles — typically measuring ten-billionths of a metre — on the middle layers of weakly bound artworks ensures effective penetration without compromising the object's aesthetic integrity. This results in a high consolidation effect thanks to their significant active surface area.

Can you tell more about sustainability?

Because GREENART regards this aspect as particularly significant, the project includes a dedicated Work Package for Life Cycle Safety and Sustainability Assessment, which involves all project partners and is coordinated by the research group from the University of Venice. Due to their nature and production procedures — which involve the use of eco-compatible reagents — we anticipate a very positive evaluation of the green consolidants I have mentioned.

What are the most important steps in evaluating the material before its use on an artwork?

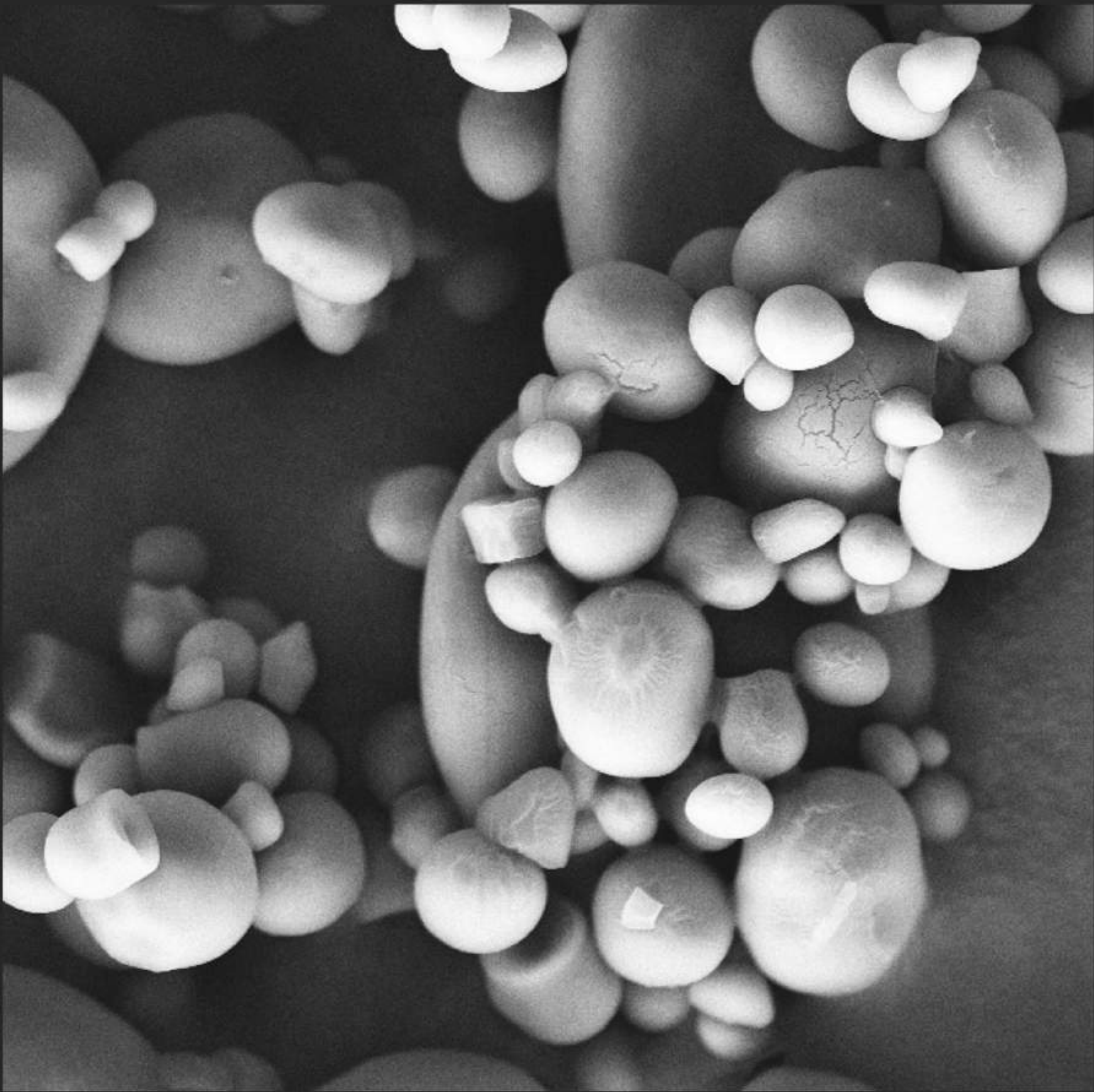
First and foremost, a consolidant must fulfil its role in consolidation. Therefore, initial tests focus on assessing the reinforcement obtained after application. Depending on the type of intervention, whether it is to restore the substrate or to strengthen the middle layer of the artwork, different pre- and post-application tests are conducted. Since our work is focused on the development of materials intended for use in cultural heritage conservation, another essential property is examined: the alteration of the appearance of samples after treatment. If this change is deemed significant, it is likely that the products will not be applied to actual samples, unless they are applied to non-exposed areas of artworks, such as the back of paintings. Additionally, particular attention is paid to evaluating the new product's ageing and identifying any changes over time. Stability is a crucial property for materials used in restoration…

Do you think they will be ready for production and sale by the end of the project?

We are confident about the progress of product development by the end of the project. If the plan proceeds as anticipated, we envisage having at least one product tested and validated in the field, ready for the subsequent pre-commercialisation phase, namely, the preparation of the prototype.


Photo Sonika Agarwal

BULK STARCH
JIN SHOFU



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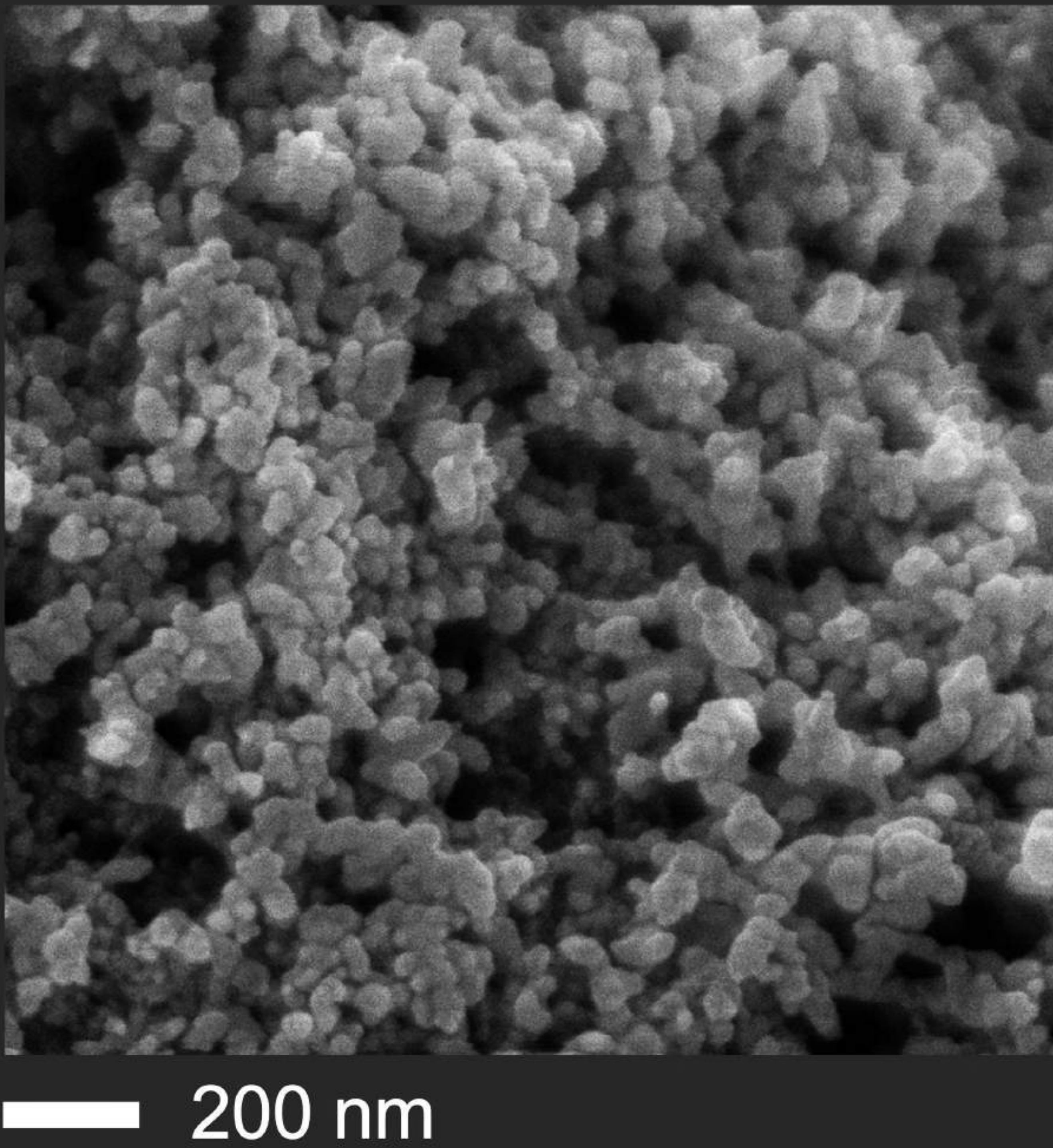
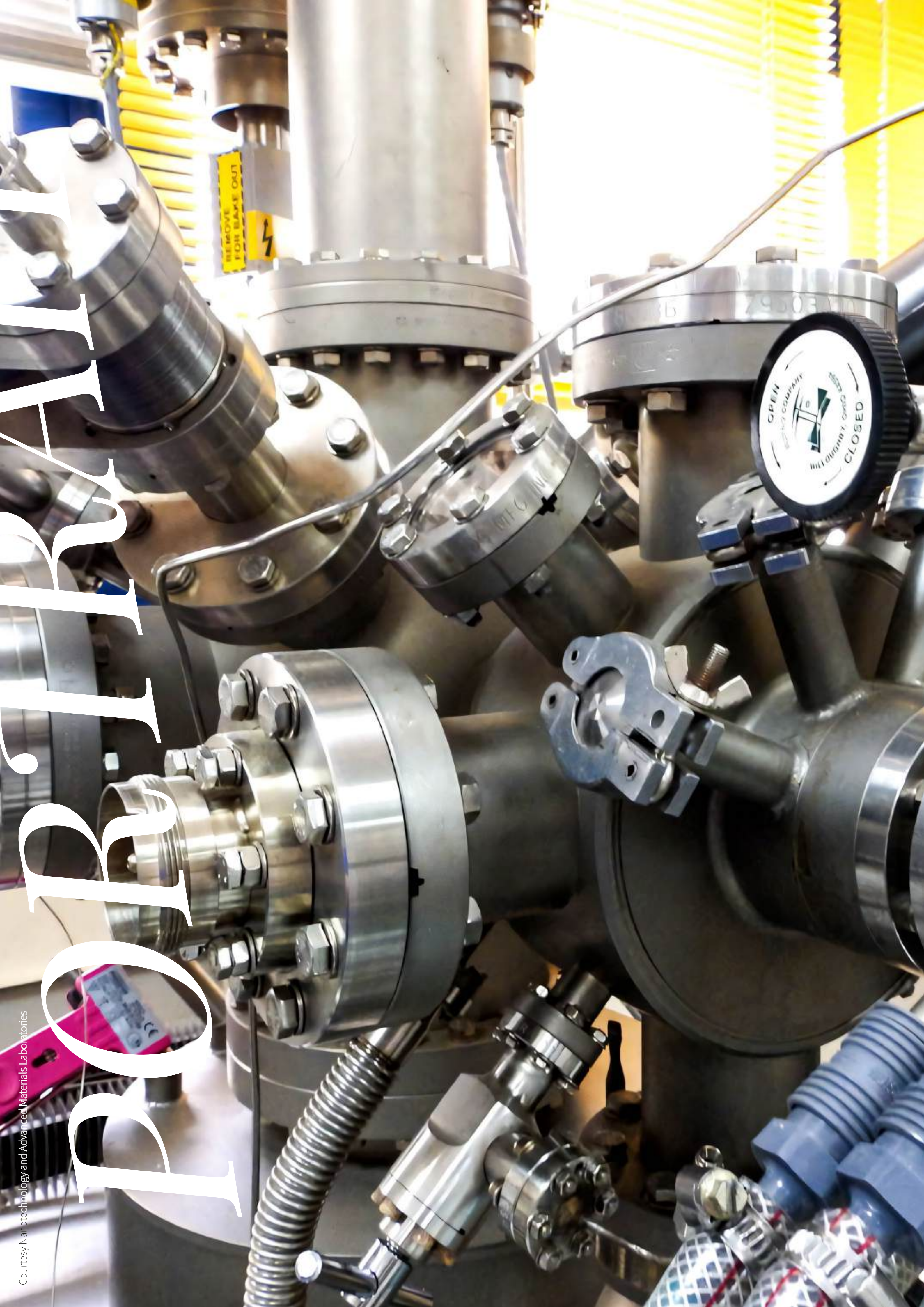
STARCH NANOPARTICLES
JIN SHOFU

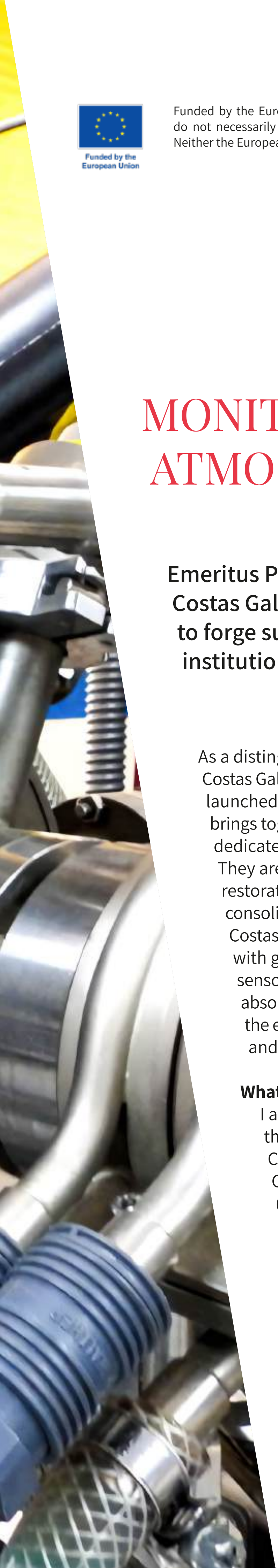


Courtesy CSGI



PORTRAIT

Courtesy Nanotechnology and Advanced Materials Laboratories



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MONITORING THE IMPACT OF ATMOSPHERIC CONDITIONS ON ART

Emeritus Professor of Chemical Engineering at the University of Patras in Greece, Costas Galiotis is delving into nanotechnologies and materials science to forge sustainable conservation solutions for cultural heritage institutions as part of the European GREENART project.

As a distinguished chemist, Greek researcher and academic Costas Galiotis is involved in GREENART, an international initiative launched by the European Union in October 2022. This project brings together scientists, conservators, and cultural institutions dedicated to the conservation and restoration of artworks. They are collaborating to develop new, green, and sustainable restoration products such as cleaners, protective varnishes, consolidants, and monitoring technologies. Within GREENART, Costas Galiotis's mission is to harness technologies associated with graphene and other two-dimensional materials such as sensors, harmful gas and moisture absorbers, and ultraviolet absorption membranes. This initiative aims to create tools for the end-users of the programme, namely cultural institutions and conservation professionals, to preserve artworks.

What is your professional background?

I am a chemist with a PhD in materials science from the Engineering Faculty at the University of London. Currently, I am a professor in the Department of Chemical Engineering at the University of Patras (since 2014) and a collaborating member of the Institute of Chemical Engineering Sciences (ICE-HT), one of eight university research institutes of the Foundation for Research and Technology-Hellas (FORTH).

What is your current role at the Foundation for Research and Technology — Hellas (FORTH) and in the within the GREENART project? GREENART project?

My present role at the Foundation involves studying graphene-related materials (GRM), 2D materials (production and properties), composites and polymers (structural, mechanical and spectroscopic characterisation of polymers and composites) and non-destructive testing of materials (a world leader in applying Raman laser spectroscopy for strain or deformation measurements in fibres and composites). My role in GREENART is to facilitate the end-use of technologies developed related to graphene and other two-dimensional materials such as sensors, harmful gas and moisture absorbers, ultraviolet absorption membranes, etc., by the end-users of the programme, who are the cultural heritage institutions (museums, galleries, academies, etc.).

We understand that you will be developing green technological solutions to monitor environmental conditions affecting cultural heritage. Could you tell us more about this?

It is well-known that atmospheric conditions can impact or even alter the materials used by artists, thereby damaging cultural heritage items. These atmospheric factors include changes in humidity and

— Antonio Mirabile

temperature or emissions from the items themselves due to their prolonged stay in enclosed spaces such as display cases or storage boxes. For the latter, there is an increase in the concentration of various harmful gaseous pollutants, due to the gradual decomposition of the items, which further accelerates the degradation process.

One of our main goals in the GREENART project is to develop green solutions to effectively monitor these essential environmental parameters.

The proposed solutions include the development of sensors to record relative humidity, temperature, and pollutants such as acetic and formic acids. Subsequently, the developed sensors will be integrated into electronic and communication solutions for real-time monitoring of environmental variations.

While this concept is not new, the innovation in our case lies in the use of green materials and sustainable methods to develop both the sensors and some of the electronic components necessary for their interconnection and communication.

Which other research institutes are collaborating with you within the GREENART project?

We have a close collaboration with various institutions from many European countries, boasting a wide range of knowledge and experience in the field of sensors. This includes material developers, electronics experts, and end-users. At FORTH (Greece), we have well-established expertise in nano-materials, particularly graphene-related materials (GRM). We are working in collaboration with the Centre for Colloid and Surface Science (CSGI, Italy) and two institutes from the National Research Council (CNR, Italy): the Institute of Polymers, Composites, and Biomaterials (IPCB) and the Institute of Nanostructured Materials (ISMN). Together, we are developing various sensing materials through green approaches. Additionally, in the development of sensor electrodes, the Tyndall National Institute at University College Cork (T-UCC, Ireland) is working with CNR-IPCB and CSGI to develop new polymer formulations suitable for creating porous electrodes. These electrodes are used by both FORTH and T-UCC in the final assembly of new green sensors. Another activity at T-UCC includes the integration of the developed sensors with electronic and communication solutions using an NFC antenna designed and developed specifically for GREENART. Finally, the produced sensors are validated and tested both in simulated environments at the University of Ljubljana (UL, Slovenia) and the University of West Attica (UNIWA, Greece), as well as in practical settings like at the Peggy Guggenheim Collection in Venice (Italy) or the Hungarian National Museum (HNM, Hungary).

What materials are these sensors related to?

Several innovative materials are being examined and utilised in the development of the sensors, which are either produced through green methods from natural raw materials or sourced from recycled materials and waste. However, graphene and its derivatives undoubtedly dominate all types of sensors. GRM are utilised in various parts of the sensor design, starting with the electrodes, which are produced through the laser graphitisation of biopolymers or natural materials, through to the detection layer where green graphene oxide (GO) is used for monitoring relative humidity. In addition to electrode development, biopolymers and natural materials such as cork are also employed in the development of substrates for sensors and NFC antennas. Furthermore, other 2D materials as well as metal oxides and chlorides have been tested for sensors detecting volatile organic compounds (VOCs) and temperature.

Are they already used in other fields?

Relative humidity and temperature fluctuations are among the primary environmental factors that are monitored and recorded daily in various application fields. In other words, these types of sensors can find applications in many areas outside GREENART, ranging from electronics to buildings, transportation, and industry. Regarding VOC sensors, we target specific pollutants that are harmful to heritage materials. However, they can also be produced from many other sources and some of them are extremely hazardous to living organisms and humans. Therefore, we believe our VOC sensors could find broad usage in a range of application fields.

How do they work?

Although the sensors differ from one another as they respond to various physical or chemical stimulus changes, they share common operational characteristics. The basic principle in all cases involves detecting changes or variations in a particular physical parameter, which are then converted into an electrical signal. Humidity sensors, for example, are designed to function like capacitors. Fluctuations in relative humidity cause the adsorption or desorption of water molecules in the detection area, thereby altering the sensor's capacitance. The measured capacitance change is then converted into relative humidity *via* a calibration curve. On the other hand, VOC and temperature sensors function like resistances. Indeed, when target molecules are detected by the detection area, the conductivity of the sensor changes, so that the recorded electrical signal can be converted into VOC concentration values. It should also be noted that a change in

Humidity sensors on ZFB archive box for museums

Photo Costas Galiotis

temperature leads to a change in the concentration of charge carriers in the graphene network, which results in a change in conductivity, which can then be converted into temperature.

How is it innovative compared to existing materials?

The use of nanomaterials such as graphene and its derivatives and many of the methods used to develop the sensors (e.g., laser writing) can be characterised as cutting-edge technology. However, in our approach, the environmentally friendly development of the sensors, which includes all green materials and sustainable methods for their production, constitutes the main innovation compared to existing materials. The materials used for the sensors are either raw biomaterials (e.g., biopolymers) or recovered from recycled materials and waste, while the methods used for their production are either eco-friendly or lead to significant reductions in harmful chemicals, water and energy waste.

Regarding sustainability, how can you monitor that the new materials are more eco-friendly?

For GREENART, we follow an integrated approach in terms of production methods and material development. Moreover, we provide all necessary information for the ongoing assessment of processes to project partners, such as the University of Venice, which handles safety and lifecycle sustainability evaluations. Additionally, we employ environmentally friendly production methods and use recycled materials/waste as ecologically compatible reactants to achieve our goals of developing green technological solutions for monitoring cultural heritage.

Are these sensors suitable for all types of environmental conditions and compatible with all types of cultural heritage materials?

Depending on the type of sensor, they are suitable for recording a wide range of measured parameters. For instance, humidity sensors can monitor the entire relative humidity range from 0 to 100% and can operate from 0 to 40°C. Similarly, temperature sensors have been evaluated from 0 to 100°C. As you can see, these ranges are much higher compared to the environmental conditions under which cultural heritage materials are stored or displayed. However, there are certain environments where the sensors are not rated to operate (e.g., a wider temperature range) or cannot function primarily due to the materials from which they are made. For example, most biopolymers are destroyed at high temperatures. Finally, regarding the range of heritage materials, I must say that the operation and performance of all types of sensors are not affected by the nature of these materials. The only issue that could arise would be the requirement to record harmful pollutants other than those for which the sensor is designed to measure.

How do you work with cultural heritage institutions to assess and validate the new sensors?

For the validation of the green sensors, we work closely with two museums, the Peggy Guggenheim Collection and the Hungarian National Museum. Furthermore, all other cultural heritage institutions that partnered with GREENART are welcome to participate in the evaluation process. Additionally, we make efforts to disseminate our findings to cultural heritage institutions beyond members of the GREENART project; we are also in discussions with the Museum of Science and Technology at the University of Patras to evaluate the green sensors in their facilities.

Do you think they will be ready for production and sale at the end of the project?

Among the three different types of sensors, the GO-based humidity sensors are at the highest level of evaluation, as their validation in real environmental conditions has already begun. Although several other tests need to be carried out before the end of the project, we are optimistic about achieving all the set goals. On the other hand, the discussion regarding the production and sale of the sensors goes beyond these objectives. We have considered this, and it could be done, perhaps not at the end of the project, as there are additional steps required beyond sensor performance, but in the near future, it is something we would like to advance. The cost of the sensors is an additional advantage in this direction, where due to the use of the materials and methods I have mentioned above, it is significantly lower compared to competing sensors typically developed from non-recyclable and expensive metals such as platinum, gold and silver.

Costas Galiotis

Courtesy: Nanotechnology and Advanced Materials Laboratories

Costas Galiotis's team at Foundation for Research and Technology-Hellas

Courtesy FORTH

INTERVIEW

FE-SEM with integrated Raman at the DINAMICO Laboratory

Photo Angelo de Simone Troncone
Courtesy CNR-ISMN

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"WE TREAT THE CULTURAL OBJECT AS IF IT WAS A PATIENT"

Dr Gabriella Di Carlo, a PhD in Chemistry and researcher at the Institute for the Study of Nanostructured Materials of the Italian National Research Council (CNR-ISMN), leads the CNR-ISMN team in developing innovative and sustainable protective materials as part of the European GREENART project.

After obtaining her PhD in Chemical Sciences from the University of Palermo in 2006, Dr Di Carlo became the lead researcher at CNR-ISMN, Rome 1. Her scientific career began at the University of Palermo, focusing on new materials for removing atmospheric pollutants. In 2010, she moved to Rome, shifting her research to the reuse and enhancement of waste such as polysaccharides, cellulose, and plastics, and their application in the field of cultural heritage. She is involved in numerous national and international projects, either coordinating activities like Plasmare and ECOforCONCRETE or leading the CNR-ISMN research unit in European initiatives such as NANORESTART, InnovaConcrete, APACHE, and GREENART. Launched by the European Union in October 2022, GREENART is an international project bringing together scientists, conservators, and cultural institutions engaged in the conservation-restoration of artworks. Together, they collaborate to develop new, green, and sustainable restoration products such as cleaners, protective varnishes, consolidants, and monitoring technologies.

Furthermore, Dr Di Carlo teaches Chemistry for the restoration and conservation of metals in the Master's program "Science and Technology for the Conservation of Cultural Heritage" at La Sapienza University in Rome. She is a member of the doctoral council for Earth Sciences at the same university and heads the Laboratory of Nanometric and Micrometric Diagnostics for the Knowledge and Conservation of Advanced Materials and Cultural Heritage (Lab DINAMICO) at CNR-ISMN. This lab is part of the ERIHS infrastructure in the Lazio region.

What is your current role within the National Research Council (CNR) and the GREENART project?

CNR is a partner in the GREENART project alongside the Institute for the Study of Nanostructured Materials (CNR-ISMN) and the Institute of Polymers, Composites, and Biomaterials (CNR-IPCB). Our team has been involved in several EU-funded projects, including the NANORESTART project (2015-2018), coordinated by the Center for Colloid and Surface Science (CSGI) in Italy. In this project, alongside CNR-IPCB, we developed new stimulus-responsive materials for corrosion inhibition. This innovative approach focused on the targeted release of protective molecules when needed. Building on this success, the current GREENART project focuses on creating durable protective materials with stimulus-responsive properties, derived from natural waste and renewable resources. Our aim is to produce materials that are not only effective but also more durable and safer than those currently on the market. In GREENART, the CNR team leads the development of eco-friendly

— Antonio Mirabile

> The main innovation lies in the way of thinking and designing new materials based on intelligent systems.
> — *Gabriella Di Carlo*

protective coatings for metal objects and other potential targets like ceramics and canvas. The main focus of the CNR-ISMN team is on producing new biopolymer-based coatings to prevent the degradation of artefacts. Our goal is to create long-lasting, safe products that can be applied and removed with non-toxic, water-based solvents, primarily aimed at preventing metal corrosion.

Do you have plans to develop multifunctional coatings for the long-term protection of cultural assets?

Indeed. In order to reduce the frequency of conservation interventions on cultural artefacts, we are focusing on creating active and intelligent protective coatings that offer long-term efficacy. Our main challenge is to prevent the degradation processes in metallic objects. The formation of corrosion products can not only alter the surface appearance but also compromise their chemical and physical stability, leading to irreversible damage or even the loss of unique and irreplaceable pieces. Our approach to long-term protection involves targeted actions, similar to how targeted drug delivery works. We treat the cultural object as if it were a patient, intervening selectively and only when necessary, which enhances the effectiveness of the protective materials while reducing the use of active substances. Previously, in the NANORESTART project, we explored the impact of stimulus-responsive protective materials on improving the effectiveness of coatings on bronzes. Currently, within GREENART, we are developing biopolymer- based coatings that include new green additives to enhance the material's stability over time. We are incorporating graphene-related materials supplied by the Foundation for Research and Technology-Hellas (FORTH) in Greece or lignocellulosic materials from the University of Campinas (UNICAMP) in Brazil to improve barrier properties. The coating acts as a shield, slowing the diffusion of atmospheric degradation towards the artefact's surface. We are also exploring the use of new stimulus-responsive nanocontainers to make the materials smarter, more durable, and more effective in the long term compared to past solutions.
A thorough understanding of these materials is crucial for fully grasping their functions and enhancing their properties when necessary. Through GREENART, we study these new materials using sophisticated methods, such as small-angle and wide-angle grazing incidence X-ray scattering, in collaboration with CSGI in Italy and NIKKO in Japan.

