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Eco-Friendly Materials in the Conservation of Cultural Heritage: A Case Study on "The Chair of The Chalice Icons " at the Virgin Mary Church in Haret Zuwaila, Egypt

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ملخص البحث :

تعد المواد الخضراء صديقة البيئة من أحدث الاتجاهات العلمية في مجال ترميم وصيانة التراث الثقافي، لما لها من دور فعّال في تحقيق أهداف استراتيجية التنمية المستدامة ٢٠٣٠ ، والتي ترتكز على مفاهيم الحفاظ على البيئة وتقليل الأثر الكربوني في مختلف القطاعات، بما في ذلك قطاع التراث وفي هذا الإطار، أصبح من الضروري استبدال المذيبات الكيميائية التقليدية ببدائل أكثر أمانًا وصديقة للإنسان والبيئة، حفاظًا على صحة المرممين من جهة، وضمانًا لسلامة الأثر من جهة أخرى، خاصةً فيما يتعلق بتفادي الآثار السلبية الناتجة عن التفاعلات الكيميائية الضارة.

وفي هذا السياق، يتناول هذا البحث تطبيق مذيبات خضراء مثل لاكتات الإيثيل (Ethyl Lactate) وكربونات ثنائي الميثيل (Dimethyl Carbonate) في عملية تنظيف طبقة التصوير الخاصة بأيقونات كرسي الكأس، والذي يعود تاريخه إلى القرن التاسع عشر للرسام أنسطاسي الرومي .وتُحفظ هذه الأيقونات حاليًا في كنيسة السيدة العذراء مريم بحارة زويلة، التي تُعد من أهم المحطات المرتبطة بمسار العائلة المقدسة في مصر، ما يُضفي على الدراسة بُعدًا ثقافيًا ودينيًا وتاريخيًا بالغ الأهمية.

ABSTRACT:

Eco-friendly green materials have emerged as one of the most advanced scientific approaches in the field of cultural heritage restoration and conservation, due to their significant role in supporting the goals of the 2030 Sustainable Development Strategy. This strategy emphasizes environmental protection and the reduction of carbon footprint across various sectors, including the heritage sector. In this context, it has become essential to replace traditional chemical solvents with safer, environmentally friendly alternatives — both to protect the health of conservators and to preserve the integrity of the artifacts, especially by avoiding harmful chemical reactions that may negatively affect the original materials.

Accordingly, this study explores the application of green solvents such as ***Ethyl Lactate*** *and* ***Dimethyl Carbonate*** *in the cleaning of the painted layer of the icons of the "Chair of the Chalice", which date back to the 19th century and were painted by the painter Anastasi Al-Roumi. These icons are currently preserved in the Church of the Virgin Mary in Haret Zuweila, one of the most significant stops along the Holy Family Route in Egypt. This association lends the study profound cultural, religious, and historical importance.*

KEYWORDS*: green materials, Ethyl lactat, Dimethyl Carbonate, Chair of Chalice.*

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INTRODUCTION

What are the words used to refer to "