What is the origin of these materials?

At GREENART, we focus on materials derived from natural waste and renewable sources. This strategy not only allows us to create sustainable products but also reduces waste production, providing both economic and environmental benefits.
Our products are based on biopolymers such as chitosan and cellulose derivatives.
Chitosan is a biopolymer obtained from crustacean shells, typically produced from the waste of the fishing industry. Besides its non-toxicity and water solubility, this polymer offers excellent transparency, film-forming ability, and ease of disposal.
Its applications are increasingly gaining interest in various fields, including food packaging and biomedicine. We are also exploring other biopolymers, with cellulose derivatives being particularly promising due to their aesthetic qualities and the possibility of deriving them from plant waste.
In developing additives and corrosion inhibitors, we follow a similar philosophy. We have enhanced our chitosan-based formulations with new additives that provide greater stability to the coatings over time. Additionally, we are studying natural and non-toxic corrosion inhibitors as alternatives to benzotriazole, seeking effective and safe solutions. Our choice of nanocarriers also reflects our commitment to sustainability, drawing inspiration from materials used in the cosmetic and pharmaceutical industries.
Indeed, chitosan and its composites have generated considerable interest within the scientific community due to their applications across various fields, particularly in the food packaging industry where these materials have been greatly beneficial. Edible chitosan-based coatings are widely recognised for their ability to extend the shelf life of perishables such as fruits and vegetables. Moreover, the versatility of chitosan has led to its use in other areas such as wound healing and water purification. Given recent trends, it is expected that new uses for these biomaterials will be discovered, potentially extending their application to the preservation of cultural artefacts.

Do these materials work on all types of cultural heritage materials?

At GREENART, we are developing eco-friendly protective coatings primarily for metallic objects composed of copper and silver

CNR-ISMN team: Gabriella Di Carlo, Lidia Baiamonte, Francesca Boccaccini, Elena Messina, Cristina Riccucci, Marianna Pascucci, Aurelio Barbetta, Chiara Fratello

Photo Angelo de Simone Troncone. Courtesy CNR-ISMN

Application of the green protective coating on a bronze bell

Photo Angelo de Simone Troncone. Courtesy CNR-ISMN

> There is a dynamic synergy and an exchange of information among the GREENART partners, who possess multidisciplinary expertise, facilitating the achievement of the project's objectives.. — *Gabriella Di Carlo*

alloys. During the optimisation phase, we use mock-ups with varying compositions and surface finishes as disposable substrates to validate our new materials. These mock-ups have been selected in collaboration with conservators from institutions such as the Italian Ministry of Culture, the Peggy Guggenheim Museum, the Hungarian National Museum, and the Museum of Fine Arts in Houston, aiming to replicate the compositional and metallurgical characteristics typical of contemporary and archaeological artefacts. After validation, the coatings we have developed could potentially be applied to other substrates. The results obtained so far indicate high transparency, great stability and ease of application and removal. Validations conducted in our laboratories, which involved very aggressive environments and natural ageing, show promising results.

How are they innovative compared to existing materials?

The main innovation lies in the way of thinking and designing new materials based on intelligent systems. Practically, cultural objects affected by a pathology are treated like patients and are protected with materials that, like a medicine, are capable of providing targeted and effective protective action.

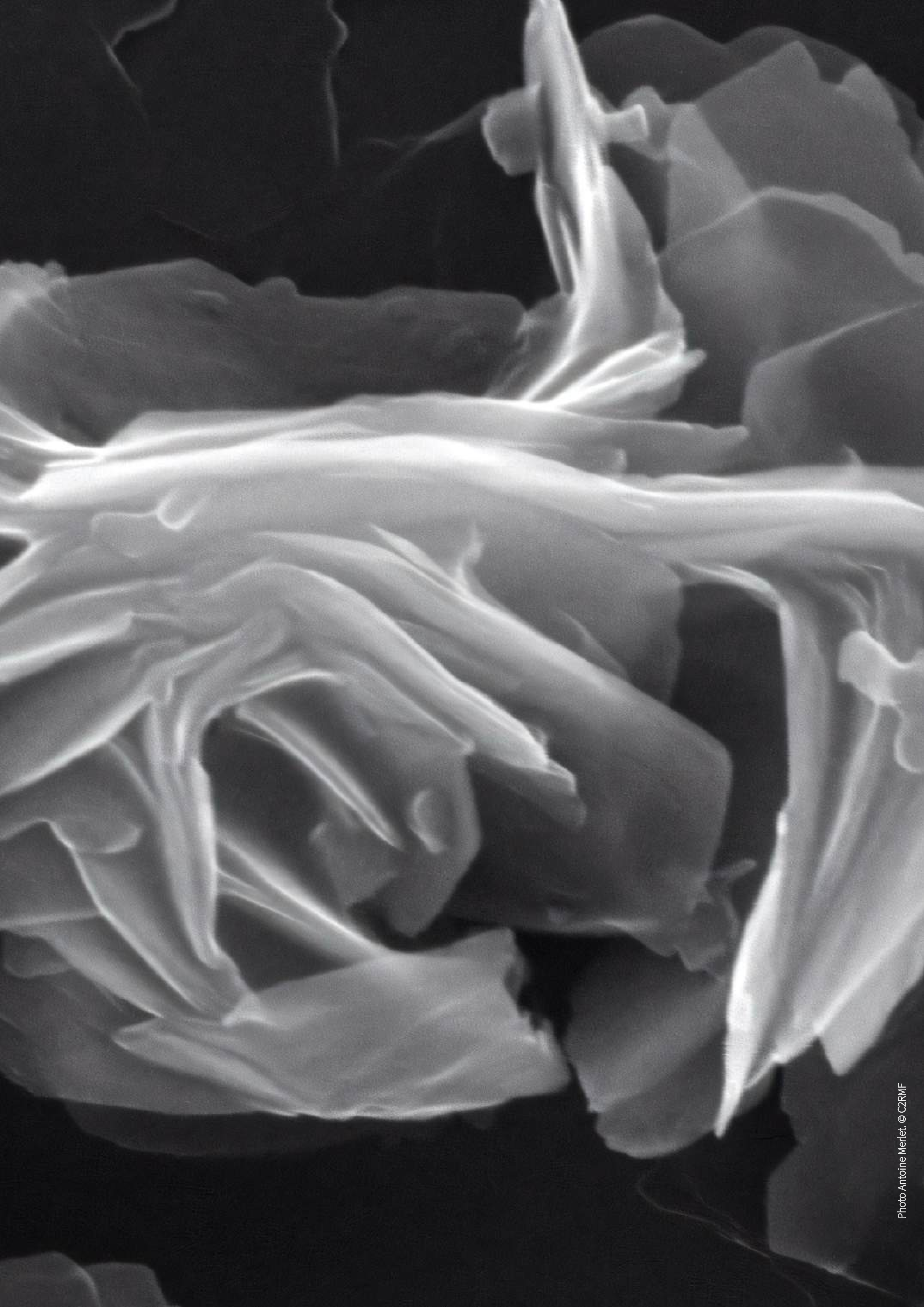
Compared to commercially available products, the new materials benefit from their multifunctional properties, offering enhanced protection against external agents of degradation and releasing protective agents in response to degradation *stimuli*, thus ensuring long-term efficacy. Additionally, the use of non- toxic solvents for their application and removal leads to safe conservation treatments. As I mentioned earlier, the innovation also lies in the use of sustainable materials, particularly focusing on those derived from natural waste and renewable resources.

Against which agents of deterioration do they offer protection? How do they work? How are they more environmentally durable?

Within the project, a partner, the University of Venice, is tasked with performing the safety and life cycle durability assessment for all new products. In our quest to develop innovative green materials, we focus on various aspects, including the selection of environmentally friendly reactants, solvents and preparation methods. We have provided all this information to the University of Venice, which in turn gives us continuous feedback to properly guide the material development process. This is extremely beneficial for quickly eliminating any compound or process that would not be acceptable. There is a dynamic synergy and an exchange of information among the GREENART partners, who possess multidisciplinary expertise, facilitating the achievement of the project's objectives.

How do you work with cultural heritage institutions?

We work with conservators from the GREENART project. They provide essential feedback on primary conservation needs, the limitations of current products, and the specifications necessary for new materials. They also contributed to the identification of the most representative references and mock-ups. Additionally, some conservators participate in validating the new materials, with experiments already underway.



DISCUSSION

Photo Engin Akyurt

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GREENART

"EUROPE'S CULTURAL HERITAGE DESERVES METICULOUS PRESERVATION"

Italian chemist Letizia Verdolotti is developing sustainable foams for the cultural heritage sector at the Italian National Research Council, a partner of the European GREENART project.

Her journey as a chemist began with a PhD thesis centred on sustainable polyurethane cement foams, conducted under the expert guidance of Marino Lavorgna. This endeavour culminated in the formulation of a groundbreaking material, subsequently licensed to Hypucem, a CNR spinoff that has since blossomed into an independent entity.

Recently, Marino Lavorgna presented her with an intriguing opportunity to delve into the realm of sustainable foams for the Cultural Heritage sector. "This venture resonated deeply with me as it seamlessly integrates my passion for designing environmentally conscious materials with the nuanced demands of preserving and transporting precious artworks," she says. "I eagerly anticipate the challenges and discoveries that lie ahead in this captivating field." Today, she participates to GREENART, a project launched by the European Union in October 2022, bringing scientists, conservators, and cultural institutions involved in the conservation and restoration of artworks. Together, they collaborate to develop new restoration products that are green and sustainable, such as cleaners, protective varnishes, consolidants, and monitoring technologies.

What is your actual role at Consiglio Nazionale delle Ricerche (CNR)?

Since 2009, I've been engaged in groundbreaking research at the Institute of Polymers, Composites, and Biomaterials within the National Research Council of Italy. This esteemed institution is renowned for its pioneering work in the development of sustainable, multifunctional polymer-based materials. My focus lies in the creation of innovative foams tailored for diverse applications, particularly within the realms of building construction, thermal insulation and automotive industries.

What is IPCB-CNR and your actual role in the GREENART project?

The IPCB-CNR is actively engaged in the GREENART project, contributing to three distinct research activities. First, the development of novel active and passive coatings aimed to protect the artworks. This involves the exploitation of potential of nanostructures and nanoparticles to serve as effective fillers for the controlled release of active compounds as well as to avoid the pollutants can get to the surface. Secondly, the development of sustainable packaging materials tailored for the storage and transportation of artworks. And then, undertaking the production of sustainable substrates to facilitate the production of graphene-based sensors. Under the coordination of Marino Lavorgna, who has been cooperating with CSGI project coordinator team across numerous European projects, the IPCB team,

— Antonio Mirabile

comprising researchers from two operational sites in Pozzuoli and Napoli/Portici, is diligently working on these initiatives.
In my capacity as the lead researcher, I am primarily responsible for developing sustainable packaging solutions based on polyurethane foams. Our aim is to engineer innovative foams capable of not only providing structural protection for artworks by acting as energy absorbers but also possessing the ability to absorb volatile organic compounds (VOCs) and regulate humidity levels within the storage containers. This multifaceted approach underscores our commitment to advancing the preservation and transportation of cultural treasures.

Can you tell us more about the packaging materials and foams for the preventive conservation of cultural properties?

Europe's cultural heritage is a priceless treasure, deserving of meticulous preservation and safe transportation to mitigate potential degradation risks. Traditionally, packaging materials such as petroleum-based polymeric foams (mainly polystyrene and polyurethane), paper tissue, and nylon fabric have been the go-to choices, albeit at environmental costs. However, CNR-IPCB has pioneered a groundbreaking solution: an environmentally friendly packaging material specifically engineered for the secure storage and transportation of cultural artefacts. This innovative material is a sustainable polyurethane foam crafted from monomers derived from biomass biorefinery, strategically infused with a natural powder, Zeolite 4A, along with additional fillers to adsorb volatile organic compounds (VOCs). In comparison to conventional options, this composite polyurethane foam offers an array of unparalleled benefits. It boasts enhanced compressive strength, exceptional energy absorption capabilities, and superior barrier properties against aggressive agents such as VOCs and acetic acid. Additionally, its adsorptive characteristics effectively regulate humidity levels, ensuring artefact preservation even in high-humidity or aggressive environments.
The conceptual basis of this endeavour was to develop a customised green packaging solution in compliance with current Europe's cultural legacy. This involved creating a multifunctional, bio-based packaging foam tailored to the specific requirements of the artwork using additive manufacturing techniques. This tailored approach ensures optimal protection while adhering to legal standards, marking a significant advancement in artefact packaging and preservation practices.

Which other GREENART research institutes are working with you?

We collaborate with Specific Polymers, one of GREENART partner because they provide us with bio-based precursor used for the polyurethane production, and CSGI because they provide us some functional fillers as VOCs adsorbers.

What is the origin of those materials?

Polyurethane foams are commonly manufactured through a polyaddition reaction involving a polyol and a diisocyanate, accompanied by an exothermic foaming reaction that releases expanding gases.
The emergence of sustainable polyurethane foams for packaging stems from a heightened awareness of environmental concerns and the imperative for eco-conscious alternatives to traditional packaging materials. Various strategies have been explored to render polyurethane foams more sustainable: utilising polymeric precursors sourced from biomass; Eliminating isocyanates and substituting them with eco-friendlier molecules like cyclocarbonates and biobased amines; Developing materials that can be thermoplasticised for easy recycling, a particularly challenging endeavour.
Furthermore, the incorporation of micro- or nanofillers derived from natural sources, biomass, or waste materials into polyurethane foams not only improves their environmental credentials but also enhances their functional properties. These enhancements encompass increased compressive and impact strength, enhanced thermal or acoustic insulation, improved thermal stability, enhanced flame retardancy, and heightened pollutant adsorption capabilities. Such modifications allow for tailoring polyurethane foams to meet diverse packaging requirements while aligning with sustainability objectives.

Are they already used in other fields?

Polyurethane foams are renowned for their versatility, with exceptional mechanical, chemical and physical properties that make them indispensable in a wide range of industries. Their applications span a wide spectrum, encompassing sectors such as building and construction, thermal insulation, textiles, furniture, automotive, refrigeration, wood substitutes, and, notably, packaging — a realm we've explored through several projects, involving also several companies. Across these diverse applications, there's a palpable surge in interest surrounding sustainable polyurethane foams. This burgeoning enthusiasm reflects a collective commitment to environmental stewardship and the pursuit of eco-friendly solutions across industries. As we navigate toward a more sustainable future, the utilisation of sustainable polyurethane foams stands as a key pillar to our dedication to innovation and responsible resource management.

Are those materials suitable for all sort of cultural property material?

Our expertise extends to finely tuning the mechanical properties of polyurethane foam, allowing for precise adjustments in terms of softness or stiffness/hardness. This flexibility enables us to tailor

Letizia Verdolotti

Courtesy Letizia Verdolotti

Rigid Polyurethane foam

Courtesy Consiglio Nazionale delle Ricerche the foam to suit the specific requirements of the object being transported, ensuring optimal protection. Simultaneously, through the incorporation of specialised functional fillers, independent of the mechanical characteristics, we can functionalise the foam with targeted properties. This multifaceted approach underscores our commitment to delivering tailored solutions that not only protect the transported artworks but also address broader environmental and functional considerations such as reduction of petroleum-based resources, improvement of carbon footprint of the materials, improve the recyclability.

How is innovative compared with existing materials?

A conventional packaging system for artefacts typically includes three layers: a direct wrapping layer — this initial layer directly envelops and protects the object, prioritising the avoidance of harm to any delicate or protruding parts; an intermediate cushioning layer — following the direct wrapping, an intermediate cushioning layer is employed to provide further protection; an outer protective box — finally, the artwork is encased in an outer hard box, often made of materials such as cardboard, plastics, or wood. This approach aims to control the microclimate conditions and ensure thermal comfort to preserve the artefacts' integrity. Unfortunately, this results in significant energy consumption during both production and transportation phases.
Most of these materials, integral to the preservation process, are predominantly derived from petroleum-based sources. This reliance on non-renewable resources underscores the need for innovation and sustainable alternatives in the packaging and conservation practices of cultural heritage. Conversely, we have conveniently designed and developed a sustainable composite multifunctional foam in which all of the required functions are adequately integrated, and which can also be customised (by using 3D printing technique) for specific artefact.

It's a temporary or long-term protection and against which deterioration agents?

Foam is designed for the storage or transport of objects and, provided that the packaging can be adapted to the object in terms of properties and shape, it can be used for a long time and, when customised on the artwork, it can be used many times with the same object. However, it should be noted that we are currently investigating the reversibility of foam, making it easily recyclable through thermal processes, as is currently the case with plastics such as PET.

What about the sustainability, how can you say that the novel materials are greener?

As previously mentioned, our composite polyurethane foam derives its eco-friendly credentials from green precursors and sustainable fillers. Moreover, our customisation approach enables us to minimise the amount of packaging required for each artefact, further reducing environmental impact.
In our ongoing pursuit of sustainability, we're also exploring the feasibility of rendering the foam reversible. This entails investigating methods to reprocess the foam at the end of its lifecycle, thereby facilitating its reuse. By embracing this circular approach to materials management, we not only enhance the eco-friendliness of our packaging solutions but also contribute to the broader goal of achieving a more sustainable and resource-efficient future.

Are you working with cultural heritage institution to assess and validate the novel materials?

Currently, our research efforts are primarily concentrated on the meticulous development of the foams, with a keen emphasis on crafting chemical structures that align with sustainability principles while meeting the requisite functionalities. Once we finalise the formulations, our aim is to transition from the laboratory to real-world applications. In this regard, I'm pleased to highlight the recent agreement forged between CNR-IPCB and the Peggy Guggenheim Collection in Venice. This collaboration marks an exciting opportunity to put our innovative materials to the test in safeguarding and conserving authentic works of art. A notable case study within this partnership involves the iconic *Box in a valise* (1941) by Marcel Duchamp. By subjecting our materials to real-world scenarios and challenges, we aim to validate their efficacy and suitability for protecting invaluable cultural artefacts. This partnership underscores our commitment to bridging the gap between cutting-edge research and practical applications, with the ultimate goal of enhancing the preservation and longevity of our cultural heritage.

Do you think the innovative foams will be ready for production and sale at the end of the project?

As the project nears completion, the optimised formulation will be thoroughly validated and ready for deployment. It's noteworthy that our polyurethane foams offer versatile commercialisation opportunities. They can be marketed as laminates with fixed thicknesses or as raw materials, allowing for on-demand mixing prior to utilisation, whether for filling empty volumes or replicating specific forms.
At our institute, we have the capability to prepare laminates in-house, ensuring quality control and precise customisation. This means we can readily provide slabs of polyurethane to fill empty volumes as needed. While feasible, the preparation of bottles containing raw materials capable of reacting upon utilisation requires meticulous planning and execution. Nevertheless, we remain committed to exploring all avenues to make our innovative polyurethane foams accessible and available.

INTERVIEW

Cleaning detail

Courtesy MNH

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"CONSERVATION-RESTORATION REQUIRES A HOLISTIC APPROACH"

For years, Dr Balázs Lencz of the Hungarian National Museum has championed the concept of "eco-restoration", a practice that benefits artworks, the environment and people alike. Here, he discusses the European GREENART project and its key challenges.

As Head of the Conservation and Restoration Department at the Hungarian National Museum (HNM), Dr Balázs Lencz stands out as a leading figure in the field of metal restoration and the preservation of delicate lacquer objects. His expertise is reflected in numerous scientific publications on Japanese art and its conservation techniques. But his role as Chief Conservator goes beyond safeguarding artworks. He is equally committed to protecting museum staff, who often face exposure to harmful substances during preventive conservation or restoration activities.

Dr Lencz is also deeply concerned with the disposal of chemical waste generated during restoration processes. The Hungarian National Museum, where he works, has earned a reputation as a trailblazer in "green conservation", a practice that safeguards both people and cultural heritage. Today, the Budapest-based institution is recognised as a European leader in the field and plays an active role in GREENART, an EU-funded project exploring innovative, eco-friendly materials and sustainable methods for preserving, conserving and restoring cultural heritage. Dr Lencz shares insights into the ongoing case studies, his involvement and the challenges the project faces.

How did the Hungarian National Museum and yourself become involved in the GREENART project? What drew you to it?

Over the past few decades, our institution has focused on replacing harmful and toxic materials used in conservation with safer alternatives. Previously, we were part of the APACHE project, which developed smart, active packaging materials and display cases. [This was another Horizon-funded EU project, completed in 2022, which introduced new tools to monitor and prevent the degradation of artworks caused by unstable climatic conditions, light and pollution, editor's note] Through this experience, we built strong connections with research institutions and museum partners, which eventually led us to join GREENART. The issues addressed by GREENART are critical for the conservation field. Over the years, we have identified serious health problems among conservators, often linked to exposure to toxic materials. Initially, our goal was to replace these substances to protect our staff — particularly those working directly on objects — and to develop new solutions that shield them from solvents, coatings and other harmful chemicals. We are honoured to participate in GREENART. Conservation is often underrepresented in cultural communication, so this project gives us the opportunity to showcase the work of conservation

— Carine Claude

and engage with society on a broader scale — not just the general public, but also stakeholders and policymakers. If we want to provoke a significant shift in thinking, we must start with decision-makers, convincing them of the importance of conservation and environmentally friendly approaches. The research results from this project provide evidence that can help them support these changes financially and politically

You mentioned health issues among staff members. Could you provide examples? Are we talking about allergies or respiratory problems?

Without going into specific cases, I can say that we have observed respiratory problems caused by exposure to harmful solvents. When working on small objects, we do not use large quantities of these substances. However, for larger projects — such as chandeliers, cars or industrial heritage objects — we end up using much more toxic materials. That is when alternatives really need to be considered. Of course, we use protective equipment, such as masks, to safeguard respiratory health. But there are situations where it is not possible to wear them or to keep them on all day. This is why it is essential to reduce the impact on our staff, the objects themselves and the environment. Additionally, many people do not realise that conservation work generates a significant amount of waste. When we use acids and bases, we try to neutralise them before disposal, but we still feel uneasy about their environmental impact.

Which Work Packages within the GREENART project are you most involved with?

Conservation requires a holistic approach — everything is interconnected. That is why we are involved in Work Packages 2, 3, 4 and 5, as well as dissemination activities. We work with solvents, coatings, consolidation materials and packaging materials. We also use sensors in our storage areas to monitor conditions both inside the museum building and in external storage facilities. It is a very complex system that we are currently renewing, so the project is extremely valuable to us.

What types of products are you currently testing?

Since we are involved in several Work Packages, we are working on multiple fronts. We are testing solvents, various gels and combinations of gels and solvents, comparing them with traditional solutions and materials. We start with sample testing, but we have also proposed using real-life scenarios with authentic artworks. After the sample tests, we move on to testing these new materials on actual works of art, always with the utmost care. Recently, we received packaging materials for our case study objects, made from different materials. We are also participating in the measurement of volatile organic compounds (VOCs) emitted either by the objects themselves or by storage and exhibition materials. These harmful substances can originate from the objects due to their degradation or from the materials used in storage and exhibition setups. We aim to measure and compare them so that, together with our development partners, we can find effective solutions for long-term preservation. While standard storage boxes can sometimes be used, special objects often require customised storage solutions tailored to their specific needs.

Is it the same for transportation?

Yes, for both transport and storage. Another important aspect of this project is the development of new absorbents for VOCs — materials that can absorb harmful substances in the environment surrounding the objects.

You specialise in metal and lacquer objects. Do these present specific conservation challenges? How might GREENART products address these issues?

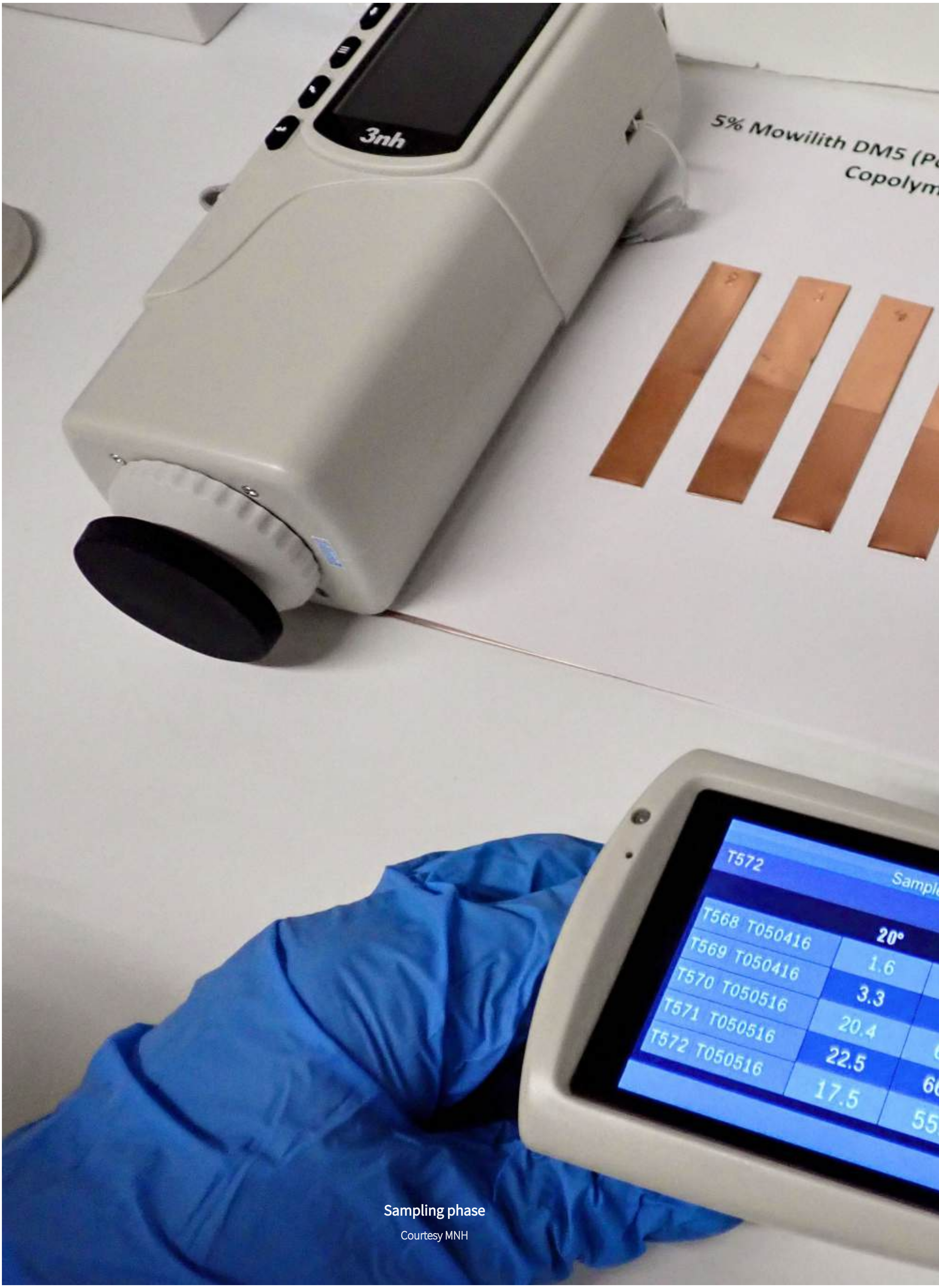
Absolutely. GREENART has significant potential to protect these types of artworks. Japanese lacquer, which I have been studying for decades, is highly sensitive to fluctuations in humidity, dry environments and temperature changes. Proper storage is crucial for these objects. In Central and Eastern Europe, our climate differs from Japan's — it is drier and storage facilities often lack adequate equipment to maintain appropriate humidity levels. Suitable storage and packaging are essential. Even if the surrounding environment is not ideal, you can protect an object by creating optimal conditions inside its storage box. GREENART focuses on developing packaging materials that do not release harmful gases.

Can you tell us more about the artworks you are currently testing with GREENART products?

We have selected a diverse range of objects made from very different materials for our case studies. One notable example is the *Handstein*, a mining model created in Körmöcbánya or Selmecbánya (now in Slovakia) in the 18th century. It depicts a small hill with figurines illustrating all stages of the mining process. The object is composed of various minerals and crystals (pyrite, quartz, amethyst, etc.) and decorated with painted organic ornaments, all mounted on a gilded silver pedestal with lion-shaped feet at each corner. It is a rare and complex piece, a true masterpiece of craftsmanship, chosen for testing because of its heavily contaminated surface. Over the years, it has been treated multiple times with different materials — waxes, epoxies and more. It also shows signs of dirt and impurities that have darkened its appearance.

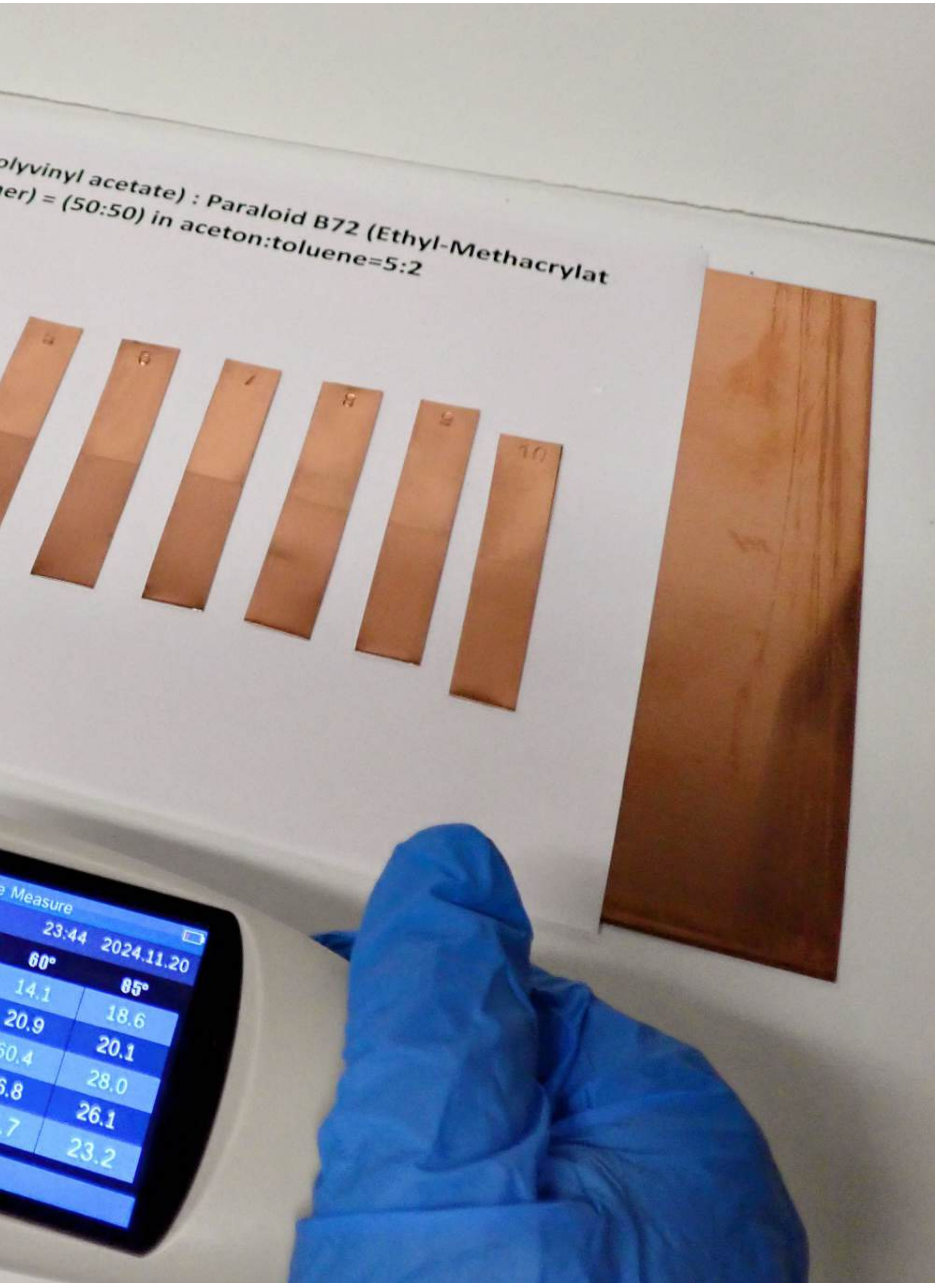
Dr Balázs Lencz during last GREENART presentation

Photo Pierre Naquin. © Art Media Agency



Sampling phase

Courtesy MNH



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> Over the years, environmental protection has also become increasingly important on a global scale. We have focused on finding eco-friendly and sustainable materials and technologies that would have less impact not only on the environment but also on the artworks themselves. These three factors — protecting staff, protecting the environment and protecting the artworks — are our main motivations.
> — *Dr Balázs Lencz*

Our goal is to find an effective cleaning solution and then stabilise its components. The object has an internal wooden structure with minerals and crystals glued onto it using animal glue and the entire piece is beginning to deteriorate. There are cracks and areas where components are detaching, so we need to clean and stabilise it simultaneously. This project offers cutting-edge technology that could be instrumental in its conservation. We hare also working on other objects, such as a modern-era *faux* leather bag in poor condition, Austro-Hungarian soldier insignias from World War I from the MNH's Coin Collection. These items represent characteristic materials of the time, made from zinc-based alloys, bronze, copper, enamel and more. Another example is a stunning 19th-century belt that belonged to a nobleman, crafted from leather, velvet, linen, gilded silver, silver, brass, iron and glass. We have tried to provide artworks with the most diverse range of materials possible for the case studies.

What are the next steps for testing the products on these artworks?

We are continuing with sample tests and case study object tests. We are considering presenting the *Handstein* at the Osaka World Expo, although we are extremely busy and I am not sure we will be able to meet the deadlines. Soon, we will receive innovative coatings to test, starting with samples. We are also developing packaging materials and have already received boxes from ZFB in Leipzig. I will be travelling to the University of Ljubljana, where they will conduct VOC measurements for the storage boxes and objects. Collaboration with our GREENART partners is essential, as we have limited access to analytical equipment. Working with partner institutions is therefore highly beneficial. We are also planning dissemination activities. As the Hungarian National Museum is a central institution in Hungary, we have a responsibility to share our knowledge about conservation and environmentally friendly approaches. We have presented at conferences and are planning a workshop this summer with colleagues from the project.

The GREENART project involves institutions from around the world, including the United States and Asia. How does your museum collaborate with all these institutions?

During our conservation meetings, it is very helpful to see the development work and test results from the various partners. As end users of these materials, it is important for us to communicate with other museum partners facing similar challenges. It is impossible to work directly with all the conservation partners, so we primarily focus on the end-user institutions. When we have direct contact with specific research institutions, it is usually because we are dealing with a particular object or issue that we cannot resolve on our own.

The Hungarian National Museum is also involved in other EU-funded projects to protect cultural heritage. Do you exchange knowledge internally about these different European projects or are they completely separate?

We try to integrate the results, ideas and key findings from all these projects. The conservation department is also involved in the AURORA project and other proposals outside the EU's Horizon framework. [The AURORA project, Artwork Unique Recognition and Tracking through Chemical Analysis, uses encoded data, miniaturised devices and blockchain technology to combat looting, trafficking and illicit trade of cultural goods, editor's note]

We see this as a knowledge network, interconnecting different aspects of conservation to generate meaningful insights into how to treat objects in general. Everything is connected, whether we are talking about storage, corrective conservation or preventive conservation. All these projects are pieces of a larger puzzle. When we put them together, we can create a comprehensive system to protect cultural heritage and preserve it for future generations.


Consolidation detail
Courtesy MNH

Testing GREENART cleaning gels
Courtesy MNH

DISCUSSION

Courtesy Polytechnic University of Valencia

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GREENART

PAPER CONSERVATION FOR A CHANGING CLIMATE

A low-tech solution in paper preservation, inspired by tradition and refined through innovation, with the support of GREENART.

In the meticulous world of art conservation, breakthroughs are rare and typically reserved for laboratories filled with cutting-edge machinery. Yet Salvador Muñoz Viñas, a seasoned paper conservator and professor at the Institute of Heritage Restoration from the Polytechnic University of Valencia, has developed a simple technique that may transform how works on paper are preserved. Drawing on old Japanese methods, modern materials and an intuitive understanding of the medium, his approach offers a sustainable and globally accessible solution to keep paper stable in fluctuating humidity.

What inspired you to develop this technique?

It began back in 2008. I was working at the university at the time. One of the blessings from working there is the freedom to choose complex projects, so I found myself experimenting with a method that combined traditional techniques with modern materials. It evolved gradually, through careful testing and refinement, but I held off on publishing anything. First, I wanted to see how it performed outside the lab, in the real world, because there is always the potential for unexpected variables. After some time, I realised that the technique was actually working better than anticipated, so I started developing it further and refining the process.

What are the main problems this technique addresses?

When paper is exposed, especially in large formats, changes in relative humidity can cause it to expand or contract, resulting in wrinkles, waves or distortions on the artwork. This physical change, called "cockling", can compromise the aesthetic and structural stability of the paper. Museums try to combat this by installing expensive air conditioning systems to keep humidity within a very narrow range. However, those systems are costly and not always the most effective. My technique helps maintain the paper smooth and visually appealing across a broader range of humidity levels, reducing or eliminating those distortions.

And how does the technique work?

The concept is relatively simple. It involves mounting the paper onto a piece of linen that has been tightly stretched over a wooden frame, just like a painter's canvas. We often use linen because it offers the best results in terms of performance and durability, although other cellulose-based fabrics can also be employed with success. The paper is adhered to the fabric using a combination of strong and weak adhesive joints. The outer perimeter of the artwork is firmly bonded to the linen. At the same time, the rest of the surface — the central area, which in practice includes nearly the entire surface except the borders — is attached with a weaker, reversible adhesive. The exact extent of this soft joint varies

— Nahir Fuente

according to the characteristics of the specific artwork. This setup enables the paper to expand and contract naturally in response to changes in humidity, without warping or buckling. The method draws on East Asian conservation traditions. Still, we have reimagined it with a creative twist and the use of modern materials, particularly a synthetic adhesive that retains its grip at room temperature, offering both stability and reversibility.

What were some of the real-world tests or applications of this method?

There have been three major unexpected tests. The first one involved 19th-century maps stored in a penthouse that flooded during a heavy storm. Surprisingly, they remained in excellent condition. The second test involved early 20th-century cinema posters that had been stored for five years in poor conditions, more particularly in a furniture warehouse without climate control. When I went to inspect them, I was surprised to find they were still in excellent condition. The third and most dramatic test came during the 2024 Dana floods in Valencia. The very same posters were stored in a building that flooded with up to 80 centimetres of water and they remained submerged in that environment for ten days. Three weeks later, when we were finally able to examine them, the lower sections, which had been submerged, were damaged and covered in mud. However, the upper portions, which had been exposed to extremely high humidity, were completely intact and perfectly flat. In all three cases, the technique not only worked, but it exceeded expectations of real-world, high-risk scenarios.

How did your involvement with GREENART begin?

When GREENART was announced, I applied on behalf of my university, proposing a system that could significantly reduce the need for strict climate control in exhibition spaces. The project provided us with the resources to study the technique rigorously — running tests, developing mock-ups and confirming that it worked across various settings. It has validated the technique to such an extent that we can now disseminate it through workshops and publications. GREENART has funded most of the research work, including staff time, materials and logistical support. All this help has allowed us to refine and document the technique. We are now starting the dissemination, as with the lecture in Paris where we presented the method for the first time and an upcoming hands-on workshop in Athens. The support we received in Paris was particularly meaningful, not least because the Centre Pompidou expressed interest in the technique. Beyond presenting the technique to the world, it is essential to ensure a genuine understanding and practical competence. GREENART has been instrumental in supporting this educational mission, helping us to emphasise teaching through small-group workshops where practitioners can engage with the method. Hands-on experience is essential; the technique must be “felt”, tested and practised.

What advantages does your technique have over more traditional methods?

It increases the relative humidity range within which paper remains flat by 10 to 20%. That is quite significant. Paper treated this way recovers its shape more quickly after humidity fluctuations. Traditional methods often leave the paper somewhat deformed after exposure to high moisture, but ours allows it to bounce back to its original shape. Additionally, it is far more affordable and environmentally friendly than building sealed microclimate display cases. It is also a low-cost, low-tech, high-efficiency technique. Unlike traditional solutions that rely on climate-controlled vitrines or air conditioning systems, both of which require ongoing maintenance and significant energy consumption, this approach avoids high expenses. Beyond that, moving a large framed paper piece mounted in a vitrine can involve specialised equipment and logistics. But works treated with this technique remain light, manageable and easy to transport. Lastly, the method uses basic and natural materials: linen, wood and starch, paired with a small amount of synthetic adhesive. Its elegance lies in its simplicity: no machinery, no sensors, no need for advanced infrastructure. This makes it especially well-suited to institutions with limited resources and regions where consistent climate control is neither feasible nor sustainable.

How does it affect the artistic integrity of the piece?

Artistically, the paper looks smoother and flatter. That might be a concern if the artist intended a more textured surface; however, the technique does not need to be applied in this case. We are also altering the original nature of paper by supplementing it with other materials. But from a conservation standpoint, most systems alter the original nature of the paper in some way. Conservation is not about freezing an artwork in time but about ensuring it remains accessible and meaningful for future generations. In that sense, change is not a failure of conservation; it is in its nature when done with care and intention. The technique alters the piece in a minimal and respectful way and this is fully reversible. The adhesive used in the central area is designed to leave no visible trace, even under magnification. It is like a Post-it note — strong enough to hold, yet easily removed without damaging the underlying material. And if, in 100 years, conservators develop a more efficient technique, then this method allows them to start again. That is the ethical cornerstone of modern conservation: do what works best today, but leaving the door open for the future.

Salvador Muñoz Viñas

Courtesy Salvador Muñoz Viñas. Polytechnic University of Valencia

Testing the technique on mock ups

Courtesy Polytechnic University of Valencia

You previously mentioned Japanese inspiration…

Japanese paper conservation is incredibly sophisticated. They use handmade paper with unique fibre structures that can be manipulated while wet, which Western papers cannot handle. They mount and dry papers on special lattices called *karibari*. My approach replaces the costly and complex system with a tensioned linen canvas, achieving a similar effect using a more straightforward and more accessible setup. The key is the interaction between the paper and the canvas — their differing reactions to humidity help balance each other out.

Could this method be scaled up?

Technically, yes. But it is not a product you can just buy — it is a technique that requires training and experience. Once someone learns it, they can adapt it to local materials and needs. Intuition and tactile understanding come with practice. That is why workshops are vital. It is not for *virtuosos*; it is designed to be simple and accessible, even in countries with limited resources. In fact, I hope to take it to Asia or Latin America in the near future. Many regions in these areas face challenging climates, characterised by dramatic and frequent fluctuations in humidity levels. This method could provide an affordable and effective solution for institutions that may not have access to high-tech conservation infrastructure or those seeking to reduce spending on room climate control.

Is anyone currently using it in an institutional setting?

So far, just the institutions I have worked with: the University of Valencia-Estudi General, the Polytechnic University of Valencia and the Valencian Institute of Cinematography. Plus, I have also used it on works from several private collections. As we offer more training and publish our findings, I expect the technique to spread. It is an easy and eco-friendly solution that could benefit museums, collectors and conservators worldwide.

Courtesy Polytechnic University of Valencia

INTERVIEW

Sugarcane cellulose fibers
Photo Mickaël Pijoubert. © Art Media Agency

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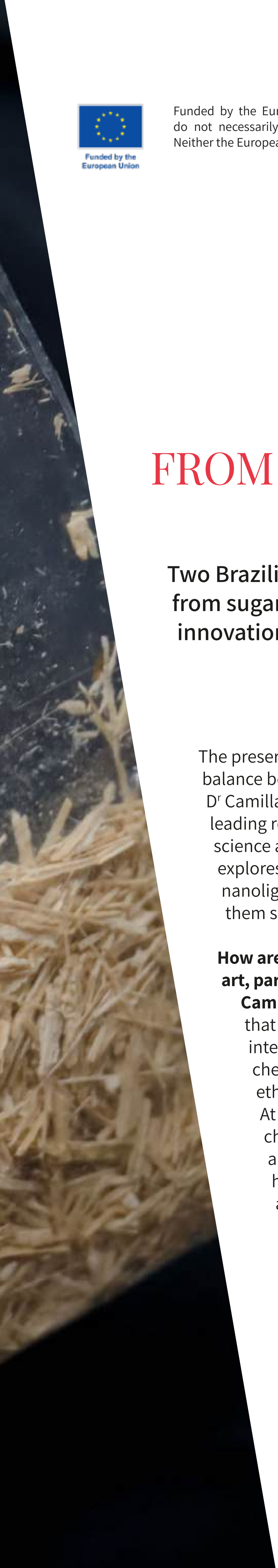

FROM SUGARCANE TO SAFEGUARDING ART

Two Brazilian researchers are pioneering the use of nanocellulose and nanolignin from sugarcane to revolutionise heritage conservation, combining scientific innovation, sustainability and respect for cultural treasures.

The preservation of cultural heritage demands a delicate balance between scientific precision and artistic sensitivity. Dr Camilla Camargos and Professor Camila Rezende are two leading researchers whose work bridges chemistry, materials science and cultural heritage preservation. Their collaboration explores how green technologies, such as nanocellulose and nanolignin, can transform conservation practices, making them safer, more sustainable and more inclusive.

How are you related to the intersection between science and art, particularly in the conservation of cultural heritage?

Camilla Camargos: Our work is rooted in understanding that cultural heritage's conservation is a highly interdisciplinary field. It draws on knowledge from chemistry, materials science, art, history, microbiology, ethics, restoration theory and conservation practice. At this intersection, we explore how science and green chemistry can contribute to the development of safer and more sustainable methods. This convergence has shaped my academic and professional journey, as I come from a background in both Conservation and Chemistry. I earned a bachelor's degree in Conservation and Restoration of Movable Cultural Heritage and a Master's in Chemistry at the Universidade Federal de Minas Gerais (UFMG). Under the supervision of Prof. Camila Rezende, I completed my PHD at the Institute of Chemistry of the Universidade Estadual de Campinas (UNICAMP), where I worked on nanocellulose and nanolignin coatings for paper, wood and textiles. Since 2023, I have coordinated research and teaching at UFMG and founded the research group NANOCOR (Nanotechnologies and Advanced Materials for the Conservation and Restoration of Cultural Heritage). In close collaboration with Prof. Rezende's research group at UNICAMP, we have been actively involved in developing novel green conservation materials within the framework of the GREENART project.

Camila Rezende: My background is in Chemistry, Physical Chemistry and Materials Chemistry, but I have always been fascinated by art-dance, music and visual arts. Being able to apply my classical chemistry background to the field of conservation and restoration is both a privilege and a great source of motivation. I studied at UNICAMP and worked with polymer nanocomposites, coatings, surface characterisation and wetting/dewetting phenomena during my graduate and postdoctoral years. Since 2012, I have coordinated the Laboratory of Chemistry and Biomass Morphology (LaQuiMoBio) at UNICAMP. This laboratory specialises in extracting plant-based components, including cellulose and lignin, for use in films,

— Nahir Fuente

cosmetics, gels and aerogels. In 2017, I was introduced to conservation and restoration by Camilla Camargos, who joined my research group to conduct her PHD project. Since then, we have been working together in a complementary way.

What does "eco-friendly conservation" mean to you?

C.R.: It focuses on preserving cultural heritage while minimising the environmental impact of conservation and restoration practices. It is a comprehensive approach that includes using natural-sourced and more sustainable materials throughout the various steps of the restoration process, reducing the use of harmful chemicals and solvents, conserving energy, minimising waste, ensuring proper disposal of materials and adopting practices to protect the artwork, the environment and conservators.

How does your background in chemistry influence your approaches to preserving and restoring art?

C.C.: Chemistry allows me to approach conservation challenges at both phenomenological and molecular levels. On one hand, it helps me interpret visible deterioration phenomena, such as discolouration, embrittlement, or surface alterations, and relate them to underlying chemical and physical processes. On the other hand, it enables me to investigate the molecular mechanisms that drive degradation and to understand the interactions between historical substrates and conservation materials. This dual perspective is essential for evaluating risks, designing preventive strategies and developing treatments that are effective and removable if necessary. Chemistry also guides the selection and modification of materials, supporting responsible solutions that respond to the specific needs of cultural heritage. Ultimately, it strengthens my ability to bridge technical conservation practice with evidence-based innovation.

C.R.: I enjoy thinking of chemistry as a fascinating science that allows us to understand systems and materials at the molecular level. In the gels, for example, we modify the base polymers, cross-linkers, formulations and preparation methods to achieve the desired performance in terms of cleaning efficiency, flexibility and other properties. These characteristics are achieved by playing with the compounds at the molecular level. The same applies to nanocomposite coating films, where the final macroscopic properties, such as transparency or UV protection, are controlled at the molecular or nanometric scale. This bottom-up approach is particularly helpful in designing materials that meet the specific needs of the application.

Your workshop at GREENART [see p.204] involves nanocellulose and nanolignin coatings as well as hydrogels. How do these green materials compare to traditional conservation techniques?

C.C.: While not all traditional conservation techniques necessarily result in high environmental impact, certain materials raise concerns regarding toxicity and sustainability, such as synthetic copolymer-based coatings. That said, some conventional coatings, especially many cleaning gels already in use, are relatively low-impact. However, thinking about sustainability today requires a broader perspective — one that goes beyond environmental concerns to include economic and social dimensions as well. We focus on developing materials derived from abundant agro-industrial residues, such as sugarcane bagasse in Brazil, to produce nanocellulose and nanolignin, which are then applied in cleaning hydrogels and protective coatings. These green nanomaterials not only present a reduced environmental impact, as they are mainly biodegradable and non-persistent, posing minor health risks for conservators, but they also have the potential to be more accessible in Brazil and across South America. We aim to contribute to a more inclusive and locally viable model of sustainable conservation.

What are the challenges you have faced in cellulosic substrates in books and artworks?

C.C.: One of the challenges lies in developing conservation solutions that are effective and respectful of the material, historical and structural characteristics of cellulosic substrates. Books and paper-based artefacts often present complex layers of meaning and construction, including inks, adhesives, bindings and supports, that require careful, case-by-case assessment before any intervention. Particularly challenging scenarios include works of art on heavily degraded wood-pulp paper, documents on vegetal parchment and collections affected by environmental disasters such as flooding. Insect-damaged graphic documents present another recurring and delicate challenge. In 1943, Monsenhor Joaquim Nabuco published a book titled *Bibliófilos versus bibliófagos* (*Bibliophiles versus book-worms*), a landmark work in which he denounced the widespread damage caused by insect activity in Brazilian collections. Nearly a century later, this concern remains highly relevant and pressing, as many of these objects are too fragile to undergo mechanical or large-scale interventions without risking further loss. In 2023, for example, I supervised an undergraduate thesis focused on the conservation of a 19^{th}-century wood-pulp book


CORNING

that had belonged to a historically significant figure in the city of Pelotas, Brazil. The book exhibited numerous small lacunae (paper losses) resulting from insect attack. Manual reintegration using nanocellulose enabled precise filling with minimal interference to the original substrate and bookbinding. While projects like this highlight the need for adaptable, low-impact and material-compatible methods, I maintain a deep appreciation and respect for traditional conservation techniques, which I continuously study, apply and pass on to my students. These methods remain essential in practice and form the foundation upon which new materials and approaches must be evaluated and integrated.

How do composites and natural nanoparticles help reduce the chemical footprint in the art world?

C.R.: Natural polymers, like cellulose, lignin and their nanoparticles, have been investigated due to their compelling properties and the potential to reduce the chemical footprint of traditional methods. To begin with, both cellulose and lignin are bio-sourced feedstocks, which already minimises the environmental impact of using fossil-fuel-based polymers and particles. Furthermore, extracting these components from agro-industrial waste, such as sugarcane, is an approach that not only reduces the amount of accumulated waste at processing plants but also adds value and gives this waste a more noble purpose. We also pay special attention to the processes for extracting cellulose nanoparticles (nanocrystals and nanofibrils) and preparing lignin nanoparticles, seeking to use milder reagents at low concentrations and aiming for routes that minimise energy consumption and waste generation. Another interesting aspect of cellulose and lignin nanoparticles is that they are dispersible in water. While macromolecules of cellulose and lignin are not water-soluble, their nanoparticles possess a negative surface charge, which allows these particles to remain stable in aqueous dispersions, significantly contributing to low toxicity. Both components are non-toxic and biodegradable, which is especially important in the case of cleaning gels. Another key point is that cellulose nanocrystals and nanofibrils naturally form gels depending on their concentration in the dispersion. Although these are soft gels that require crosslinkers to become suitable for cleaning applications, their predisposition to gelation facilitates the entire preparation process. The nanoparticles are also compatible with other natural polymers such as alginate, gelatin and gluten, allowing for fine-tuned modulation of the properties needed for cleaning gels. Finally, lignin is a multifunctional compound with antimicrobial, antioxidant and UV-absorbing properties, which is highly beneficial, for example, in film preparation. One single component can provide the functionality of several ingredients in a formulation, minimising the total number of components required. The protective films developed, for instance, contained only three elements: nanolignin, cellulose nanocrystals, and cellulose nanofibrils. Considering all the beneficial properties, natural polymers and their nanoparticles are promising for applications in the art world.

How feasible is it to implement these eco-solutions in museums and archives globally?

C.R.: We are not yet at a stage of large-scale implementation in museums and archives worldwide. Many of the eco-friendly materials we work with are still under development and several aspects must advance before broad adoption becomes feasible, including production processes, testing protocols and long-term performance evaluations. That said, we are actively working toward scalability. Currently, we can produce nanocellulose at pilot scale using an ultrafine friction grinder, which allows us to generate sufficient quantities for experimentation and pre-application studies. Coatings based on nanocellulose and nanolignin are the most promising candidates for short-term scalability, as they are easier to produce, apply and integrate into existing workflows. Gels, on the other hand, remain more challenging. Currently, we can produce cleaning hydrogels in sheets approximately 10 × 10 cm in size, which takes up to 48 hours to be ready for use. Scaling up gel production is one of our current priorities and we are working to optimise formulations to make this possible.

What role do eco-friendly technologies play in the future of art conservation?

C.C.: They are fundamental in shaping the future of art conservation, not only from an environmental perspective, but also through the broader lens of sustainability, including social and economic dimensions. These technologies aim to reduce the use of highly toxic solvents, non-renewable materials and waste-generating processes, thus minimising harm to both conservation professionals and the ecosystems around them. Economically, they represent an opportunity to develop more accessible solutions, especially in regions where high-cost imported products are not viable. By working with renewable raw materials, such as lignocellulosic agro-industrial residues, we can create locally sourced alternatives that reduce dependence on international supply chains and better align with the financial realities of many institutions in South America and Africa. Socially, sustainable innovation in conservation promotes inclusion by creating knowledge and tools that are adaptable to diverse contexts and available to a broader range of professionals and communities. It also reinforces ethical commitments to future generations by ensuring that our interventions are responsible, considered and attuned to long-term impact. Eco-friendly technologies are not just alternatives; they are part of a necessary transformation of conservation practice, grounded in innovation, responsibility and regional protagonism.

How do you balance the scientific rigour with the artistic sensitivity required when working with cultural artefacts?

C.C.: Conservation and restoration are, by definition, a transdisciplinary field. It draws from the humanities, social and natural sciences, and arts. Scientific rigour is essential to understanding the materials, mechanisms of deterioration and effectiveness of interventions. At the same time, artistic sensitivity is crucial to respecting the formal, symbolic and cultural values embedded in each cultural object. Rather than seeing scientific contribution and artistic interpretation as opposing forces, I approach them as complementary ways of knowledge. Understanding the historical context of an artefact, its original techniques and its meaning to different communities is as important as identifying the molecular aspects involved in its degradation and the material interactions related to its conservation. In practice, balancing both dimensions often means listening closely to the object. In my teaching and research, I emphasise that sensitivity and precision are not mutually exclusive. Meaningful conservation approaches require a deep engagement across disciplinary frontiers.

Camila Rezende and Camilla Camargos

Photo Mickaël Pijoubert. © Art Media Agency.

DISCUSSION

ZFB boxes

Photo Mickaël Pijoubert. © Art Media Agency

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GREENART

SUSTAINABLE INNOVATIONS IN ARCHIVAL PACKAGING

Manfred Anders and Katharina Schuhmann of ZFB discuss their work on archival packaging, sustainable materials, automation and collaboration within EU-funded projects like GREENART.

Since 1997, ZFB Centre for Book Conservation has been at the forefront of archival packaging and paper conservation, combining traditional expertise with cutting-edge research. Manfred Anders, a chemist specialising in cellulose, paper and textile chemistry, has been with ZFB since the beginning, serving as Head of R&D and later as Managing Director. Katharina Schuhmann, an engineer in printing and packaging technologies, joined in 2015. Together, they drive innovation in sustainable packaging materials while tackling the challenges in archival storage, alternative fibres and intelligent packaging solutions.

What are the core services of ZFB?
We focus on the preservation and conservation of paper-based cultural heritage, offering mass deacidification, freeze-drying, surface and dry cleaning, as well as paper and cover restoration. Since 2015, ZFB has also expanded its production of archival boxes. In Germany, these boxes are primarily used for storing books, files, and other written documents. However, we also produce fully customised designs tailored to the storage needs of diverse collection objects, regardless of shape or material. These solutions are particularly beneficial for museums.

What problems in the use of traditional box materials might arise for conservation?
Archival boxes significantly improve storage conditions, offering protection against UV light, mechanical damage, and dust, while providing a buffering effect against humidity fluctuations. To ensure long-term protection, it is recommended to use materials that comply with ISO standard 16245-A. This standard requires lignin-free and alkaline boards made from cellulose-based materials. Achieving the “lignin-free” benchmark (kappa value below 5) typically excludes recycled fibres of unknown origin and composition, as they may not meet the purity and durability criteria. Instead, the industry standard relies on virgin wood fibres. However, given the high energy and water consumption required for pulping, we have explored plant residues as a more sustainable alternative for archival board production. Additionally, the long-term availability of wood as a raw material for paper production is expected to be limited in the coming decades, making alternative sources an important area of research.

What materials do you use for your boxes? Do you foresee any improvements in this aspect?
Currently, we produce archival boxes and enclosures using corrugated and solid boards made from virgin wood fibres — specifically northern bleached

softwood pulp (NBSK) — in compliance with ISO 16245-A requirements. This material is exclusively developed and produced for ZFB, and we maintain continuous collaboration with paper mills and converters. Over the years, we have made significant improvements, particularly in non-fade properties and moisture resistance. As part of the GREENART project, we have explored the potential of fibres from annual plant residuals as a sustainable alternative to replace one or more paper liners in our boards. Additionally, we are investigating the use of polypropylene hollow chamber sheets and bubble boards, particularly those made from recycled or bio-based plastics, as another innovative approach to archival storage materials.

How automated is your custom-made box production and how are you improving it?

ZFB primarily manufactures and distributes archival boxes. Currently, we produce 50,000 to 100,000 archival packaging boxes and aim to scale up to several hundred thousand boxes annually. Over the past years, we have developed a highly automated workflow, creating an extensive library of standard construction templates. For example, when packaging a large collection of books, we use a survey device to measure each book's dimensions. These measurements are seamlessly integrated into our workflow, where all CAD drawings are automatically generated, sent to, and processed by an automated cutting table. However, we collaborate with external die-cutters for large-scale production runs of identical designs.

When it comes to custom-made constructions, our product designers develop tailored solutions. We can generate 3D previews and provide physical samples to ensure clear communication with our customers, allowing them to review the design before production begins.

What challenges do the fast-growing plants you are sourcing present?

So far, we have evaluated a wide range of plant fibres and papers, including hemp, abaca, bagasse, flax, jute, wheat straw, cotton, silphia, and mixed agricultural residuals. We have produced our own papers on a lab scale and at a technical centre, while also exploring commercial papers made from these materials.

However, we are not directly involved in the planting or farming processes. Many plant fibres were used in paper production before wood pulp became dominant.

Our research confirms that they can still produce high-quality papers. To ensure suitability, we have tested them for compliance with ISO 16245-A and assessed their material emissions and impact on cellulose degradation, in collaboration with the University of Ljubljana. Several promising fibres have been identified from a technical perspective. In the final year of our project, the University of Venice and Green Decision will conduct a life cycle assessment on all proposed materials.

This will help determine the most sustainable option based on environmental impact.

One of the biggest challenges remains cost. Although these fibres are agricultural byproducts, their specialised production in small batches (a few tonnes) makes them more expensive than virgin wood pulp. As with many sustainable choices, it ultimately comes down to deciding what price we are willing to pay for the benefit of our planet and future generations.

What box designs are you developing?

As part of the GREENART project and the previous APACHE (Active and Intelligent Packaging Materials for Cultural Heritage) project, we have developed tightly sealed archival boxes with no holes or slits and additional material layers. Climate chamber tests with cyclic humidity changes have demonstrated that this tight construction provides a two to six times higher buffering effect compared to a standard box.

What types of coatings do you use?

We have tested various coatings, including water-based dispersions, UV-curing varnishes, and bio-based wax coatings to enhance air-tightness and improve the buffering effect. While these coatings improved humidity regulation, tests according to ISO 23404 revealed emissions that slightly degraded cellulose-based objects. For this reason, we cannot currently recommend the tested coatings, but we continue searching for effective and sustainable solutions that balance protection, conservation, and long-term material stability.

Do you plan to standardise the addition of sensors to your boxes?

Yes, we plan to develop optional sensor systems that can be integrated into newly purchased

Katharina Schuhmann

Courtesy ZFB

ZFB box

Courtesy ZFB

and existing archival boxes. In an airtight enclosure, temperature and humidity monitoring are the most critical factors for ensuring the safety of stored objects. By tracking these conditions, we can help prevent deterioration caused by fluctuations in moisture and temperature, which are major risks for paper-based and other sensitive materials.

Can standard boxes be improved?

Yes, they can be equipped with sensors for environmental monitoring or integrated with adsorbing materials developed by other GREENART partners. However, available space inside the box is a limitation — safe integration requires room, typically in the lid or base area. We also explored a refurbishing treatment to reduce harmful emissions from aged, acidic archival boxes. A water-based deacidification solution was developed for spray or brush application directly within collecting institutions. However, our tests showed that this treatment had limited effectiveness while requiring significant effort. Compared to bespoke boxes, standard boxes offer some degree of improvement, but they cannot match the precision fit, tailored protection, and advanced material options of custom-made solutions.

Have you worked on previous EU projects before GREENART?

Over the past ten years, we have contributed to several EU-funded projects led by Piero Baglioni and his team at CSGI (Centre for Colloid and Surface Science) in Florence. In the NanoForArt and NanoRestArt projects, we worked on developing formulations for the protection of leather book bindings, stone and metal surfaces, as well as the consolidation of canvas using in-house-developed nanodispersions and nanocellulose. Since the APACHE project in 2019, our focus has shifted toward active, intelligent and sustainable solutions for improving conventional archival packaging boxes.

How do you collaborate with GREENART project partners?

We closely collaborate with various partners, adapting our approach based on their expertise. We have a strong partnership with the University of Ljubljana, which plays a key role in chemically assessing our proposed materials and solutions. Additionally, we coordinate the integration of greener adsorbing materials and sensors developed by partners such as Chalmers University (Göteborg, Sweden), University College Cork (Ireland) and The Foundation for Research and Technology – Hellas (FORTH, Greece). For museum case studies, we design custom-made boxes that include at least one active component tailored to the specific needs of the stored objects. While the collaboration process varies, scientific institutions primarily focus on research, material testing, and innovation, while museums and institutions provide practical insights and real-world applications. The exchange is dynamic, but the highlight is always the opportunity to meet in person at annual consortium meetings, where interdisciplinary discussions greatly enrich our development process.

Which museums and institutions are testing your products? Have you received any unexpected feedback?

Our novel greener packaging materials are being tested by several prestigious institutions, including the Peggy Guggenheim Collection (Venice, Italy), Hungarian National Museum (Budapest, Hungary), Ministero della Cultura (Rome, Italy), Los Angeles County Museum of Art (LACMA, USA), Slovenian National and University Library (Ljubljana, Slovenia) and the National History Museum (Leipzig, Germany). So far, all institutions have been enthusiastic about testing our packaging solutions. However, since we are still in the middle of the GREENART case studies, we anticipate more detailed feedback in the coming months.

Do you collaborate with other scientific projects?

Yes, ZFB has always been actively involved in internal and national research projects, with a large R&D department for an SME. Beyond archival packaging, our recent research focuses on microfibrillated cellulose production and innovative mass treatments for paper conservation, including paper strengthening and cleaning processes. We would be grateful to continue developing these innovations within the international research network, contributing to future EU projects that support sustainability and conservation advancements.

ZFB factory

Courtesy ZFB

Manfred Anders
Courtesy ZFB

INTERVIEW

Photo Alexander Psiuk

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GREENART

"EUROPEAN PROJECTS GIVE US THE OPPORTUNITY TO DO SOMETHING REAL"

Italian scientist Isella Vicini has made community funding for research projects one of her areas of expertise. She is involved in GREENART, a project launched by the European Union in October 2022, which is developing new green and sustainable restoration products to preserve works of art.

With a master's degree in computer science, this former researcher at the CNR's Robotics Department (Italian National Research Council) coordinated and managed targeted activities for research projects in the ICT field from 1986 to 1993. She co-authored more than 30 scientific articles published in national and international journals and conference proceedings. As a project manager at Think3 Inc. and head of European project management and administration from 1993 to 2008, she has since been the director of the European Funding Division (EFD) at Warrant Hub, an Italian company offering integrated services to support industrial development projects. In this role, Isella Vicini provides methodological and strategic advice on accessing European funding for research and innovation, as well as preparing, submitting and managing European proposals. Drawing on this experience, she was involved in setting up the GREENART project, which benefits from HORIZON funding, the European Union's main programme for research and innovation, with €95.5 billion allocated for the period 2021 to 2027.

To develop its innovative methods, GREENART relies on a multidisciplinary partnership bringing together several European universities and research institutions, as well as industrial companies, SMEs, museums and conservation professionals collaborating to develop new green and sustainable restoration products, such as cleaning agents, protective varnishes, consolidants and monitoring technologies. This European consortium is funded by the European HORIZON programme under a Culture, Creativity and Inclusive Society agreement. The project began on 1st October 2022 and will end on 30 September 2025. In the meantime, the funding arrangements for European projects have evolved. Isella Vicini explains the potential impacts of these changes on GREENART's development.

Nowadays, how are European research projects funded?

Initially, Europe finances 45% of the total budget in advance to start the project. As it is public money, progress reports must be submitted, but funding is provided for the entire project. The change coming next year, and generally in future calls, is that there will no longer be an obligation to submit economic and financial progress reports. In fact, a small advance will be paid at the start, and the rest will be granted based on the results obtained, objective conditions and achievements made.

How long should projects last?

Projects generally last for three years, or a minimum of 36 months. However, in some sectors, such as

— Pierre Naquin and Carine Claude

health, they can last up to 60 months due to lengthy experiments and tests on people.

What impact will this change in funding method have on projects?
The problem may arise, for example, when work is organised in work packages, as in the case of GREENART. Payment will only be made when the work package is completed and all related results have been validated. It is only at this point that the entire consortium will be paid.
So, will each member organisation of the consortium depend on the results of the others? Exactly. What will also change, and become more difficult for people like me who set up projects, is that we now need to integrate this dimension of achieved results into a budget that, from an economic and financial point of view, meets the expectations of the European Community, but also takes these variables into account.

Could this lead to deadlock situations?
The whole question is where to set the research objectives, because if the TRL is very high, there's a risk of not achieving the results and consequently not being paid.
So perhaps we should consider lowering the TRL at that point.

What are the consequences for the work you do?
When setting up this type of project, we obviously look at the economic and financial aspects. But we also need to take into account the concrete actions and research objectives, because being funded in this way means knowing all the details in advance very precisely.
The feasibility study must include everything: what activities are planned, the number of days needed to carry them out, the skills, material and human requirements, material costs, and so on. If the package estimate isn't realistic, there's a risk of losing the entire project.

from the university and industrial sectors. And also someone who does the economic and budgetary follow-up. This means that for each project, every 18 months, a team of 5-6 people is mobilised just to monitor its progress. These are very high costs. The idea is to reduce these management expenses.
It is true that it is simpler, because there is nothing to demonstrate, no control from the point of view of invoices, for example, which was the case previously with funding under the advance system for the entire project. From now on, everything must be attested precisely, for each stage.

When will the new European programme funding arrangements be implemented?
Implementation will be gradual, but it will become the rule for the next framework programmes starting in 2027 for a seven-year period. Discussions are ongoing.

> Cooperation is essential. In an uncertain world affected by climate change, technology can offer the possibility of preventing future problems, and culture allows us to connect and project ourselves into a desirable future. We need to think about the message we want to convey. I believe that European projects, and research in general, give us the opportunity to do something real. — *Isella Vicini*

How do you proceed?
We need to look at the TRL, which stands for "Technology Readiness Level", an assessment method used to estimate the maturity of the results of a particular technology. It includes a whole range of indicators that demonstrate exactly the steps taken and the viability of the project, with numerous testing and validation stages. Of course, activities that have been completed and successful will be paid for.

Why has Europe decided to change its funding methods?
The aim is to reduce costs from an administrative bureaucracy point of view. What does this mean? Behind every funded project, there is a project officer in Brussels who provides technical follow-up, but who does not necessarily know the subject matter or research area.
So, for each project, they need three experts paid directly by the European Commission who come

The election of the Commission President has put things on hold [Ursula von der Leyen was reappointed as head of the European Commission on 18 July, Editor's note]. For the moment, we don't yet know what the next lines and budget for next year will be. Normally, the European Community gives them two years in advance. For example, I already knew the details of the 2023 and 2024 calls in 2022. After the elections,


Isella Vicini
ARR

we should know the details of the 2025 and 2026 calls, but for the moment we only have a macro vision of future calls, i.e. the general themes. Further details should be given in September-October.

Which won't leave you much time to prepare the call…

There will not be any calls before the end of 2024. The next ones will start at the beginning of 2025, around March. This means that next year there will certainly be a complementary calendar, as many projects end at the end of 2024.

Do you have any idea of the general themes that will be supported?

There are numerous budgets dedicated to climate change, renewable energy, artificial intelligence for all medical applications, but also in terms of "hard" sciences.

And what about GREENART?

GREENART's budgetary destination falls under the "Culture and heritage" domain in European funding. When we talk about heritage conservation, we are not just talking about sustainable innovation or new environmentally friendly materials, but also about traditions, crafts, cultures, music, intangible heritage, and so on. The overall budget will undoubtedly be significant, even if it will not be comparable to that of the medical sector. It will cover culture and humanities, and therefore everything relating to the conservation of our history and heritage. Today, projects like GREENART are organised in different clusters. It's almost certain that this organisation will not change for the three remaining years of the HORIZON 2021-2027 programme. GREENART also calls on Information Communication Technologies, which can be directed to other clusters or other funding. Ultimately, the GREENART project is highly cross-cutting.

European parliament

Photo Frederic Köberl

WIDE ANGLE

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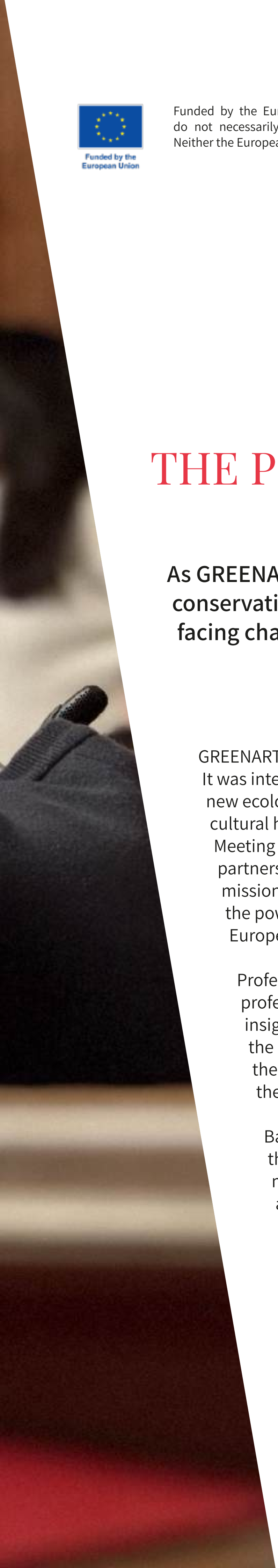
GREENART



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

Photo Pierre Naquin. © Art Media Agency

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.

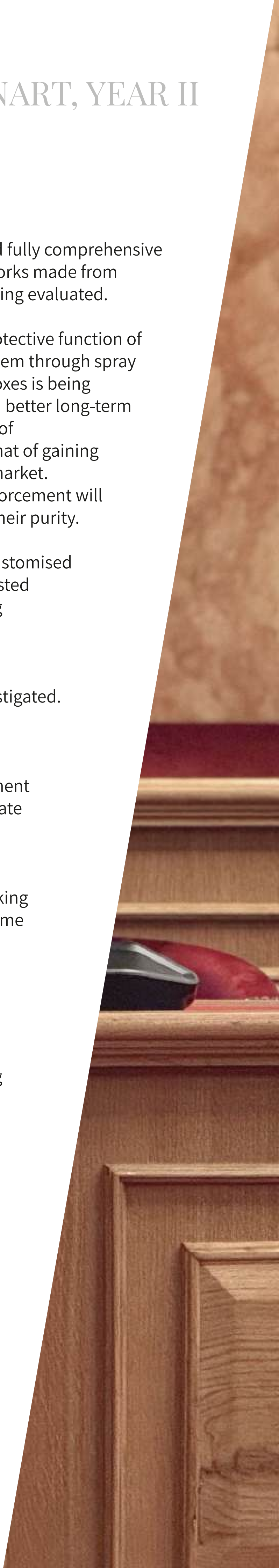



Photo Pierre Naquin. © Art Media Agency

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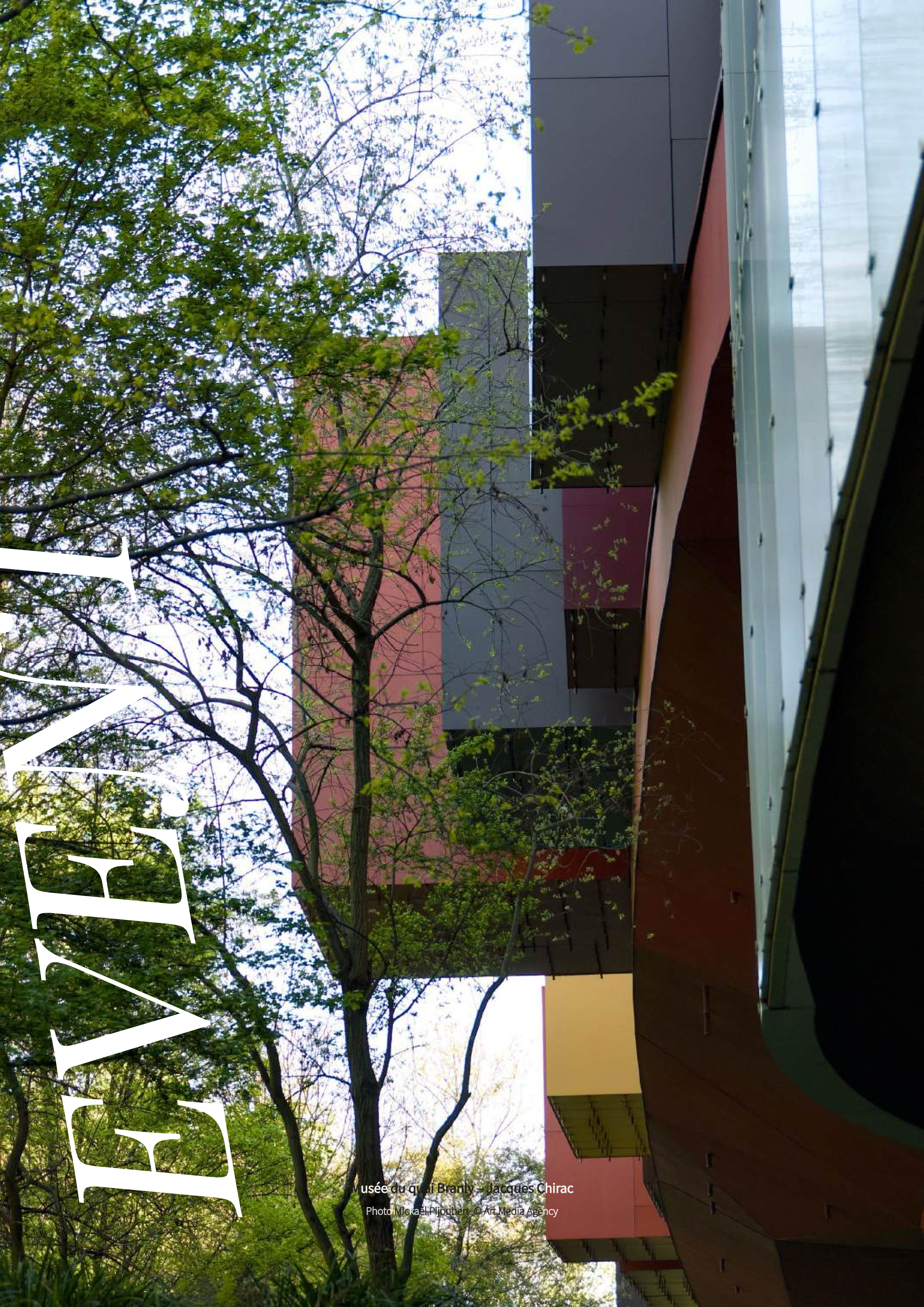

Musée du quai Branly – Jacques Chirac

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GREENART

SUSTAINABILITY IN PRACTICE: GREENART'S PUBLIC TRAINING SESSION IN PARIS

Lead scientists and conservators on the EU's GREENART project recently offered a public update and training session in Paris, sharing the latest results from their groundbreaking research.

On 10 and 11 April 2025, representatives of EU's GREENART Project gathered at the Musée du quai Branly – Jacques Chirac in Paris to offer the latest update to their project. GREENART's stated mission is to develop new sustainable tools and methods "to preserve, conserve and restore cultural heritage". Inherent in that goal is the development of novel cleaning solutions, packaging materials, solvents and other products that could replace current non-sustainable solutions used in the field. The public training session included a comprehensive series of lectures from leading researchers working on various projects, who shared progress reports in their areas of interest — including stakeholders from various international museums where GREENART's products and methods are being tested in real world situations. Following the talks, five practical training workshops were offered elucidating the topics discussed in the talks.

Session one began with Martina Menegaldo, a PhD student in Environmental Sciences at Ca'Foscari University of Venice, Italy, giving a talk about Life Cycle Assessment (LCA) and Life Cycle Costing (LCC). These are metrics used to compare the environmental and economic impact of GREENART's solutions compared to existing products. Menegaldo outlined the steps of the assessment process as goal scope definition (the case study), inventory analysis (collecting information about the product), impact assessment and interpretation (conclusions drawn about results). The impact assessment includes 16 categories, Menegaldo said. "When we talk about sustainability, it is not only one problem like climate change, but we have several problems for the environment, such as toxicity for both human health and the environment, the use and the depletion of resources like mineral metals and fossil resources, the formation of particulate matter, water consumption, land use, land transformation and so on. It is quite a challenging assessment."

Next was a talk from Manfred Anders [see p.180] from Zentrum für Bucherhaltung (ZFB) in Leipzig, Germany, where conservation is done on paper-based materials for archives and libraries. Anders is specialist for paper, cellulose and textile chemistry. His talk covered intelligent and sustainable solutions for archival packaging. One of the most important aspects of packaging, they noted, is to create a protective environment for whatever is in the package to protect it from environmental fluctuations outside. In addition to using more sustainable materials to make the packaging, they cited the importance of "smart packaging" that stabilises the "microclimate" inside the box, including internal

— Pierre Naquin and Phillip Barcio

humidity sensors for packaging. This, he said, allows an institution to spend less resources on room climatisation. He reported progress in better package construction to create a tighter seal. One problem the company still faces is finding materials that will help them move away from trees, such as hemp, which grows back quickly. One challenge with hemp, however, is that the fibres are too long and they have a negative effect on the paper machines causing them to need additional clearing. These issues add to the cost and complexity of the technology.

Next was a presentation by Salvador Muñoz-Viñas [see p.164], Professor in the Universitat Politècnica de València, Spain and Head of the Paper Conservation group of the university's Instituto de Restauración del Patrimonio, and María Sobrino-Estalrich, who is pursuing a PhD in Conservation and Restoration at the Universitat Politècnica de Valencia. They offered a proposal for a "greener" mounting system for paper artworks. Their goal, they explained, is to develop a better solution for keeping "a paper drawing, map, poster or whatever, flat and nice" while on display in a museum. "The solution is usually to try to keep the room's relative humidity within a very tight range," they said, but that takes a lot of energy so is not sustainable. A better solution is to develop a mounting system that resists changes in humidity and temperature. With the help of GREENART products, the team developed a system that achieves this goal, even at extreme humidity levels. Their work was recently tested incidentally in real world conditions during the floods in Valencia, when posters mounted using their technique were partially submerged in water. Only the submerged parts showed damage — the rest were still in nearly pristine condition.

Session 2

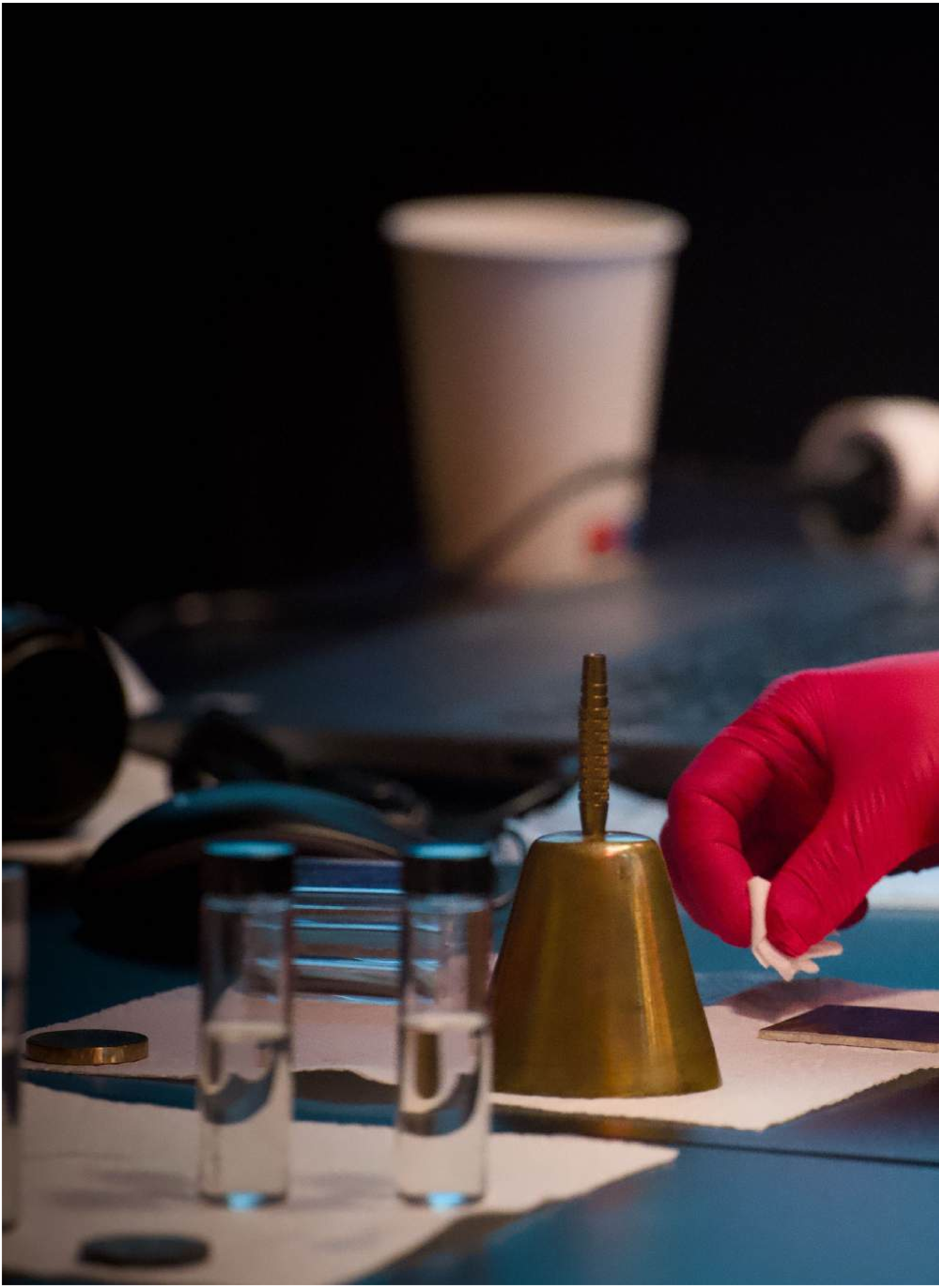
The next session began with a presentation by Giseppe Cesare Lama, PhD, Marino Lavorgna and Letizia Verdolotti, [see p.148] all from the Institute of Polymers, Composite, and Biomaterials of the National Research Council. Their talk was about eco-friendly and bio-based coatings and polyurethane foams used for packaging and transporting artworks. They discussed two applications: one that coats the artwork itself and one that protects it inside the packaging during shipping. They compared the first application to a *Torrone*, which they said is basically "an edible composite". Instead of chocolate, they use polymers, they said, and instead of pistachios, they use "mesoporous silica nanoparticles". For the second application, they reported progress on making packaging foams from food waste, in particular cashew nutshell liquid. This material can be used to create a perfect mould for the actual object in the packaging, and afterward can be reprocessed by compression moulding and used in another application.

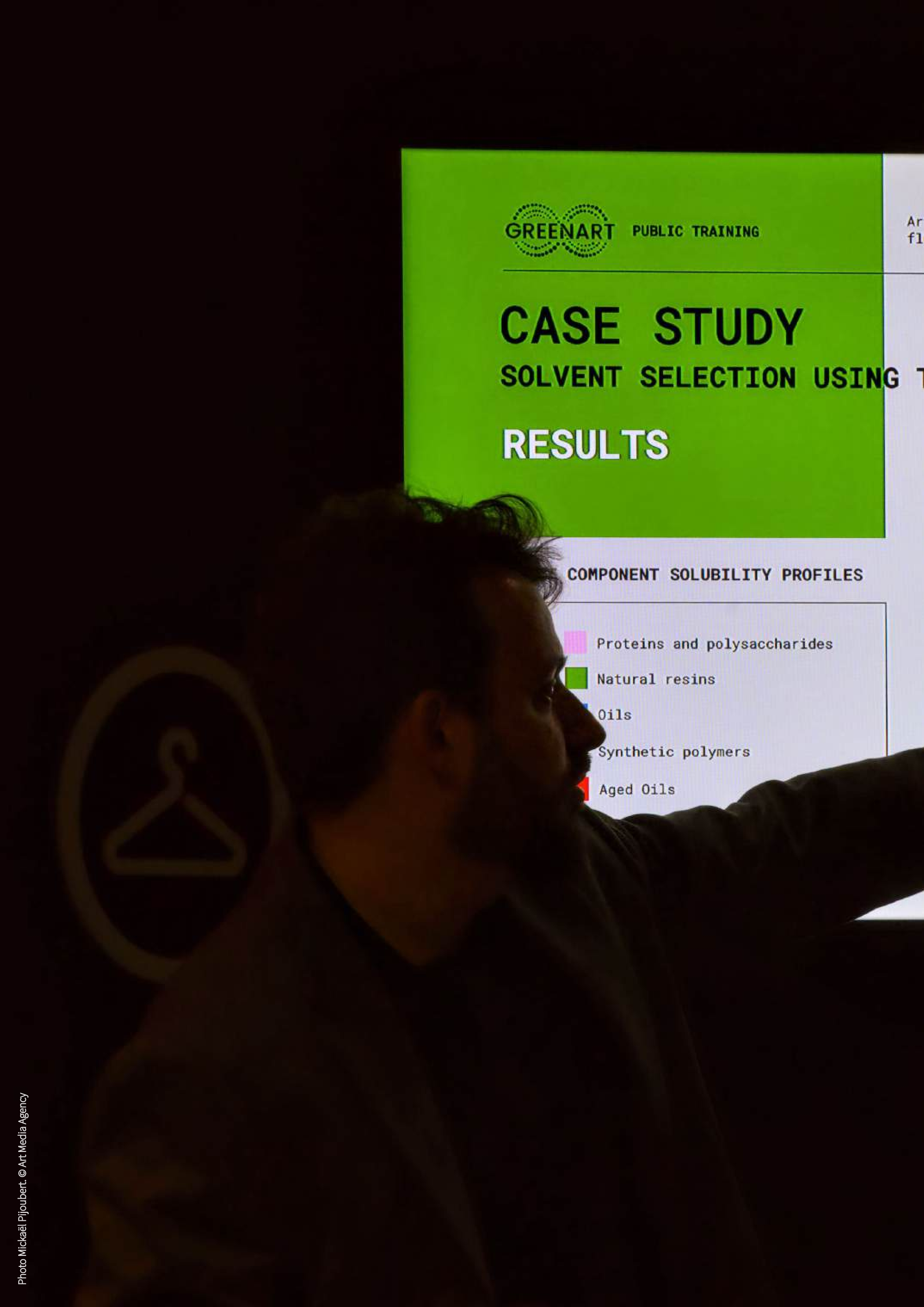
Gabriella di Carlo [see p.140] spoke next about bio-based multifunctional coatings for tailored and long-term protection of metal cultural objects. Di Carlo is a Senior Researcher at Istituto per lo Studio dei Materiali Nanostrutturati, Rome, Italy. The most important thing, she said, is to achieve high transparency with any coatings applied to metal objects so as not to alter the object's appearance. As part of her project, her team worked on the development of new solutions based on chitosan, which she said "is a biopolymer with a low cost, commercially produced from renewable sources, like for example, waste of the fishing industry." That coating succeeded in protecting metal objects on which it was tested and achieved high transparency at first, but after time a slight yellowing was observed. Di Carlo's team is working with researchers now to achieve longer term results.

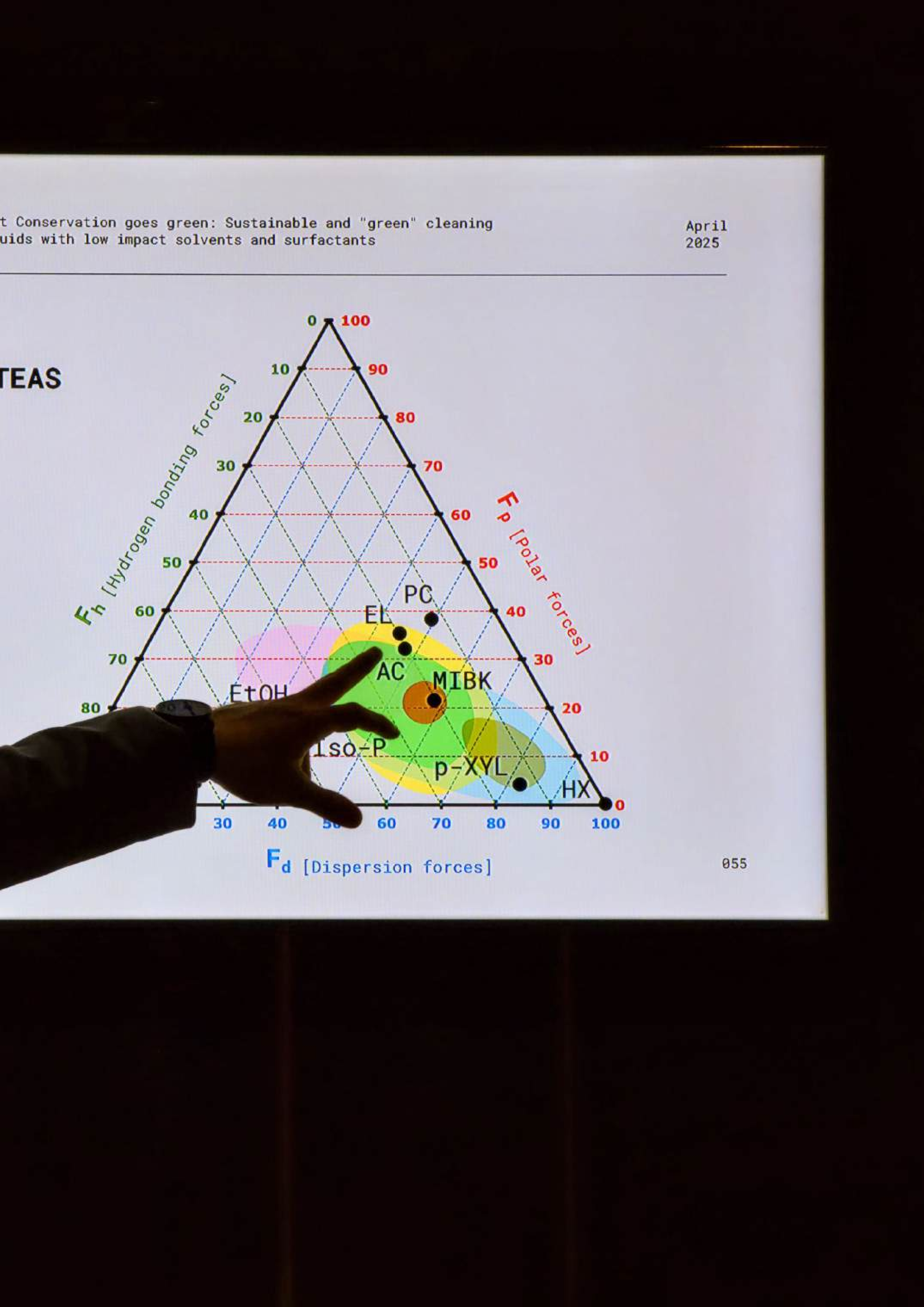
Next was a presentation from Camila Rezende and Camilla Camargos, [see p.172] who have been studying nanocellulose-based coatings and hydrogels for cultural heritage conservation. Rezende is an Associate Professor at the Institute of Chemistry at UNICAMP. Camargos is an Assistant Professor in the Conservation and Restoration of Cultural Heritage program at the School of Fine Arts, UFMG. They reported progress in utilising plant-derived nanostructures extracted from sugarcane bagasse, an agro-industrial residue, to fabricate protective coatings and hydrogels for cleaning cultural heritage objects. The coatings still require some development in order to become colourless, they said. And the hydrogels were highly effective for cleaning. They concluded that these products have "high potential for cultural heritage conservation", "can offer high transparency, removability, antioxidant, antimicrobial and UV shielding properties, efficient and gentle cleaning performance" and "are potentially more accessible to conservation professionals in South America and beyond."

Next, Romain Bordes [see p.100] spoke about the development of green dispersion for the consolidation of encaustic paintings. Bordes leads a research group in the Applied Chemistry division at Chalmers University of Technology in Gothenburg, Sweden. He spoke about the particular challenges of conserving encaustic paintings and offered a report on his team's progress developing "a family of novel consolidants designed specifically for encaustic paintings, using a microstructured dispersion system of beeswax (BW), cellulose nanocrystals (CNC) and ethyl hydroxyethyl cellulose (EHEC)." Bordes reported that he was happy with the results, concluding that the system "has a good tendency to restore the mechanical properties of, first the encaustic painting —

Photo Mickaël Pijoubert. © Art Media Agency




GREENART
PUBLIC TRAINING
CASE STUDY
SOLVENT SELECTION USING
RESULTS
COMPONENT SOLUBILITY PROFILES
Proteins and polysaccharides
Natural resins
Oils
Synthetic polymers
Aged Oils


t Conservation goes green: Sustainable and "green" cleaning
uids with low impact solvents and surfactants
April
2025
TEAS
Fh [Hydrogen bonding forces]
Fp [Polar forces]
Fd [Dispersion forces]
PC
EL
AC
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EtOH
Iso-P
p-XYL
HX
055

it can work as a glue — but can also work for reinforcing textile like material."

Session 3

The third session began with a talk by Piero Baglioni [see p.108] on new green and sustainable materials for wet cleaning of artworks. Baglioni is Emeritus Professor of Physical Chemistry in the Department of Chemistry at the University of Florence. He discussed using colloids and soft matter solutions like gels and nanofluids "to selectively remove unwanted layers in sustainable and cost-effective interventions." He highlighted "twin-chain" polyvinyl alcohol gels, "which can be loaded with water or different water-based cleaning fluids" and concluded that much can be achieved with these new solutions that is far more difficult to achieve by traditional means.

Next, Bronwyn Ormsby, [see p.118] Principal Conservation Scientist at Tate, London, spoke about real world testing that the institution has been conducting on artworks in their collection. Their research is focused on the works of British painter Bridget Riley, whose paintings from the 1960s are currently undergoing conservation treatment for the first time. The two paintings they are working on are *Fall* (1964) and *Hesitate* (1963). Both are painted on Swedish hardboards using house paints and both have accumulated a layer of "gray yellow" soil which Ormsby said is common to the Tate. Preliminary testing of the gels has proven very effective in removing the soil, Ormsby said, although a complete and final cleaning and assessment has yet to be completed.

Athina Georgia Alexopoulou spoke next about the creation of more user-friendly methodologies for the evaluation of green materials. Alexopoulou is Professor at the Department of Conservation of Antiquities and works of art at the University of West Attica, Athens, Greece. She declared that "the heart of conservation restoration lies in answering critical questions. Did our treatment work? Was it the right approach? Were the appropriate materials used? And what is the impact of our treatment on the project?" Her main emphasis was on the importance of non-destructive methods of analyses prior to restoration, so that objects can be assessed *in situ* using tools such as hyperspectral imaging, colourimetry and glossimetry. These solutions, she notes, "do not require sampling, have quick *in situ* application, do not involve consumables or waste materials, have very low energy consumption as well as the ability of post-processing imaging data."

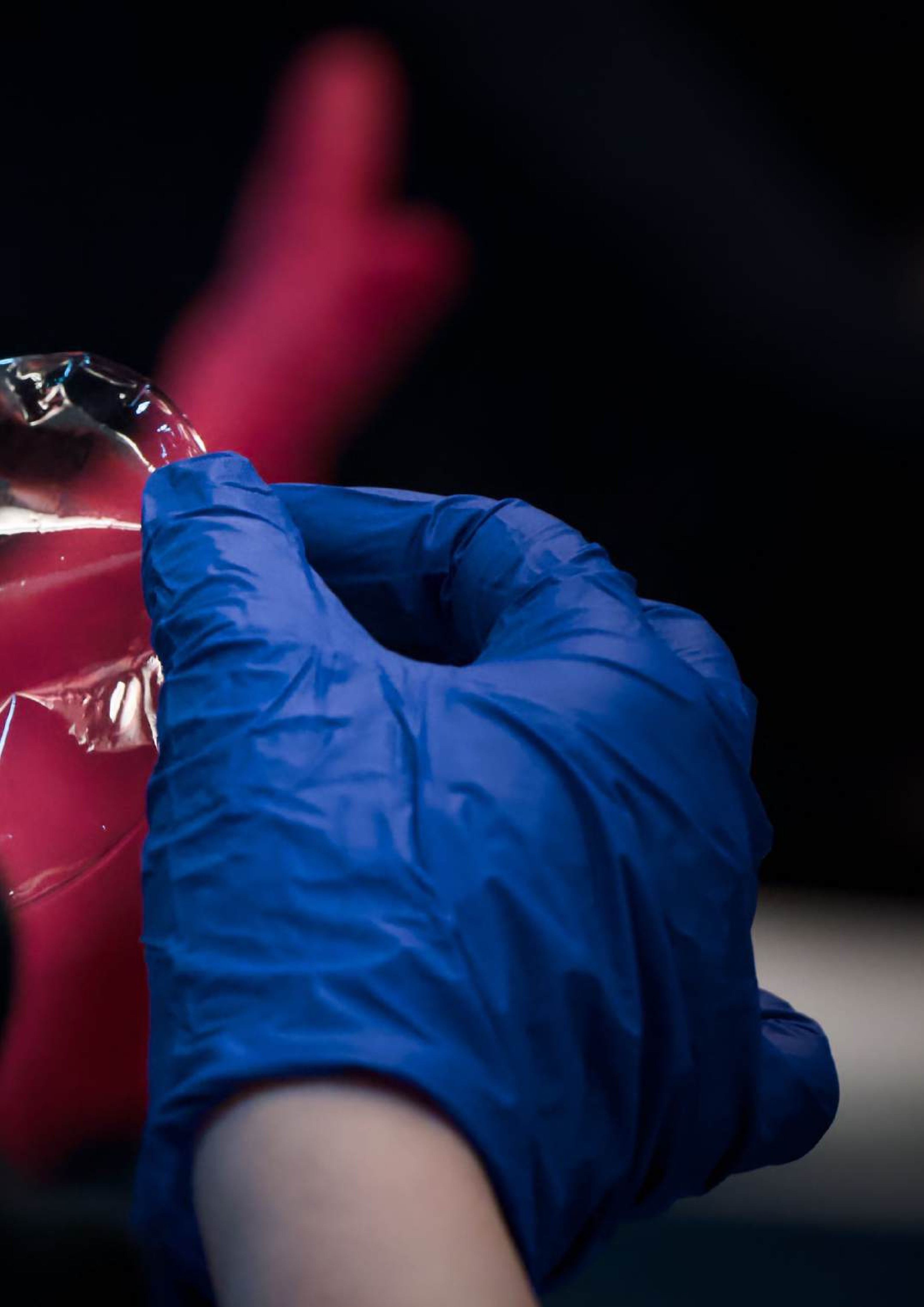
Session 4

Penelope Banou kicked off session four with a talk on varnish removal on works of art on paper. Banou is a lecturer in the MA Conservation of Fine Art program, Northumbria University, UK. Her research centres on a 17th century black and white intaglio print. GREENART's organogels and nanofluids were used in the trials. Her conclusion was that GREENART's organogels were very promising, "because they managed to swell or solubilise the varnish layers adequately to be removed." More testing is needed, she said, on a range of different types of works on paper. [see p.196]

Next, Martina Vuga and Lucija Močnik Ramovš from the Academy of Fine Arts and Design, University of Ljubljana presented [see p.248] their observations on GREENART's cleaning systems for varnish removal. Their trials were conducted on a 19th-century polychrome wooden sculpture and two oil paintings on canvas. They tested GREENART's nanofluids and organogels, using multiple solutions on each artwork, and testing for different durations. Their conclusions regarding the paintings were positive, noting that varnish was successfully removed." For the sculpture, they noted that the GREENART solutions were more time consuming, required more effort and were potentially more damaging to the artwork than traditional solutions.

The final speaker was Soraya Alcalá, head of the paintings conservation lab at the Museum of Fine Arts (MFA), Houston [see p.234]. She delivered an update on her team's use of GREENART's solutions to clean two paintings on unprimed canvases: Kenneth Noland's *Eyre* (1962) and Morris Louis's *Slides* (1962). Her team collaborated with a team at The Peggy Guggenheim Collection in Venice, which had works by the same artists that were experiencing similar conservation issues. The results were positive, she said, but revealed that success depends on how the solutions are applied. "A well-structured protocol is crucial in achieving effective results," Alcalá said.

After the talks, on the second day of the conference, a training session including five workshops was held, during which attendees were able to see the solutions in action and in some cases test the solutions out themselves. Giovanna Poggi [see p.126] led a workshop on green gels for cleaning works of art; Camila Rezende and Camilla Camargos led a workshop on nanocellulose / nanolignin protective coatings and nanocellulose / biopolymer hydrogess; Francesca Boccaccini's workshop dealt with the properties and application of sustainable protective coatings for metal cultural objects; Manfred Anders led a workshop on the integration of sustainable raw materials, novel regulators and sensing devices in archive box production; and Andrea Casini a workshop on sustainable cleaning fluids with low impact solvents and surfactants.



INTERVIEW

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GREENART PUBLIC TRAINING: FROM THEORY TO PRACTICE

During the GREENART Public Training held at the Musée du quai Branly – Jacques Chirac on 10 and 11 April 2025, Éléonore Kissel discusses the challenges of ecological conservation in the art world and the evolution of practices in this field.

She carefully oversees the museum's impressive collection of around 370,000 archaeological and ethnographic objects. Since 2014, Canadian-born Éléonore Kissel has led the Conservation-Restoration department at the Musée du quai Branly – Jacques Chirac in Paris. With a long-standing career as a consultant in cultural heritage preservation, she holds degrees in conservation-restoration and preventive conservation from Paris 1 Panthéon-Sorbonne University, specialising in graphic arts. Her doctoral thesis focused on post-colonial material conservation practices at the museum.

On 10 and 11 April 2025, her institution hosted the GREENART Public Training, an event designed to share the latest developments from this European project. The initiative brings together a consortium of universities, museums and professionals, all working towards sustainable solutions for restoration and preventive conservation. Their aim: to develop low-impact, environmentally friendly materials sourced from renewable natural resources or recycled waste. Éléonore Kissel reflects on two intensive days of conferences and practical workshops dedicated to researching and implementing new materials, technologies and solutions for "green" cultural heritage conservation.

How did you organise this event presenting the outcomes of the GREENART European project?
This training continues the partnership the museum had already established with the European Apache project, which included Antonio Mirabile. Nearly two years ago, Antonio suggested I do something similar for GREENART. What I particularly appreciate about these European projects is their commitment to sharing knowledge freely and openly. I began by formally seeking permission to involve the museum in this venture, to make our facilities and technical resources available. After that, I had to manage every aspect of the organisation: finding dates when the Lévi-Strauss Theatre would be free, handling logistics, preparing the programme, arranging moderation and ensuring communication through the museum's website and social media channels. Compared to the scale of the GREENART project, this commitment remains limited in time, but I accepted it willingly. Organising a day of presentations followed by practical workshops poses a real challenge in a venue like ours, which was never designed for such events. We had to equip the theatre foyer with screens and a dedicated Wi-Fi network, and the security team needed to approve the introduction of external materials into a public building of this size.

— Pierre Naquin and Carine Claude

Did you follow the progress of the GREENART project or did you only get involved for the public presentation?

I focused on outreach and promoting the project to professionals. My discussions with Antonio began about eighteen months ago and I gradually saw the programme take shape. I kept an eye on GREENART's research, but I did not take part directly, as the Musée du quai Branly is not, strictly speaking, a member of the GREENART consortium.

> Material conservation borrows a great deal of knowledge and expertise from other disciplines, and innovations developed specifically for our field remain the exception rather than the rule.
> — *Eleonore Kissel*

Would it have been beneficial for the museum to take a more active role in this project, as other institutions have done?

To join a major European research project, you need to ensure you have enough people to commit. Our team consists of just six members: four in conservation-restoration, one in conservation science and one in preventive conservation. We are already involved in various research projects, usually on a smaller scale. I am not sure we would have had the time to take on more. That said, the Musée du quai Branly team has taken a proactive approach to ecological transition in material conservation for several years now. We have organised public talks and workshops on these issues, and secured funding to work on bio-based packing materials. More broadly, the museum created a Corporate Social Responsibility (CSR) position at the start of 2022, with a full-time staff member coordinating efforts across all teams to adopt more environmentally responsible practices.

For example, my team is deeply involved in a green alternatives project led by the Ministry of Culture, which questions environmental guidelines: should we stick to the traditional standard of a stable climate at 18 degrees and 50% humidity all year round, or can we allow for some flexibility? Meanwhile, the Collections Management team is working on a European project to replace wooden crates for transporting artworks with recyclable cardboard alternatives.

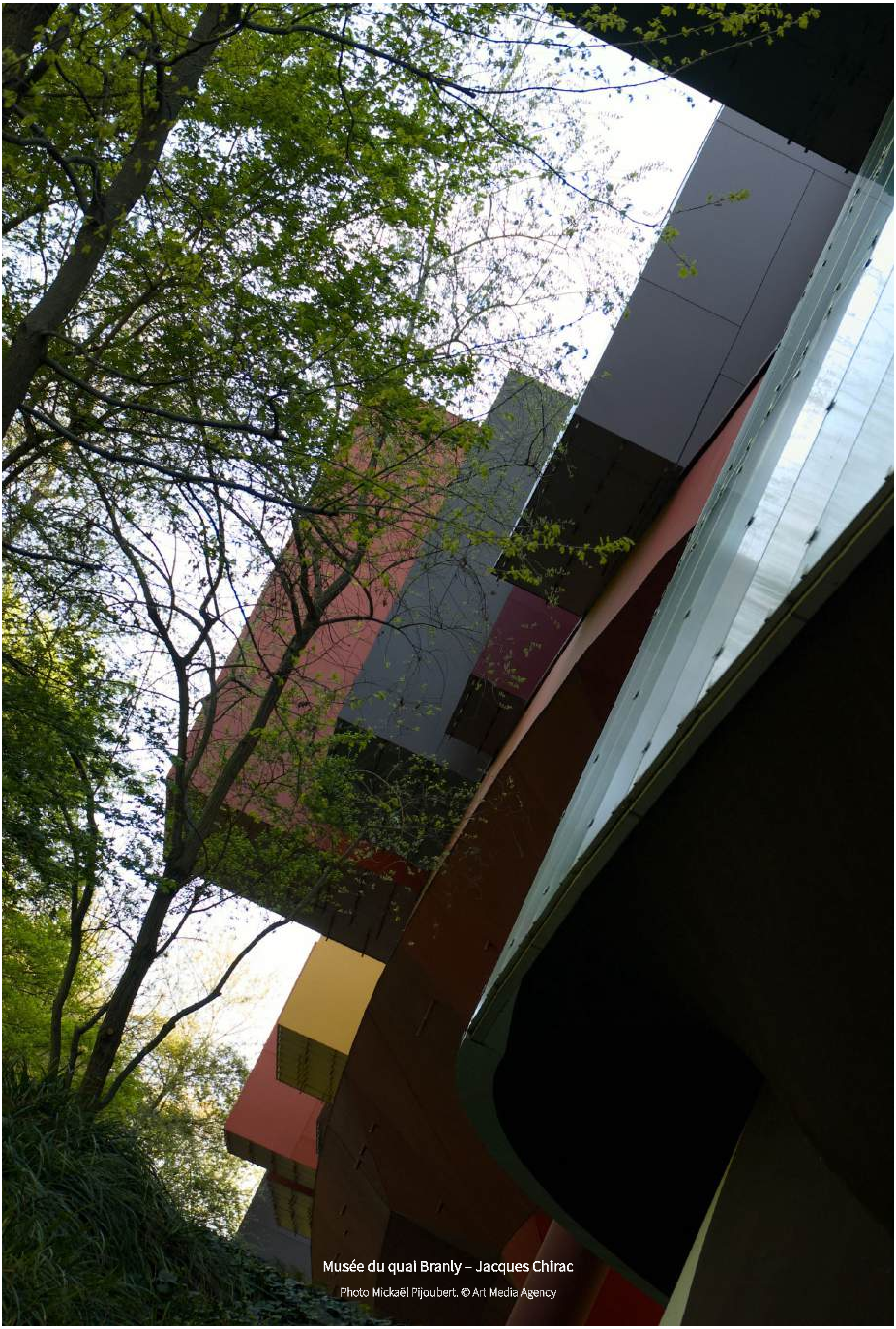
Do you think there is now enough information available on ecological practices in conservation-restoration?

At the end of 2019 or the beginning of 2020, I carried out a literature review on the ecological approach to material conservation, organising the references by theme — climate control, transport and conservation-restoration treatments. Even then, there were already several hundred references and since then, the field has grown exponentially. It has now reached a point where it is difficult to keep up with all the new initiatives and publications. This is precisely where projects like GREENART prove their worth: they help bridge the gap between theory and practice. I can give you a concrete example. We are currently launching a project at the museum focused on the conservation-restoration of metal objects, specifically looking at the shine and brilliance of ornaments, ceremonial weapons and jewellery. In this context, several members of my team attended Gabriella Di Carlo's workshop on innovative and eco-friendly materials for protecting metal surfaces. The timing of this training could not be better and it may offer us a real opportunity for practical application. We are still in the testing phase, but we are considering scaling up what GREENART has developed and applying it to specific collections. Gabriella Di Carlo's team has worked extensively with the bronzes at the Vedova Museum in Venice and we could use their methods on North African jewellery to observe, over the long term, how these materials perform.

GREENART covers a wide range of areas, from transport boxes to cleaning and various types of protective coatings. Were you aware of all these aspects?

I was fairly aware of the different strands of the project: one part focused on conservation-restoration, with both cleaning and protective treatments, and another part on preventive conservation, covering monitoring, storage and pollutant absorption.

I am not sure this structure was as



Musée du quai Branly – Jacques Chirac

Photo Mickaël Pijoubert. © Art Media Agency

clear to all participants in the presentations and workshops, as GREENART is indeed a project with multiple objectives, underpinned by analytical sciences. Personally, because I followed the development of the programme, I had a fairly clear understanding of the different directions.

Had you already tested any of the products developed as part of GREENART?

Not those from GREENART specifically, but we had tried some materials from Nanorestore and exchanged ideas with speakers who led workshops as part of the Apache project — some of whom are also involved in GREENART. For example, Gabriella Di Carlo ran a workshop with us and we also discussed conservation box solutions with Manfred Anders [see p.180].
We were aware of ongoing developments and knew that some aspects of GREENART are entirely new compared to Apache, such as the creation of polyurethane foams from bio-based materials or the focus on the ecological assessment of materials. Others seem more like a continuation or deepening of developments first explored in Apache.

Was there products that particularly interested you during these two days of training?

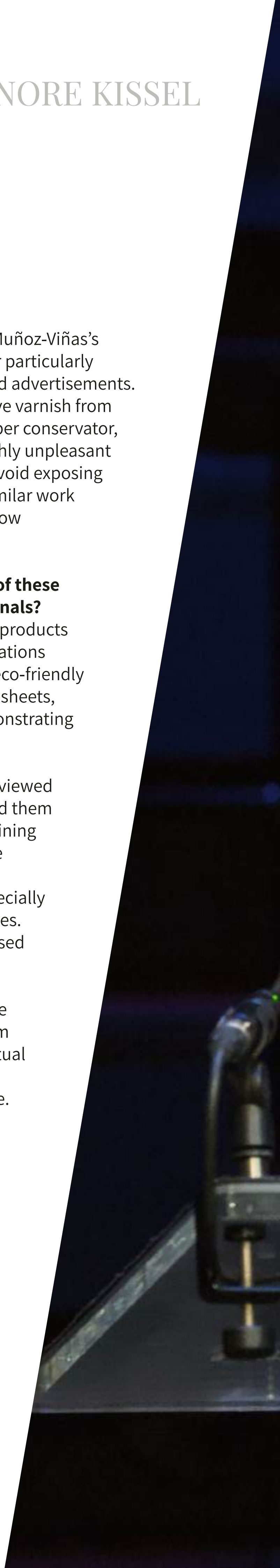
I was especially impressed by the coatings for metal objects that can be reversed using very low-toxicity solvents like water or ethanol. The nanocellulose-based coatings also caught our attention. On the other hand, dispersions for consolidating encaustic paintings are less relevant for our collections.
Each participant found different aspects appealing, depending on the specificities of their collections.
Some of my colleagues, for instance, found Salvador Muñoz-Viñas's presentation on mounting systems for works on paper particularly interesting as they work with collections of posters and advertisements. Pénélope Banou's presentation on using gels to remove varnish from works on paper also stood out for me. As a trained paper conservator, I remember having to treat a varnished print using highly unpleasant solvent baths, which meant working at weekends to avoid exposing colleagues to toxic fumes. If we ever need to treat a similar work among the museum's 10,000 graphic pieces, I would now consider the solution presented by Pénélope Banou.

What steps are necessary between the development of these products and their widespread adoption by professionals?

A combination of factors needs to come together. The products must be developed and supported by scientific publications that explain their properties. If a manufacturer offers eco-friendly consolidants but refuses to provide full technical data sheets, or if there are no comparative laboratory studies demonstrating their effectiveness, penetration and reversibility, it becomes difficult for us to adopt them.
Ideally, these products should be published in peer-reviewed journals (A-grade), ensuring that experts have assessed them and can highlight any methodological flaws. Then, training sessions like the GREENART workshops allow us to see these materials in practical use on sample objects.
Then comes the question of product accessibility, especially for public institutions bound by strict procurement rules. It is much easier to purchase a product from a recognised supplier in the conservation-restoration sector than directly from a university laboratory.
Finally, you need a motivated team willing to test these innovations and a project that allows you to move from the laboratory context to real-world application on actual objects. This requires a certain level of trust, as well as the ability to monitor how treatments evolve over time.
For example, we are considering testing the coatings developed by Gabriella Di Carlo's team on five North African jewellery pieces that will go on display, alongside more traditional techniques. This will allow us to observe their behaviour on a daily basis.

Is it common to test new products in your field?

It is relatively rare. Conservation-restoration is a niche market, with few scientific developments dedicated exclusively to this sector. Most of the products we use — resins, boxes, pollutant sensors, insect traps, disinfectants — were originally developed for other fields, such as medicine, the food industry, or manufacturing. The first vibration sensors, for example, came from the construction industry.



Éléonore Kissel

Photo Mickaël Pijoubert. © Art Media Agency

GREENART's public training session in Paris

Photo Mickaël Pijoubert. © Art Media Agency

DISCUSSION

Photo Felipe Callado

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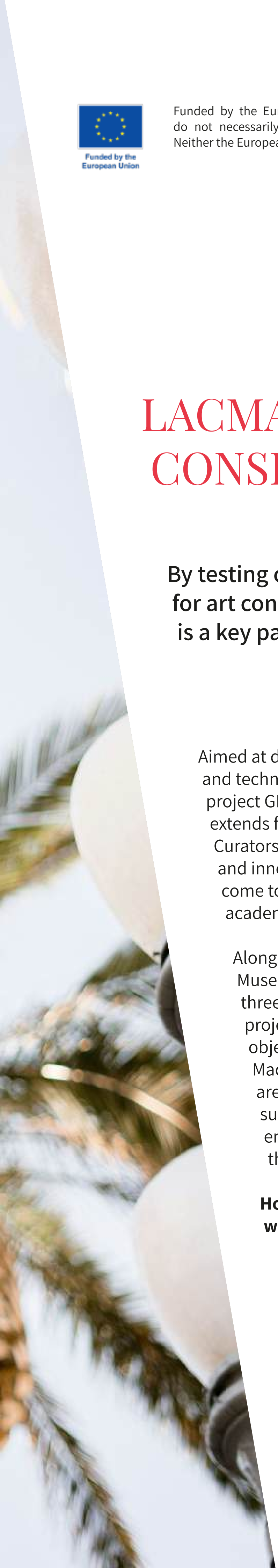


LACMA: A PIONEER IN SUSTAINABLE CONSERVATION WITH GREENART

By testing cutting-edge, eco-friendly, and sustainable nanomaterials for art conservation, the Los Angeles County Museum of Art (LACMA) is a key partner in the European GREENART project.

Aimed at developing sustainable and ecological materials and techniques to preserve cultural heritage, the European project GREEN Endeavor in Art Restoration (GREENART) extends far beyond the borders of the European Union. Curators, scientists, art conservators, researchers, experts and innovative companies from around the world have come together in this collaborative consortium, thanks to academic and scientific partnerships with 28 institutions.

Alongside the Metropolitan Museum of Art and the Museum of Fine Arts in Houston, LACMA is one of only three American museums involved in this European project. Within this major Los Angeles Museum, objects conservator Jessica Chasen, head scientist Laura Maccarelli and conservation-researcher Chiara Biribicchi are contributing to the development of innovative and sustainable cleaning and packaging materials. These environmentally responsible practices aim to reduce the ecological footprint of art conservation.

How and when did you initially got involved with the GREENART project?

Laura Maccarelli (LM): In 2019, Diana Magaloni, Senior Deputy Director, Curator, and Director of Conservation, invited Professor Baglioni to give a lecture to LACMA's conservation centre team on the nanomaterials developed by CSGI. During his visit, Professor Baglioni also toured our laboratories, offering insightful suggestions on how to perform tests using these nanomaterials. Following his visit, the Mellon Fellow in Paintings and Textiles at LACMA began preliminary testing of the gels on two specific case studies. The first was a textile case study involving a *thangka* [a Tibetan Buddhist painting, editor's note] that had suffered extensive dye bleed due to past flooding. The second was a painting by Ernst Ludwig Kirchner, which had been coated with varnish during a 1970s conservation treatment, despite the artist's well-documented preference for matte, unvarnished surfaces. This initial testing led to an extensive exchange of emails between our team and Professor Baglioni's group as we worked to refine the application of these materials. I believe that this collaboration demonstrated our strong interest in and capability to work with these innovative gels. As Professor Baglioni and his colleagues were developing the GREENART project, they likely saw LACMA as a valuable partner for the beta testing phase, given our prior experience and engagement with these materials.

— Pierre Naquin and Carine Claude

As a non-EU partner, how do you "benefit" from the project?

LM: For LACMA, there is no direct financial or institutional benefit from participating in the GREENART project. However, our involvement allows us to test innovative materials, ensure their safety for use in the art world, and contribute to the development of guidelines for their application. LACMA is deeply committed to sustainability, recognising that museums, as custodians of cultural heritage, should play a leading role in driving positive change. Projects like GREENART and CRAIT — our Institute of Museum and Library Services (IMLS)-funded initiative focused on sustainable materials for art transportation — are essential for advancing more environmentally responsible practices in the field. By engaging in these projects, we aim to help shape a more sustainable future for conservation and museum operations worldwide.

With what Work Packages are you involved?

Chiara Biribicchi (CB): LACMA is involved in Work Package 2 (Cleaning) and Work Package 4 (Consolidants and Packaging Materials). For Work Package 2 we are testing organogels, focusing on the ECO-systems developed by CSGI [Consorzio interuniversitario per lo sviluppo dei Sistemi a Grande Interfase, Interuniversity Consortium for the Development of Large Interface Systems, an Italian research organisation affiliated with the Chemistry Department at the University of Florence, editor's note] in combination with specific solvents. Additionally, we are working with hydrogels based on Polyvinyl Alcohol (PVA) and various acids, including succinic acid (PVA-SU), salicylic acid (PVA-SA), and adipic acid (PVA-AD), alongside PG PLUS 3 and Peggy 5 and 6, which are CSGI nanogels developed during the Nanorestart EU project. All the hydrogels are being tested with both standard water-based solutions and new nanofluids based on diethyl ketone, provided by CSGI, and compared to more traditional hydrogels, such as agarose and a blend of xanthan gum, agarose and konjac. We are testing the cleaning materials on two different case studies. The first is a soffit [architectural element, editor's note] from a *Damascus Room* (polychrome wood, 1766-1767), which exhibits surface dirt accumulation, and potential degradation of its polychrome layers. The second case study is a Tibetan cabinet, which presents a complex stratigraphy of paint layers and coatings, requiring a careful and controlled cleaning approach.
For Work Package 4, we are evaluating the effectiveness and suitability of newly developed sustainable packaging materials for conservation use. Our primary focus is on the newly developed packaging material and absorbers, which shows promise for preserving deteriorating plastics.
For this part of the project, we selected a deaccessioned work by László Moholy-Nagy. The object is made entirely of cellulose acetate, a well-known problematic plastic that, when degrading, emits a characteristic vinegary smell due to off-gassing. The goal is to have the volatile organic compounds (VOCs) released by the object absorbed by filters incorporated into archive boxes made of sustainable raw materials, preventing them from spreading to other objects in the collection.

Why did you choose those works and on which criteria?

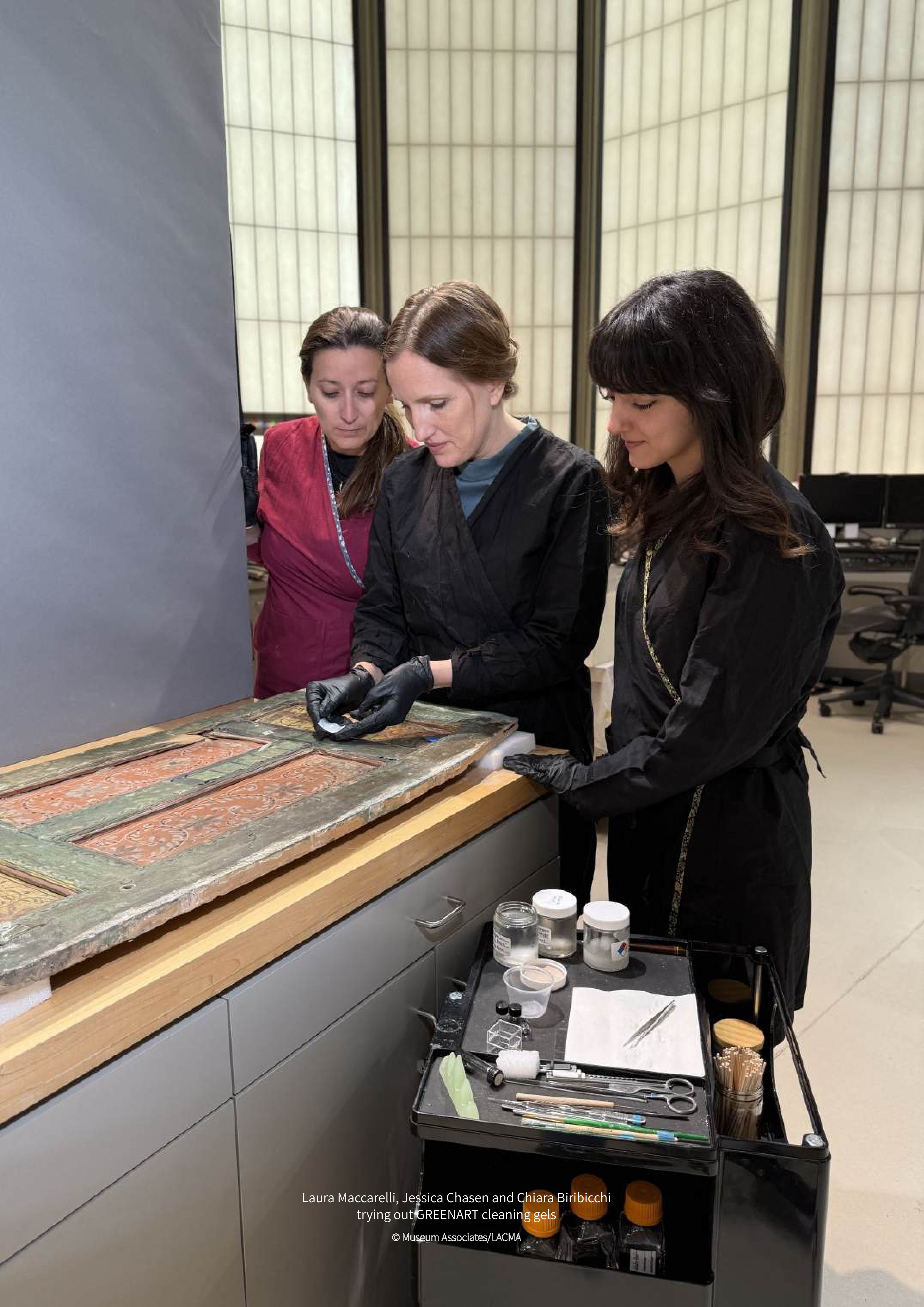
Jessica Chasen (JC): We chose these works based on their anticipated installation in the David Geffen Galleries, set to open in April 2026. As part of the preparation for display, the objects will undergo conservation treatment. Cleaning is a crucial step in this process to improve their readability and ensure they are presented in their best possible condition while preserving their historical integrity. These two three-dimensional objects with their water-sensitive paint surfaces represent a common challenge conservators face. Aqueous solutions are typically the most efficient for cleaning, but they can also risk compromising the original paint layers and porous wood substrate. Therefore, finding ways to contain these solutions to the surface interface is essential for safe and effective cleaning. While similar materials have been tested on modern painted surfaces, highly dimensional nature of these types of surfaces, combined with their complex histories, provided a new avenue to explore the versatility of the newly developed materials.

> The green aspect of these products is very important to both LACMA and our conservation team, as we work toward integrating more sustainable practices into our work. At LACMA, we believe that museums should lead by example in the shift toward sustainability, which is why we are involved in projects like GREENART and CRAIT.
> — *Laura Maccarelli*


Laura Maccarelli
© Museum Associates/LACMA

Damascus Room, Syria, Damascus (AD 1766-1767), AH 1180, Los Angeles County Museum of Art.

Conservation of the room was organised in partnership with King Abdulaziz Center for World Culture; additional conservation support was provided by the Friends of Heritage Preservation.



Laura Maccarelli, Jessica Chasen and Chiara Biribicchi trying out GREENART cleaning gels

What are you evaluating and what is your evaluation process?

CB: The two case studies require different types of evaluations based on the specific needs of the object. In both cases, we have conducted preliminary assessments of the cleaning efficacy of various fluids. Afterward, we selected the best fluids and tried to incorporate them into hydrogels and organogels. For the soffit panel of the Damascus room, we chose to first evaluate the spread effect of the hydrogels to select those with the least spread effect for use on a water-sensitive object like the Soffit panel from the Damascus Room. In addition to these tests, we performed handling assessments to evaluate the hydrogels' ability to adapt to surfaces in relief. For the Tibetan cabinet, the evaluation process focuses on the cleaning system's ability to remove the layer of wax on the surface while preserving the underlying paint and varnish. To achieve this, we tested both nanofluids and selected organic solvents, both as neat fluids and in combination with hydrogels and organogels. The aim was to assess whether the gel system could reduce solvent release, thereby minimising the risk of damaging the underlying paint. As with the previous case, we also evaluated application times and considered the effects of repeated application cycles. For both case studies, different analytical techniques, such as technical photography in visible light and ultraviolet fluorescence, digital microscopy, spectroscopy and elemental techniques, will be used to assess cleaning efficacy and eventual varnish or pigment pickup. Results will be summarised in a star diagram.

With which universities are you interacting with?

CB: We are in constant contact with CSGI (Consorzio interuniversitario per lo sviluppo dei Sistemi a Grande Interfase), collaborating closely to refine and evaluate materials. Over the past month, we have held weekly meetings to discuss the testing of organogels loaded with fatty acids for the removal of a wax layer from the Tibetan cabinet. Both CSGI and LACMA are conducting tests to determine which solvents are most suitable for specific gel formulations. Our feedback focuses on several key aspects: solvent compatibility, assessing which solvents work best with different types of gels; Loading efficiency, evaluating how long the gels need to be infused with solvents for optimal performance and Gel behaviour, observing changes in release rate, malleability, and overall handling after solvent loading. Based on the partners feedback, CSGI refines and updates the formulations, providing us with new versions of the organogels for further testing. This iterative process helps ensure that the materials perform effectively in real conservation scenarios.

Can you tell us about some of your experiences of the products you tested?

JC: We compared the spread effect of different hydrogels and found that the fluid release is much more gradual compared to traditional gels. This is particularly important as it combines gradual release with flexibility and surface conformity, which traditional rigid gels achieve by using lower concentrations of gelling agents, resulting in faster release. With organogels, we observed that they perform well on flat surfaces with solvents of medium volatility, across a wide range of polarities, which is especially important because gels with these properties are lacking in the conservation field. Both hydrogels and organogels allow for gradual release of the encapsulated fluid, thereby minimising the conservator's exposure to solvent vapours and their release in the environment. These gels allow us a whole new level of control, enabling us to carefully tailor our treatments to meet a wide range of challenges often presented by a single object.

LM: The green aspect is essential. However, sustainability needs to be balanced with efficacy, ease of use, existing conservation know-how, and practical considerations such as cost and accessibility. While we fully support the development of greener conservation materials, their cost and availability can sometimes be a challenge, especially for institutions outside the EU. Many of these materials are still in development, and as with any innovative technology, they can be more expensive than traditional alternatives. Additionally, international shipping means that purchasing materials from the EU is not entirely carbon neutral, which is an important factor to consider when assessing their overall sustainability. For these greener materials to be widely adopted, it is important that they perform effectively, offering results that are comparable to or better than conventional materials; that they are practical to use, fitting seamlessly into conservation workflows; that they remain financially accessible, so that institutions of different sizes and budgets can incorporate them and that they consider the full environmental impact, including their production, transportation, and disposal. This is why our collaboration with CSGI is so valuable. Through testing and real-world application, we provide feedback to help refine these materials, ensuring that they meet both conservation and sustainability goals in a way that is practical for the field.

Are you participating in other international projects?

LM: At this stage, we are not participating in any other EU projects. LACMA is an exhibition-driven museum, which means that dedicating time to research can be challenging due to other institutional priorities. Additionally, the lack of funding for non-EU partners places an added strain on our budget, which often needs to be more exhibition focused. However, we do engage in other international research collaborations, which differ from EU-funded projects in terms of structure, funding models, and institutional priorities. While EU projects emphasise large-scale, multi-institutional collaboration with a strong focus on sustainability and knowledge sharing, other international partnerships are often more flexible, tailored to specific research questions and dependent on external grants or institutional support.

Will you be interested in participating in follow-up projects?

LM: We are always open to engaging with new projects; however, we have to carefully consider time and budget constraints with each new commitment. While we are certainly interested in learning about potential follow-up projects, we would need to evaluate internally whether we have the necessary resources to commit to another iteration of the project. Given LACMA's exhibition-driven priorities and budget constraints for non-EU partners, our participation would depend on the project's alignment with our institutional goals and the availability of funding and staff capacity.

Analysis of an altar table with auspicious symbols (19th century), Los Angeles County Museum of Art

FOCUS

Half (1959), Kenneth Noland

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MFAH TESTS GREENART PRODUCTS ON RAW CANVAS

Conservators at the Museum of Fine Art Houston are putting GREENART's sustainable cleaning products to the test on mid-century paintings on raw canvas.

EU's GREENART Project is, at its core, a case of research in action — expert scientists working in labs to develop new, ecologically sustainable products for the conservation of cultural heritage. But what makes GREENART unique is that its story does not end at the research phase. The project's goal is to develop products that can actually be introduced to the market. To have relevance within the global art conservation field, these products must not only be environmentally friendly, but they must also be as effective or more effective than the non-sustainable products already in use — some of which have been embraced by conservators for centuries.

Real-world product testing is therefore crucial to the GREENART project. Rather than relying on in-house testers or institutions that are also receiving funding from the EU, GREENART made the decision to invite multiple independent institutions around the world to test their products. Some of these institutions, in particular, have no financial or political stake in the project, so are free to give honest, direct feedback about whether their products work or not. The scientists at GREENART can then use that feedback to make their products as good as they can be.

Soraya Alcalá is a Conservator of Paintings and head of the paintings lab at the Museum of Fine Arts Houston (MFAH) in Texas and through her existing relationship with the Center for Colloid and Surface Science (CSGI), the MFAH Conservation Center became involved with the GREENART project. The interest in CSGI's work on clearing gels — specifically developed for the unique needs of art conservation — aligned with the MFAH team's commitment to exploring innovative, conservation-focused materials. Unlike traditional materials often borrowed from other industries, these gels were designed with the complexities of cultural heritage in mind.

MFAH is involved in several work packages, focusing on the assessment of new cleaning, consolidating and coating formulations. Something she appreciates about the way the project leaders have approached the testing phase, is that the museum was asked to take the lead. "The project leaders asked, 'what problems do you have?'" Alcalá says.

MFAH team thus set out to find conservation problems they were currently facing. This was no easy task. MFAH is an encyclopaedic museum, meaning they have items from all over the world that span more than 5,000 years of art-making. They ultimately decided to focus on how to clean paintings executed on raw canvas. They chose to start with a selection of works by Morris Louis and Kenneth Noland.

— Pierre Naquin and Phillip Barcio

Louis and Noland were early protagonists within a mid 20th century movement called the Washington Color School. They copied a technique innovated by Helen Frankenthaler known as "soak-stain". It involves allowing pigments to soak into canvas that has not previously been treated with gesso or another priming layer. Soak-stained paintings almost take on the aesthetic of watercolours on paper. The paint essentially stains the surface, becoming integrated with the fibres in a way that is fundamentally different from paintings on gessoed canvases.

"We had a very complex case study, Alcalá says. The cleaning of raw canvas is an issue that a lot of other institutions have too and there is currently no product on the market that can help achieve the desired result."

MFAH team — Per Knutås, Head of the Conservation Department; Silvia Russo, Conservation Scientist; and Soraya Alcalá — collaborated with the Peggy Guggenheim Collection GREENART team, including Luciano Pensabene, Head of Conservation, and Maria Laura Petruzzellis, Paintings Conservator, to create a series of mock-ups for parallel testing. The goal was to determine which combination of gel and cleaning fluids was most appropriate for this case study. By conducting the tests simultaneously, we were also able to assess the influence of the individual conservator as a variable in the cleaning treatment.

MFAH created mockups as diligently as possible so they were true to the original works, using old canvases and paints from the era. "But there were still challenges, Alcalá says, because even if you can replicate the original artwork, it is impossible to copy the exact types of degradation that the painting has gone through over more than half a century."

"After a thorough and systematic series of tests on mock-ups, we had enough information to begin testing on the original work — starting in a discreet area, such as the tacking edges of the painting, Alcalá explains. It was still a daunting process, especially at the beginning, since we were not yet familiar with the new products. CSGI was looking for our most honest feedback so they could refine the materials to perform at their best. We carried out the tests, assessed the results and shared our observations with them. They responded by saying, 'Okay, we can improve this aspect or that one.' Based on our input, they are now working to further adapt the materials to meet our specific needs."

"One of the biggest questions we kept coming back to, says Alcalá, was what does 'green' even mean in this context?"

It is not a simple answer. The definition of "green" is still evolving, and within the project, a specialised group of experts in Life Cycle Assessment (LCA) is working through a detailed protocol to measure the environmental impact of these new materials. "So, it is not just a label — we are trying to base these decisions on data," she explains.

At the same time, there is a practical side to all of this. Many of the materials conservators rely on have been in use for decades, even centuries. They might not be perfect and they were not necessarily designed for conservation, but conservators know how they behave. "It takes time — and a lot of testing — for a conservator to feel comfortable replacing something they trust with something completely new," Alcalá says.

Still, the motivation is there. "Not only there is a shared understanding of the importance of achieving more sustainable and safe conservation practices, but everyone involved in this project came in knowing that if we want things to change, we have to be part of that change," she adds. "It is not just about accepting new materials—it is about helping design them so they actually meet our needs and our standards."

So in other words, regardless of how the term "green" is precisely defined, the philosophy behind sustainability is inherently important to people in the art conservation field. That is their professional *raison d'être* — to sustain cultural heritage for as long as possible. So if the new products are indeed more environmentally friendly, conservators who otherwise might have been reluctant to switch will adapt simply because it fits the underlying philosophy of their work.

Alcalá has seen firsthand the willingness of other conservators to get behind the idea of sustainable products. She has participated in numerous workshops and presentations that have attracted hundreds of conservators from around the world. She says the participants are showing a high

> "We, as cultural heritage conservators, must not just acknowledge the issue but actively embrace sustainable thinking and work practices. It is not just a professional statement; it is a commitment that the conservation community needs to embrace to the extent of its possibilities.
> — *Soraya Alcalá*

Soraya Alcalá

Courtesy Museum of Fine Art Houston

Per Knutås carefully sampling a stained area
of the canvas from painting *Slide* by Morris Louis

Courtesy Museum of Fine Art Houston

degree of enthusiasm and curiosity, which reveals another fascinating change in the contemporary conservation field.

“There are, she points out, innumerable different surfaces and products that have been used by artists over the millennia. Yet, there have been almost no products developed especially for conserving those materials. Historically, art conservators have developed their products and tools from within the field, and mostly learned their craft from more experienced mentors, who sometimes seem almost like the protectors of a mysterious library of esoteric knowledge.”

“GREENART, she says, is directly challenging that old way of doing things. The craft part of conservation is still vital as is mentorship from conservation experts. But there are now more scientists taking an interest in the conservation field, using a more academic approach to studying their tools and techniques.”

“This is positive for many reasons, Alcalá says. It gives conservators a more research-based, and thus louder, voice within their institutions; it connects institutions around the world who can now more openly trade knowledge and experience; and most importantly it creates opportunities for the conservation field to take the lead in the wider culture, towards a more sustainable future.”

As Alcalá has stated, “We must not just acknowledge the issue but actively embrace sustainable thinking and work practices. It is a commitment that the conservation community needs to embrace to the extent of its possibilities. It is incongruous for me to spend my professional life trying to slow down the degradation of human artefacts, testimony of our culture and history of humanity and at the same time deny the care of the planet. Museums, as cultural and educational institutions, have the potential to be leaders in implementing more sustainable practices and showing more care for the planet.”

Lucija Močnik Ramovš

Courtesy Université de Ljubljana

Paintings conservation at MFAH

Courtesy Museum of Fine Art Houston

Metropolitan Museum of Art
Courtesy Metropolitan Museum of Art

Photo Engin Akyurt

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GREENART

THE MET PARTNERS WITH GREENART

The departments of Textile Conservation and Scientific Research at the Metropolitan Museum of Art have been testing GREENART's sustainable cleaning products on selected pieces from the museum's textile collection.

"Textiles offer one of the most challenging substrates to work with for an art conservator," says Dr Janina Poskrobko, Conservator in Charge of the Department of textile conservation at The Metropolitan Museum of Art in New York (The Met). One of the world's premier art museums, The Met manages a permanent collection of around 1.5 million objects. Its Textile conservation department, which Dr Poskrobko oversees, cares for around 36,000 objects. Most of the challenges involved in preserving and conserving that collection relate to the inherently complex nature of the textile medium, Dr Poskrobko says.

Textiles exhibit a richness and complexity of weave structures, fibres, textures and surface finishes, and are often diversely decorated with addition of other materials, such as metal thread, glass beads, leather or layers of *appliqué*. Textiles are often delicate and typically unsupported, so they can be a fickle substrate to work on and thus need extra attention during handling. Special care must be taken if there is a patina (or multiple patinas) which needs to be preserved. The textiles' fragility and sensitivity to light and humidity require highly sophisticated and scientifically complex protocols for storage, exhibition as well as conservation treatment. A particular cleaning method, such as gel or solvent might be effective in treating those different surfaces. One of the challenging factors in treating these complex pieces involve opening historic stitches, which makes it difficult to perform treatments from the underside. Maintaining historic integrity is a critical choice and a tough call for conservators and curators alike that involves many discussions and analyses before a final determination is made.

"What makes a textile conservator's work even more challenging is the fact that textiles are water sensitive materials," add Giulia Chiostrini, Met's point conservator for the GREENART International coordinating committee.
"Each textile conservator must identify the nature of the material to remove before selecting the most suitable cleaning treatment. This identification is based on analysis done at the Met by research scientist Adriana Rizzo, who is collaborating with the team of conservators in the project. The analytical results inform about possible cleaning solutions and their efficacy beyond visual methods.

In the effort to promote sustainability in the field the museum's mission is to improve and use the best green conservation methodologies possible.

— Pierre Naquin and Phillip Barcio

European Union's GREENART project was initiated precisely to address this ubiquitous problem. The project's goal is simply stated: to develop and bring to market sustainable products for the conservation of cultural heritage. But to achieve such a simple goal is, like the textile medium, unimaginably complex. Among the biggest complications GREENART faces is the reality that art makers follow no rules. Every item in a particular museum's collection could be unique in its material makeup. So to be successful, GREENART must first consider the wide range of art making materials and processes, and then what products conservators are currently using to clean them. Then they must formulate replacement products that can work in a multitude of circumstances and be easily and quickly modified to adapt to variations encountered in the field. The products GREENART creates must be as good or better than whatever conservators are currently using, or the historically cautious field will be reluctant to adapt. Finally, they must qualify as being "green", a designation for which no universally agreed upon definition exists.

The Met is one of several important international museums that agreed to test GREENART's formulations on the irreplaceable objects in their collections. GREENART's methodology, meanwhile, is not to simply ask these institutions to test whatever formulations the project's scientists are already developing. Rather, they ask the museums to bring them their most complicated conservation problems. GREENART's scientists then send specific formulations engineered for those scenarios for the conservators to test.

As Giulia Chiostrini has explained, The Met's conservation team decided to focus their testing on textiles because even within the already complex realm of art making, the textile medium is one of the most diverse. In addition, there is a philosophical debate that frequently arises in the textile conservation field that renders conservation even more nuanced. The issue is whether conservation or repair of a particular textile might jeopardise the historical or aesthetic value of the work. "We must collaborate with curators and exchange information about the technical aspects of the textile under discussion as well as its cultural context. For example, following our discussion we agree that a wax deposit on an ecclesiastic vestment is representative of the original artwork's function. As a result, the deposit on the vestment will not be removed exemplifying our understanding that the identity of the artefact is of primary importance. So again, the secret is to find solutions that address the complex world of textiles. The nanotechnology approach seems to be promising in achieving both: new and green methodologies."

The Met has been working with GREENART's Work Package #2, the one presenting cleaning nano gels products. Among those, the Met team has tested GREENART's microemulsions, hydrogels as well as organogels. "First of all, just the fact that they can provide new, more sustainable solutions that we can experiment with in different ways was important." "We can add water or different solvents. It is a new paradigm that we are interested in investing our time in, to find more consistent and effective local cleaning solutions that are different from the traditional gel applications." The goal is to find what is going to be the most versatile. "We also want to know what we can treat *in situ*, right in the gallery," she says. "Conservators are all about making the treatment faster and smoother. So the practicality of using one single gel on a three dimensional object without moving it would be a significant improvement."

Like the project's other museum partners, the Met's conservation team is meanwhile engaged in a back and forth with GREENART's scientists, with conservators providing specific feedback about how well the formulations are performing; and GREENART modifying their formulations so they can be tested again and further improved. "Last December we had the first meeting," Chiostrini says. "We discussed our case studies and they gave us some suggestions. We shared our opinions and offered honest assessments about what does and does not work. Our approach is always collaborative with the goal of improving and refining our current practices. Importantly, our feedback is valued — it is a true partnership in the development and testing of new formulations.

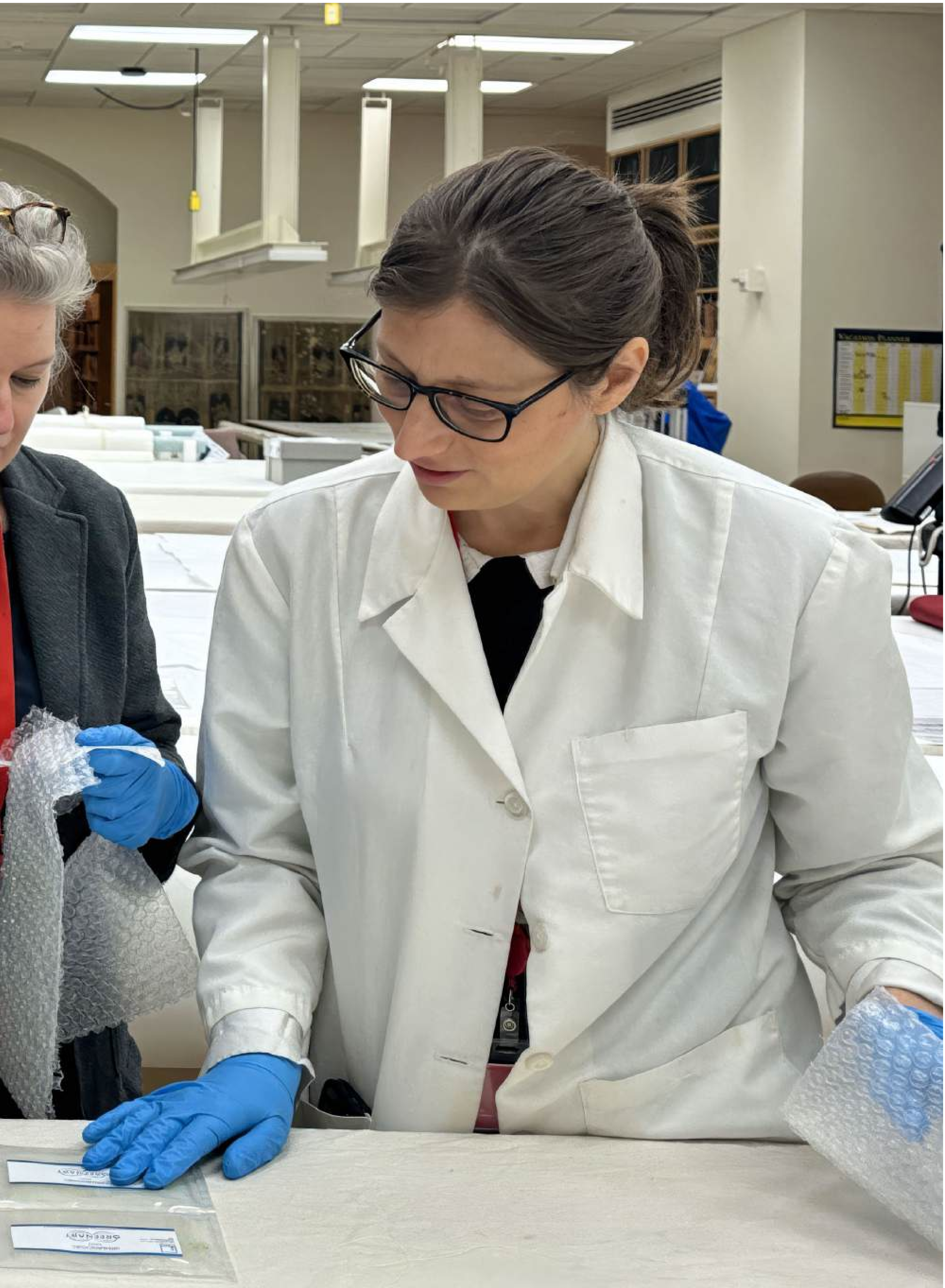
"Eventually, says Dr Poskrobko. There is still much more testing to be done before these products are available on the market. We are satisfied with the results we have attained to date. The Met, the institution we represent, is committed to the development of the best sustainability solutions and practices and supports this joint endeavour. We are proud to contribute to GREENART's goals and Met's Strategic Plan goals of improving environmental sustainability, in collaboration with a team of renowned scientists and conservators. We have learned a great deal and will continue to expand our knowledge in our association with this exciting research".

Dr Janina Poskrobko testing Hydrogels on a velvet panel

Courtesy Metropolitan Museum of Art

Dr Janina Poskrobko, Giulia Chiostrini and Adriana Rizzo

Courtesy Metropolitan Museum of Art



Martina Vuga

Courtesy University of Ljubljana

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OBSERVATIONS ON GREENART'S NEW CLEANING SYSTEMS FOR VARNISH REMOVAL

Conservators with the University of Ljubljana have been testing the effectiveness of GREENART's gels and nanofluids on the removal of natural varnish from paintings and wooden sculptures.

GREENART's new art conservation solutions are being formulated with ecological sustainability in mind. By the time a solution is sent out from the lab for real world testing, it already meets that standard. The professional conservators enlisted to test the products then have a host of their own standards they expect these new solutions to meet. For example, they need them to be at least as effective as existing products on the market and at least as affordable and shelf stable — otherwise how could they convince their institutional employers to adapt?

At GREENART's public training in Paris on 10 and 11 April 2025, Associate Professor Lucija Močnik Ramovš and Assistant Professor Martina Vuga, both from University of Ljubljana in Slovenia, delivered a talk sharing the results of their ongoing testing . The pair has been working with GREENART's Work Package 2 which produces new green nanofluids and organogels since October 2023. "I was always interested in what is going on behind the scenes, understanding materials, says Ramovš, so this project was something I was really looking forward to. In theoretical ways it is interesting, because it combines chemistry with our conservation work. It is helping us understand the behaviour of materials. The more we test these products, the more we understand."

Their main focus was on varnish removal, so they specifically looked for older artworks to test the products on. They sought pieces that showed significantly altered varnish appearances, with a suitable varnish thickness on relatively stable painted surfaces. They looked at ease of preparation of the new cleaning solutions, ease of application, adaptation of the solutions to the surface of the various artworks, ease of removal of the products and the effectiveness of the products in removing varnish from the artworks. Specifically, their testing centred on removal of natural varnishes from a 19th century polychrome wooden sculpture and two oil paintings on canvas.

"For the paintings, we tested the various materials on similar surfaces, making comparisons of different gel systems, Ramovš says. We tested various application times. Many materials were successfully used. There was no universal solution. For example, two paintings may have the same type of varnish applied to the painting with the same binder, but the effectiveness of the system may be different." Their conclusions regarding GREENART's cleaning solutions on the paintings were largely positive — for the most part the varnishes were successfully removed.

For the sculpture, however, they had more mixed results. "Of course, there are different challenges when working with 2D and 3D objects,

— Pierre Naquin and Phillip Barcio

Vuga says. With paintings, the surfaces are generally flat, making gel application relatively straightforward. In contrast, 3D objects present greater challenges in terms of the flexibility and adaptability of the gels needed to ensure proper contact. That said, similar difficulties can also arise with heavily textured or *impasto* paint layers on 2D surfaces."

"A common problem I see in sculptures is overpainting, says Vuga. Removing overpaint is very difficult with traditional materials." The sculpture she selected had a surface with a particularly complex structure caused by deep brush marks. Layers of varnish had accumulated in the low spots of the brush marks. There was also gilding, so in the end the overpainting was really thick. The polychromatic surface further complicated the process. "I thought maybe if I applied these new cleaning materials for several hours they could do something," Vuga says. But in the end it was clear that GREENART's cleaning solutions were insufficient in this particular test case. They were more time consuming to prepare and apply than existing products and they showed signs that they could potentially cause damage to the sculpture's surface.

Ramovš and Vuga also have thoughts about the shelf life of the products and how the solutions are being packaged. "The gels have limited time use, Ramovš says. That means you cannot afford to buy a lot of these materials if you do not think you are going to use them quickly." After the use-by date, the materials would have to be thrown away, so even if they are more "green" in the beginning, that designation goes away once they perish. "If they only last for a year and then are also packaged in plastic, you have to think about that, too," she says.

A collective effort

The beauty of GREENART's testing process is that researchers are keen to receive what could be called "negative feedback" from real world testers. These reports are not the end of the process, but simply the next phase. Constructive back and forth has been part of the project from the start of each collaboration. For example, at the start of their relationship with GREENART, Ramovš and Vuga had ideas about the specific challenges they faced in their conservation work. "I had in my mind what would be possible with the problems we have, Ramovš says and asked the scientists if they could suggest solutions to us."

"We had many meetings before we received the materials and had many questions about them afterward, Vuga adds. I had questions about the stability of the organogels and hydrogels, so we asked questions and were prepared in advance." GREENART's testing process is not only a collaborative effort between conservators in the field and GREENART's scientists back in the lab. In the case of Ramovš and Vuga, the collaboration also included their students. "Because we are professors, we have Masters students who have time to arrange for research, Ramovš says. We always can find some students who are interested. They can prepare the materials and so on, so we do not have to do everything on our own. It is good if you work together. If you are alone, it is difficult."

The testing is also a collaboration between a wide range of institutions who are all simultaneously testing the products in various different conditions. Ramovš and Vuga have participated in regular feedback sessions that include researchers at other institutions, who each present their findings. "We held monthly online meetings where we regularly shared experiences, insights and discussed any issues that arose. They hear us and we hear them and exchange knowledge, Vuga says. We are quite a big group doing different work. There are some who work on sculptures, but even if they present contemporary art or paintings or works on paper, you always can use the knowledge wherever it comes from. It is very important even if it is not exactly the same as yours."

These exchanges are particularly important because it offers an inside glimpse at how various research groups are developing the specifics of their testing protocols. "Using these materials is not just a matter of selecting the right gels, Vuga says. It is also about the overall approach to choosing and combining materials. We always use gels in conjunction with various liquids, meaning the effectiveness depends on the combined action of all components. The physical properties of the gels play a significant role, which is why we do not adopt new materials simply because they are innovative, but rather consider them as additional tools in our toolkit. What is most important is to understand both the surface being treated and the composition of the materials involved, alongside a thoughtful and informed approach."

By the time a group distills their findings in all of these areas in preparation for an event like the recent public training in Paris, many of those intricate details are left out, because they are perhaps too esoteric and granular for a public talk. "When you present the work to the public you have to concentrate your outcomes, so people never know what was going on behind the scenes," Vuga says. Ramovš adds that it will also be nice to learn about what happens in the laboratory after the scientists receive feedback from these real world tests. "You know about this new material, how it works and you have all these different test cases, so it will be good to hear going forward how the scientists are dealing with the results…"

Lucija Močnik Ramovš

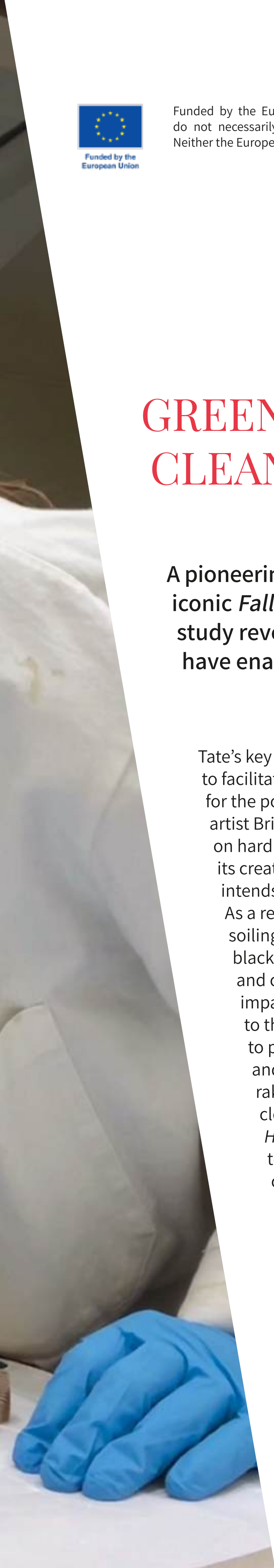
Courtesy Université de Ljubljana

Laboratory of the University of Ljubljana
Courtesy University of Ljubljana

CASE

Anna Cooper preparing mock-ups based on Bridget Riley's *Fall* and *Hesitate*

Photo Katey Twitchett-Young. © Tate



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GREENART

GREENART AT TATE: SURFACE CLEANING BRIDGET RILEY'S *FALL*

A pioneering conservation project at Tate preserves the visual impact of Bridget Riley's iconic *Fall* (1963) using innovative GREENART hydrogel cleaning systems. This case study reveals how scientific research, technical analysis and a rigorous approach have enabled the safe removal of decades of accumulated surface soiling.

Tate's key contribution to the GREENART project has been to facilitate a low-risk, appropriate conservation treatment for the popular mid-20th century painting *Fall* (1963) by British artist Bridget Riley. *Fall* is a polyvinyl acetate (PVAc) painting on hardboard and was purchased in 1963, shortly after its creation, and has been displayed regularly as the artist intends — unframed and unglazed — across the last 60 years. As a result, the painting surface had a light, but persistent soiling layer which dampened the contrast between the black and white painted lines, obscured painterly detail, and created an overall grey-yellow tone which somewhat impaired the powerful, visual effect of this work. In addition to the soiling layer, *Fall* was noted as being sensitive to pressure which manifested (though cumulative scuffs and marks) as gloss changes that were clearly visible in raking light. Thus, *Fall* had been earmarked for surface cleaning (soiling removal) for many years, alongside *Hesitate* (1964), also in Tate's collection, which together were proposed as challenging, important, case studies for the GREENART project.

Tate has been developing and refining a methodology designed to embed case study conservation treatments (where appropriate) into science-lead research. This featured in the NANORESTART project, and was employed once again for GREENART. Tate's project consisted of several investigative research streams which were naturally inter-dependent. These included: identifying case study artwork(s); exploring context through art historical and conservation documentation, as well as artists interviews, painting technical examination and analysis, the creation of mock-ups to understand the making of *Fall*, as well as creating substrates for cleaning treatment assessment and development, informing treatment risk through explorations into the constituents and properties of polyvinyl acetate paints, comparative cleaning system evaluation using GREENART and established cleaning systems, cleaning system optimisation for each case study painting, exploring cleaning system residues, the execution of conservation treatments (wet surface cleaning) and the evaluation of the painting surface pre- and post-treatment.

Several interviews with Bridget Riley are available at Tate (and elsewhere) and a range of art historical and conservation documentation informed the history and wider contexts of these two key works. The team also had the privilege of meeting the artist in early 2024 to discuss *Fall* and *Hesitate* which helped clarify the aims of the conservation treatment, explore their making and to understand which aspects of these paintings Riley views as fundamentally significant.

— Bronwyn Ormsby

Photographic and microscopic examination as well as extensive scientific analysis (of both works) confirmed that the paints are based on a polyvinyl acetate (PVAc)-polymer medium, and that *Fall* has no traditional size or ground layer. Interviews revealed that house paints were deliberately used and that the white paint was by Della Robbia and the black paint was by Ripolin. *Fall*'s hardboard panel was prepared with the white Della Robbia paint in several layers (the initial layers were diluted with water) to achieve opacity, then sanded to a smooth finish. In person, Riley described the consistency of the white paint as being like "single cream".

This combined information enabled the Tate team to prepare mock-ups for *Fall* and *Hesitate* using contemporary materials. Mock-ups serve several functions within conservation treatment research, such as enhancing our understanding of the materials used by the artist and the making processes involved, providing similar surfaces for evaluating and fine-tuning cleaning systems, and facilitating knowledge and skill acquisition around the novel GREENART materials. In this case, contemporary Lefranc Bourgeois paints were used with similar, though not identical compositions and aesthetic qualities, as were similar hardboard supports. The mock-ups were then light aged for the equivalent of about 30 years display in a museum environment (which about equals the cumulative display of *Fall* since its acquisition in 1963), followed by artificial soil application and ageing again for a short period to approximate the level of soiling imbibement noted on the paintings.

In parallel, we carried out a range of activities to identify any risks associated with the conservation of PVAc painted works of art, including a literature review of current knowledge on the analysis and properties of polyvinyl acetate paints, fine-tuning a pyrolysis gas chromatography-mass spectrometry analytical method to optimise the detection of PVAc paint additives, as well as paint extraction and swelling studies using aqueous systems and solvents commonly employed for modern painted surfaces. These studies informed the types of polymer and additives present in the paints, the likely materials at risk from solvent extraction within these paints, formulation changes over the years and new information about the effects of aqueous pH and conductivity on the swelling potential of PVAc paints.

The next stage was to use the carefully constructed mock-ups to evaluate and ultimately design a surface cleaning system for *Fall*, which would; remove the imbibed soiling layer evenly, not disturb the pencil lines and artist adjustments, and would not cause any swelling, blanching or other unwanted changes to the painting surface. Thus, we began an extensive comparative cleaning study after carrying out discreet aqueous and solvent tests on the painting surface, which confirmed that an aqueous system was required for optimal soiling removal. We began by using swabbed free liquids on the aged and soiled mock-ups, exploring the effects of aqueous pH and conductivity on the cleaning and paint response, followed by the gradual introduction of chelating agents and non-ionic surfactants at relatively low concentrations to enhance cleaning power. Empirical observations were made of each test and recorded using Excel spreadsheets and radar charts (also known as star diagrams), augmented using microscopic examination and photography. In this phase, it was quickly established that the action of swabs on the mock-up paint surfaces resulted in unacceptable pigment pickup and gloss changes and that any aqueous system was likely to require additional agents to enhance cleaning power.

Based on previous experience and knowledge of the painting condition we expected that "gels" would pose less risk to Fall, hence we embraced a range of "contained" systems where the solvent is thickened/held in a polymeric material (thickeners, tissues, hydrogels, emulsifiers) which offer more controlled release of the aqueous liquid onto the paint surface. Many of these (e.g. xanthan gum) required mechanical action during application, removal and clearance, which once again unfortunately caused unacceptable change to the mock-up paint surfaces. Finally, we moved onto more rigid hydrogel systems such as agarose, gellan, as well as the semi-rigid hydrogels Peggy 5 and Peggy 6 from the Nanorestore Gel group, all of which offer the possibility of reduced mechanical action, as well as the new group of GREENART hydrogels: PVA-SA, PVA-SU, PVA-AD, Peggy Plus 3 and a few more!

There were several iterative phases during this final comparative stage where the hydrogels were optimised and some were then ruled out due to inefficient soiling removal/uneven cleaning, etc. Towards the end of this phase, the polyvinyl alcohol-based Peggy 6 and the two GREENART gels PVA-SA and PVA-AD (also polyvinyl alcohol based, modified with diacid chains) were proving the most promising of the more rigid hydrogel group (offering an even and efficient cleaning action) with the additions of low concentrations of triammonium citrate chelator and/or non-ionic surfactant ECOSURF-EH6.

The optimal GREENART gel systems were then taken to the painting surface to assess their cleaning action and other effects. These options were augmented with two additional versions of PVA-SU (PVA-SU2) and PVA-SA (PVA-SA2) provided by CSGI which were also put through their paces on the mock-ups and in discreet tests on the painting. The chosen optimised system — PVA-SU2 (polyvinyl alcohol decorated with succinic acid) with

Black mock-up with comparative test squares evaluating and comparing GREENART gels

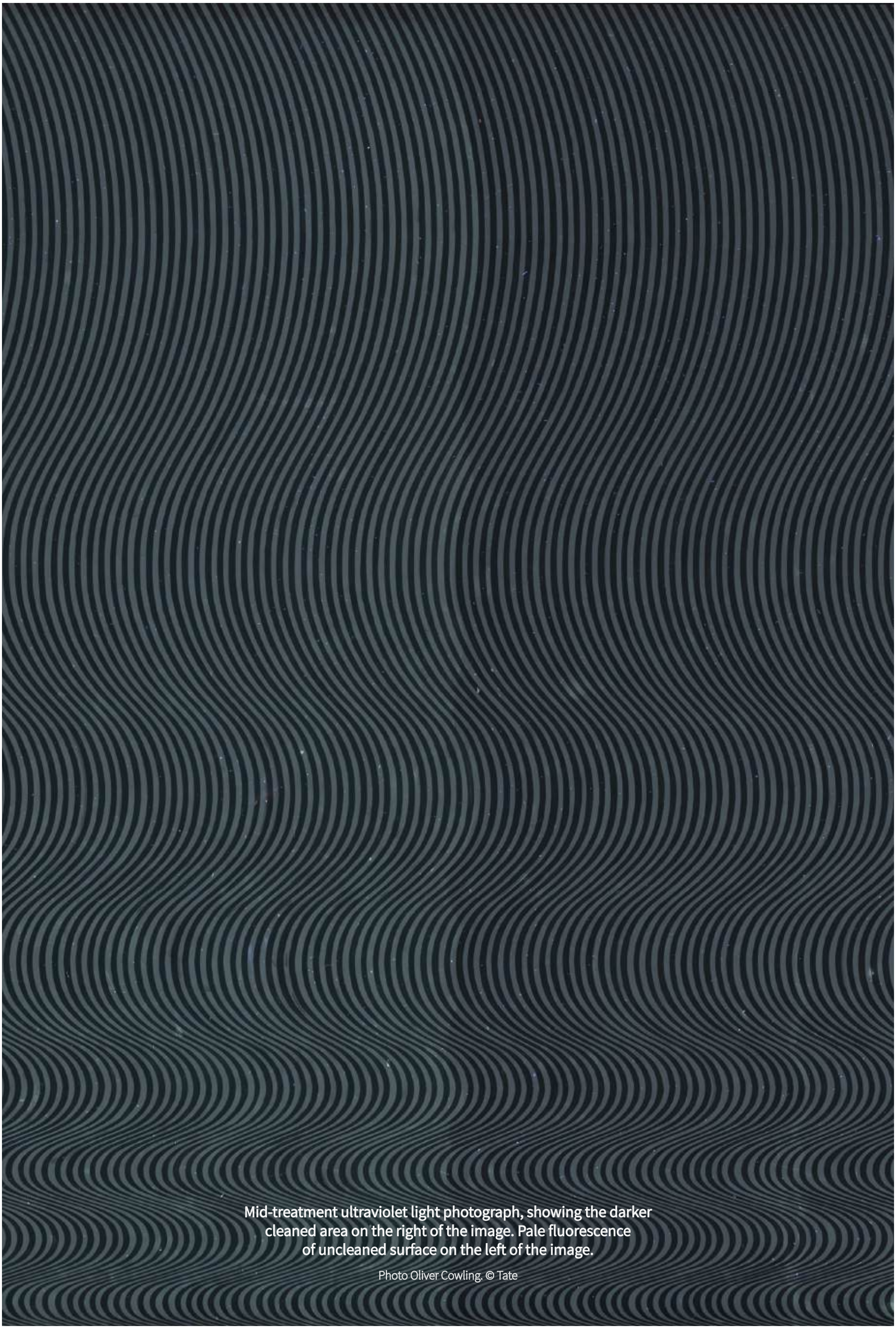
Photo Annette King. © Tate

Annette King and Katey Twitchett-Young cleaning *Fall* (1963) with GREENART SU2 gel

Photo Bronwyn Ormsby. © Tate

GREENART SU2 gel placed on *Fall* (1963) over an exposed cleaning window between Melinex templates

Photo Bronwyn Ormsby. © Tate



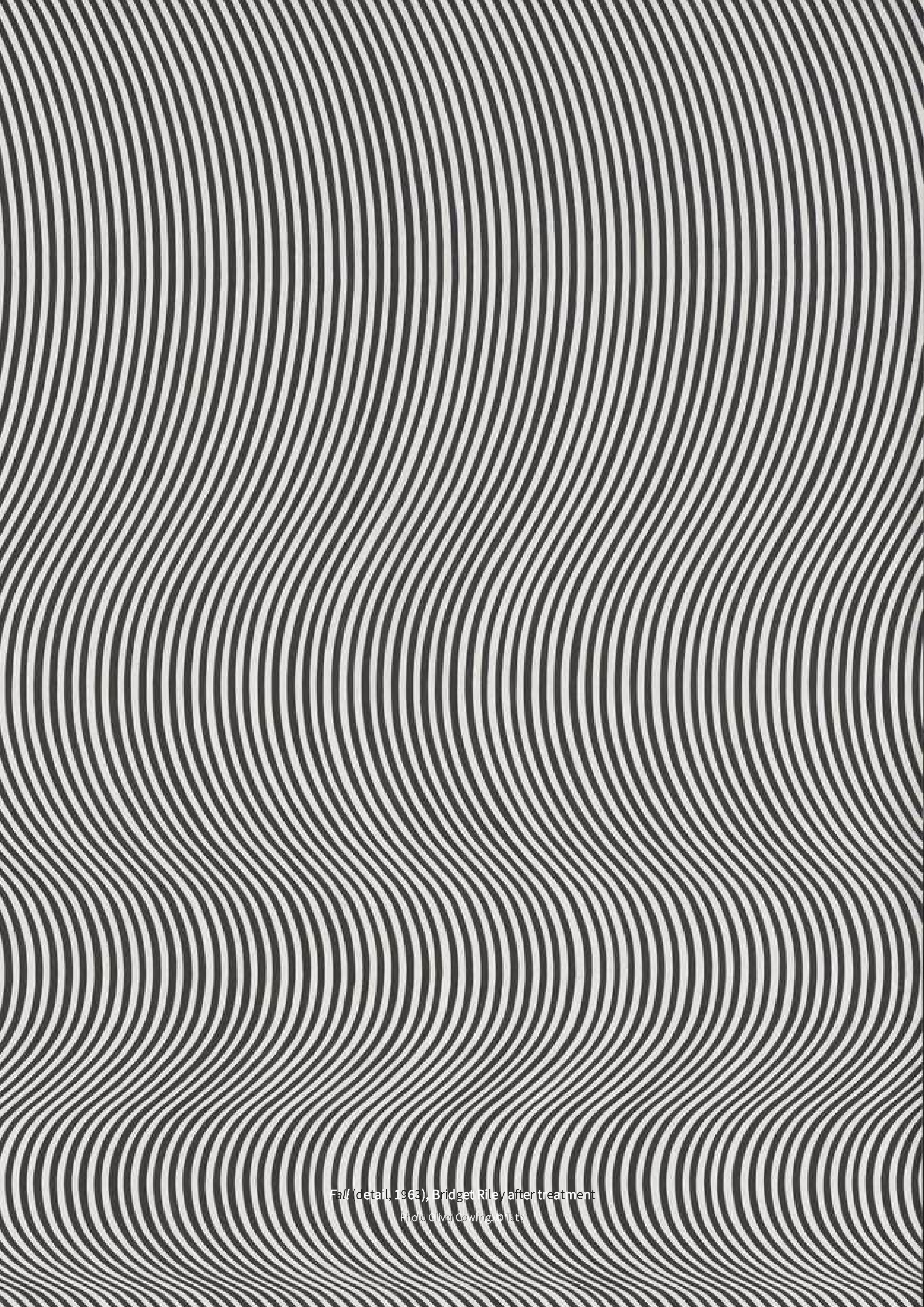
Mid-treatment ultraviolet light photograph, showing the darker cleaned area on the right of the image. Pale fluorescence of uncleaned surface on the left of the image.

Photo Oliver Cowling. © Tate

added triammonium citrate and ECOSURF-EH6 — was then evaluated on the painting to determine the final application time of 2 minutes to achieve an even, efficient removal of the soiling layer. The final steps involved exploring how the gels could be optimally applied to avoid over- or under-cleaned areas which, in this case, involved making a cleaning window with Mylar polyester film which was designed sympathetically with the painting composition in mind, then carefully and systematically moved across the painting as the cleaning treatment proceeded.

After many months of examination, analysis, evaluations and treatment design, the treatment of *Fall* was completed in around 12 days. It was important to have the gel preparation and blotting station set up, and to have two people moving the Mylar template and applying the gels across the painting surface according to strict timings. Consistency and planning was key to the success of the treatment, which is evident in the evenness of the cleaning result seen in ultraviolet light. For this treatment, the GREENART gel PVA-SU2 offered the most efficient, even cleaning action, where the gel conformed well to the (in this case relatively flat) painting surface, the soiling layer was efficiently absorbed into the gel and the cleaning and clearance steps did not require problematic mechanical action.

Post-treatment evaluations documented changes such as a reduction in the yellow tone and a slight overall increase in gloss which results from the removal of the light scattering, yellowed soil and thus far, though some studies are ongoing, no residues of the cleaning systems have been detected. This highly successful treatment has resulted in visibly enhanced contrast between the black and white lines, the removal of the overall yellow-grey tone, reduced the risk of the accumulated soiling becoming more permanently imbibed, and has hopefully contributed to the recovery of the intended visual energy of this impactful painting.



Fall (detail, 1963), Bridget Riley after treatment

Photo Oliver Cowling. © Tate

GREENART on Osaka 2025 World Expo

Courtesy BeWarrant

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WHEN ART MEETS COSMETICS: GREENART AT THE OSAKA EXPO

From 3 to 5 May, European GREENART project takes centre stage at the Osaka World Expo, showcasing how green technologies can transform both art restoration and the cosmetics industry.

At the heart of the Osaka 2025 World Expo, the European Union Pavilion presents GREENART at the beginning of May. This flagship project, funded under the Horizon programme, aims to produce sustainable solutions for conservation-restoration and preventive conservation of heritage. The team develops low-impact, environmentally friendly materials, sourced from renewable natural resources or recycled waste.

Visitors, young and old, spend three days experimenting with innovative, sustainable restoration techniques developed by GREENART. They handle green nanomaterials, manufacture bio-based cleaning gels and dust models of artworks. The project's researchers lead practical workshops, allowing everyone to discover these cutting-edge methods first-hand. The demonstration, entitled "Sustainable materials: From art to cosmetics", pursues another goal as well: to prove how green technologies can revolutionise two sectors that, at first glance, seem unrelated — cultural heritage conservation and the beauty industry. In partnership with global cosmetics giant Shiseido, the GREENART workshops highlight international collaboration between European and Japanese partners, and reveal the potential for new interdisciplinary applications. The event explores the parallels between restoring paintings and the science of skincare.

"I had the good fortune to meet Professor Piero Baglioni, Director of the Centre for Colloid and Surface Science (CSGI) at the University of Florence, who stands as a leading figure in my fields of research. Without hesitation, when he launched the GREENART project, I decided to join him," says Taku Ogura, principal researcher at Shiseido and visiting associate professor at Tokyo University of Science, specialising in surfactant science and surface chemistry [see box p.266]. "Moreover, the European Union is developing some truly fascinating initiatives in the preservation of art and paintings, which is highly stimulating for research." Author of hundreds of publications and dozens of patents, Piero Baglioni has indeed pioneered the application of bicontinuous microemulsion technology to the conservation of cultural heritage — having worked in the laboratory of Pierre-Gilles de Gennes, Nobel Prize winner in Physics in 1991. "Through Piero, I also learned from Pierre-Gilles. So, this is a continuation towards the new generation," the Japanese researcher notes, visibly moved and proud.

The microemulsion revolution

A sophisticated technology with surprising applications,

— Carine Claude

microemulsion stands as a key focus of research and development at GREENART — and in the cosmetics industry. “This technology enables the selective removal of stains, both from the surface of artworks and from the skin,” explains Taku Ogura, an expert in the field. “For example, when restoring paintings, we want to remove only the stains without damaging the paint layer itself. Previous technologies sometimes accidentally removed parts of the painting.”

This surgical precision resonates within the cosmetics industry. “People want to remove stains, makeup and foundation while preserving the skin’s natural moisturising factors, which are essential for skincare, continues the Shiseido researcher. Microemulsion technology can gently eliminate only the targeted substances.” The same technological backbone adapts to different applications. “To remove a black, grimy layer from a painting, we select specific surfactants and oils, he explains. For cosmetics, when we work with lipstick, we also choose different surfactants and oils. It is the same technology, but we must select the right ingredients.” Cleansers, lotions and serums — microemulsion technology plays a “very important” role in the products developed by Shiseido, renowned for its luxury ranges. The researcher also leads one of the GREENART introductory workshops, demonstrating how the same materials and technologies used in art restoration find applications in the cosmetics industry — and *vice versa*.

A pop-up laboratory

Like a pop-up laboratory, the GREENART space at the Osaka Expo offers three interactive workstations for visitors of all ages, turning science into hands-on experimentation. Alongside Taku Ogura and Isao Yotanda, associate professor in the Department of Advanced Chemistry at Tokyo University of Science, the European team gets involved in designing and running the programme: Andrea Casini and Rachel Camerini, young postdoctoral researchers specialising in nanoparticles and biopolymers; Giovanna Poggi, an expert in hydrogels and organogels; Silvia Lob, a specialist in physico-chemical interactions at the nanoscale and Isella Vicini, director of European funding development. All work under the scientific coordination of CSGI (Centre for Colloid and Surface Science), the renowned Italian centre of excellence led by Piero Baglioni, who heads the international consortium of museums and universities that make up GREENART.

For adults, the alginate sphere workshop offers the chance to create the flags of Italy, Japan and the European Union. Made from a natural polymer extracted from brown seaweed, mixed

3 questions to... Taku Ogura

Taku Ogura serves as principal researcher at Shiseido and at the MIRAI Technology Institute.

How did the Shiseido Group decide to get involved in GREENART? After all, skincare and artworks seem to be very different fields…

It is actually a scientific connection. Our project focuses mainly on using hydrogels to remove stains from artworks and paintings. This technology involves microemulsion cleaning, which is also highly important in the cosmetics field. One of Shiseido’s flagship products is a microemulsion cleanser for the skin. We need to master this peeling technique and combine it with the “green” aspect of GREENART — that is, sustainable, natural and biocompatible approaches, which are crucial in cosmetics. That is why Shiseido joined this project.

Does sustainability form part of Shiseido’s corporate philosophy?

Yes, Shiseido’s policy and philosophy revolve around a key concept: “Art and science”, which has been in the group’s DNA since its founding in the late nineteenth century. This means we focus on developing cosmetic technology while considering the face as a canvas. We always strive to advance technologies, combining art and science.

How does your laboratory at Shiseido work with the GREENART project?

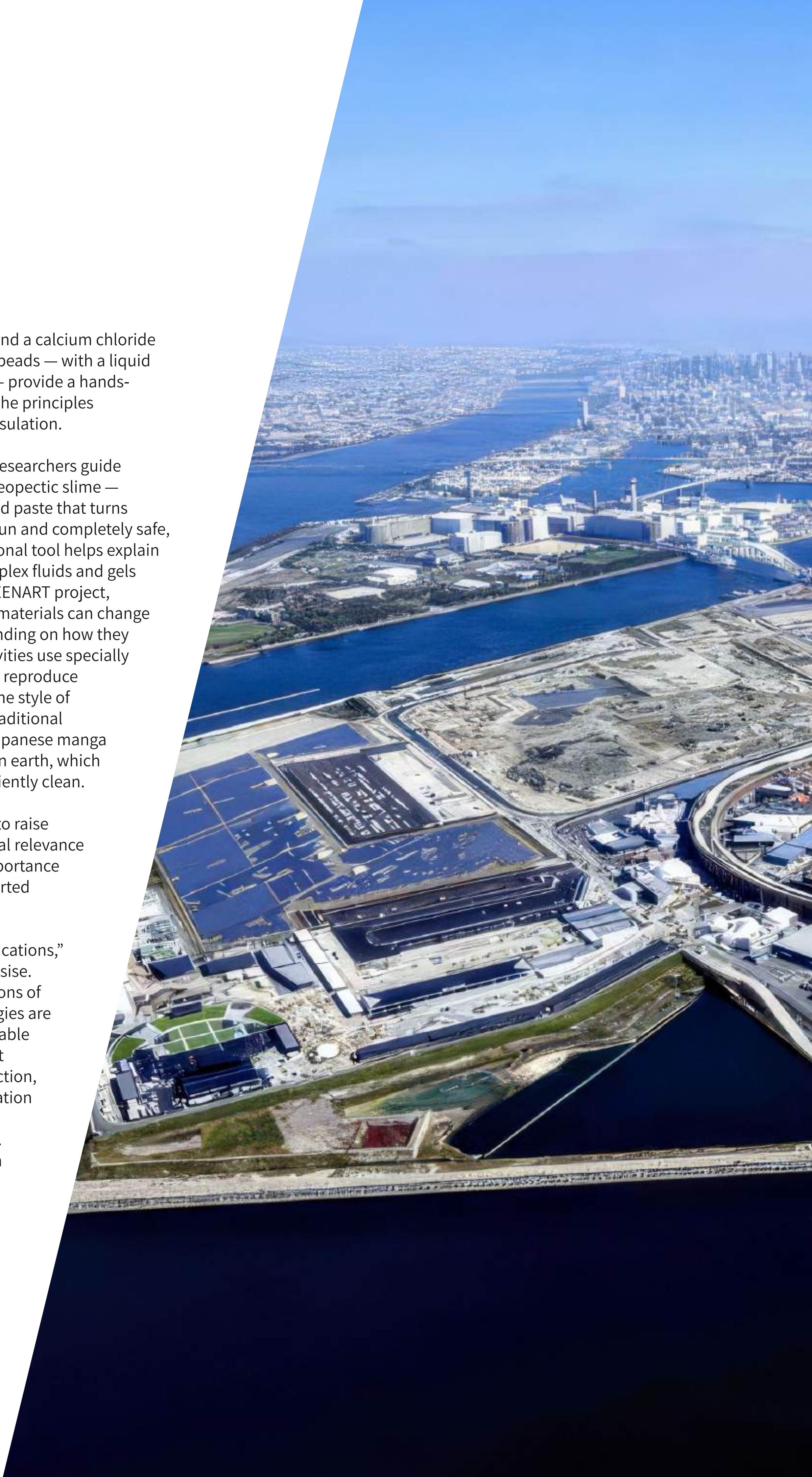
I focus on how the results of the GREENART project can be used for industrial applications, particularly in cosmetics. I also work at the University of Tokyo in an academic role, integrating this technology into other industrial fields, such as the metallurgical industry. The GREENART project centres on the sustainability of technologies and “green” materials, which can also be applied beyond heritage preservation. Cosmetics have already made progress in terms of eco-responsibility but other sectors of the chemical industry still rely on petroleum and hazardous products.

Taku Ogura

Courtesy Shiseido

Teresa Guaragnone from CSGI

Courtesy CSGI



with coloured liquid and a calcium chloride solution, these small beads — with a liquid core and a soft shell — provide a hands-on demonstration of the principles of gelation and encapsulation.

For younger visitors, researchers guide children in making rheopectic slime — a viscous, starch-based paste that turns solid when pressed. Fun and completely safe, this excellent educational tool helps explain the properties of complex fluids and gels developed by the GREENART project, showing how certain materials can change their behaviour depending on how they are handled. The activities use specially prepared models that reproduce abstract artworks in the style of Pollock, samples of traditional paintings and even Japanese manga illustrations covered in earth, which the children must patiently clean.

“The exhibition aims to raise awareness of the social relevance of restoration, the importance of scientifically supported methodologies and the potential for new interdisciplinary applications,” the organisers emphasise. The societal implications of these green technologies are wide-ranging: sustainable museum practices, art education, skin protection, cleaning and regeneration and the development of a circular economy. This holistic approach reflects the spirit of the Osaka World Expo, whose theme — “Designing future society for our lives” — encourages reflection on innovations that serve humanity.

Osaka 2025 World Expo

Courtesy Osaka World Expo

An interior view of the Department of Chemistry "Ugo Schiff" at the University of Florence (DICUS) which hosts the Center for Colloid and Surface Science (CSGI), coordinator of the GREENART project.

Photo Mickaël Pijoubert. © Art Media Agency

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DEMYSTIFYING THE PRODUCTION OF GREENART'S SECRET GELS

Behind CSGI's lab doors, green chemistry meets fragile art. Here "Peggy" gels and other microemulsions travel from beaker to canvas, carrying water and nanofluids with surgical calm. Chemists, researchers and microscopes share the bench; mock-ups take the risks so museum works don't have to.

Enter CSGI at the University of Florence, where research proceeds with a quiet focus and an easy collegiality. The spirit is studious but warm Here, green chemistry is not a slogan but a working constraint: materials must be safer, methods more contained, outcomes at least as good as the *status quo* — or they do not leave the room.

This is where Nanorestore' "Peggy" hydrogels came of age and where new variants are refined within GREENART. The idea is simple and demanding at once: carry aqueous or nanostructured cleaning fluids in a controlled, sheet-like network; release them slowly; lift unwanted layers without stressing what lies beneath; leave no mark of your passage. The practice is incremental. Mock-ups stand in for canvases and polychrome surfaces; trials compare selectivity, working time, residue; small adjustments in formulation are recorded, argued, kept or set aside.

At the centre of this work is Professor Piero Baglioni, who steers by (im)patience and precision. Alongside him, conservation scientist Davide Chelazzi keeps the line open between chemistry and practice: what a gel can do on paper is never separated from what a conservator needs it to do on a surface.

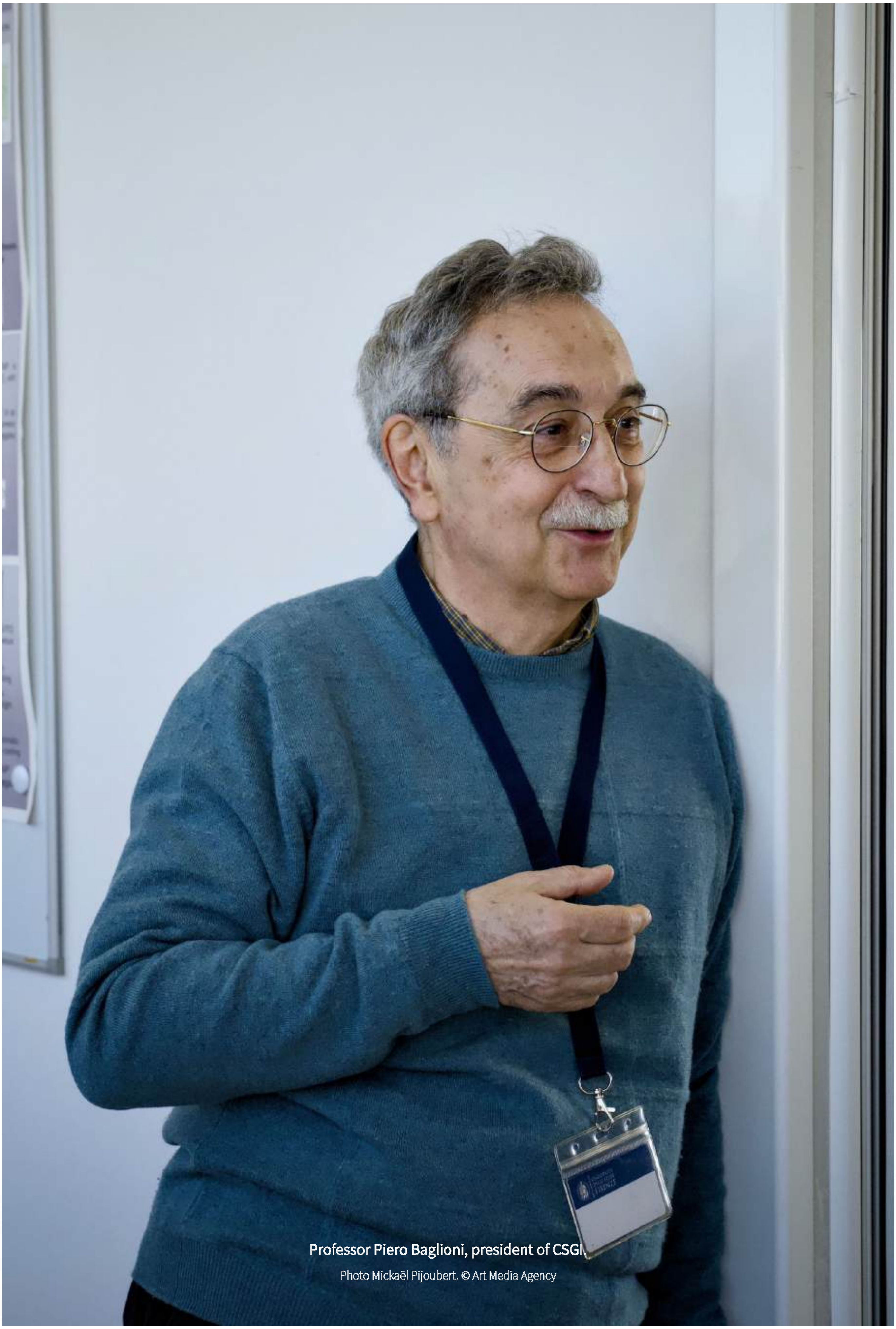
Carrying much of the day-to-day production are two PhD researchers, Andrea Casini and Teresa Guaragnone. They are the hands that translate recipes into reliable sheets, the eyes that catch the small differences between an almost and a right. There is always room for a smile or a quick joke… the kind of easy rapport that makes long days feel shorter.

Much of what leaves the lab is made to measure. CSGI produces near-bespoke gels in response to conservation briefs from museums. Requests arrive with constraints; the lab replies with options, notes and (mostly) magical solutions.

GREENART's expectations — lower toxicity, renewable or waste-derived inputs where effective, confined application that limits exposure, clear documentation for training — are integrated everywhere into the work. The gels happen to embody the approach, but the approach is larger: do more with water; make selectivity the first virtue; prefer lifting to dissolving; match performance with responsibility.

By day's end, the lab has produced what looks, from a distance, like clarity: stacks of transparent white sheets, labelled and logged. Up close, one would instantly notice all the work behind it — constant small iterative improvements — as well as the temperament that goes with it: caring, collaborative and fun.

— Pierre Naquin



Professor Piero Baglioni, president of CSGI.
Photo Mickaël Pijoubert. © Art Media Agency

A CSGI researcher adds reagents into a laboratory reactor to prepare a reaction batch. By controlling temperature and mixing speed, a polymeric dispersion can be produced. It then undergoes freeze-thaw cycles, yielding a gel with properties optimised for the controlled and effective cleaning of delicate artistic surfaces.

Photo Mickaël Pijoubert. © Art Media Agency

A CSGI researcher from the GREENART project selects the polymeric precursors that will form the gel's matrix.

Photo Mickaël Pijoubert. © Art Media Agency

A newly developed polymer solution is being handled in the lab. By tuning its composition, researchers can chemically engineer eco-friendly hydrogels that effectively remove unwanted substances while remaining safe to both artworks and the environment.

Photo Mickaël Pijoubert. © Art Media Agency

The hydrogel can be loaded with an innovative nano-structured cleaning fluid designed to remove unwanted polymeric materials from artworks.

Photo Mickaël Pijoubert. © Art Media Agency

The polymeric dispersion is poured into a mould designed to give the gel material the shape best suited to conservation needs. It then undergoes freeze-thaw cycles, forming a gel based on modified polyvinyl alcohol.

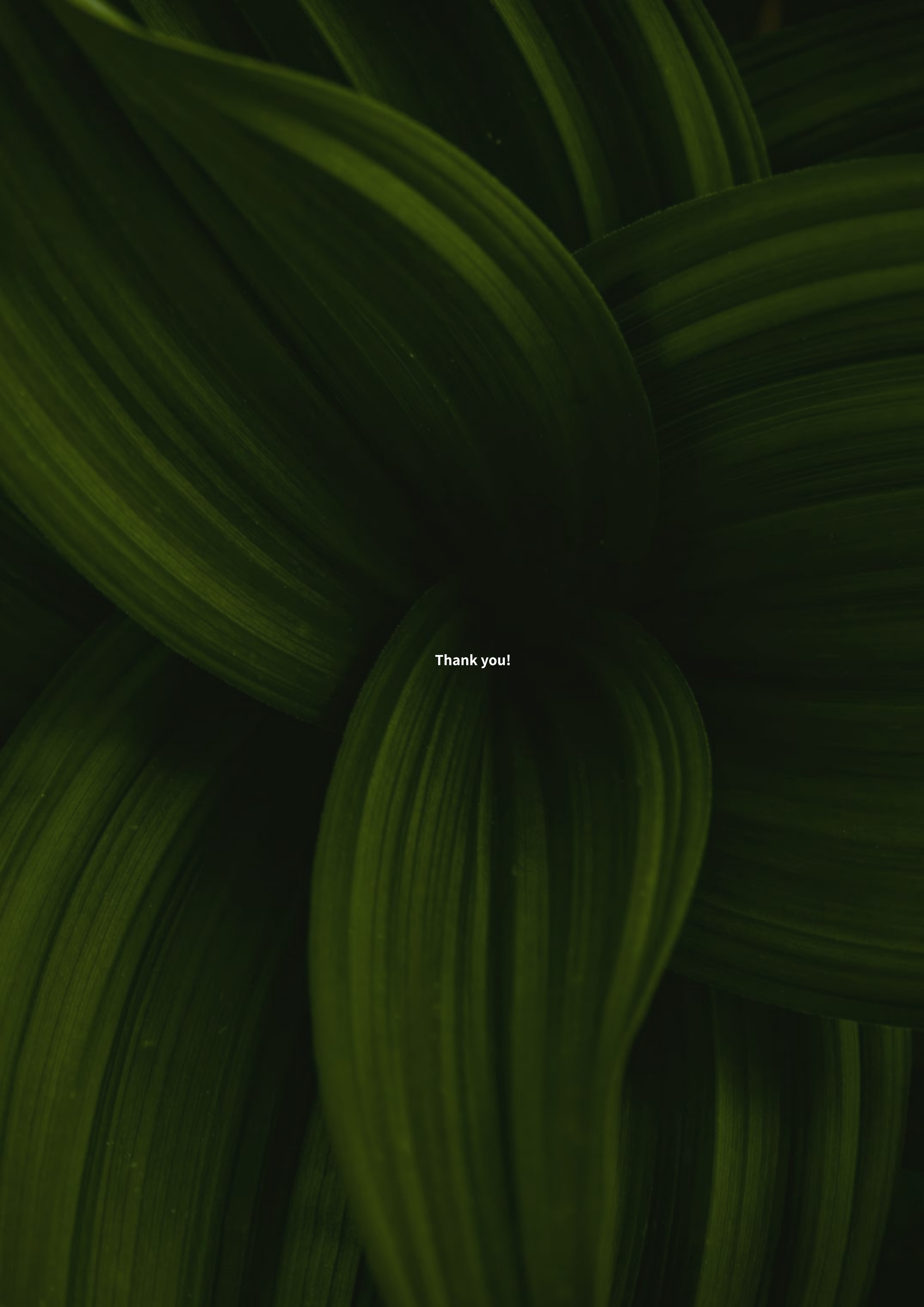
Photo Mickaël Pijoubert. © Art Media Agency

A novel "twin-chain" hydrogel, synthesised from modified renewable polyvinyl alcohol through freeze-thaw cycles, is employed to gently remove water-soluble dirt from a model modern art surface. Its unique polymer network adapts to uneven textures, cleans in a controlled way and leaves no residue, supporting the project's sustainability goals.

Photo Mickaël Pijoubert. © Art Media Agency

GREENART meeting, Naples, December 2023

Courtesy GREENART


Thank you!

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Università Ca'Foscari Venezia

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CHALMERS UNIVERSITY OF TECHNOLOGY

CNR ISMN Istituto per lo Studio dei Materiali Nanostrutturati

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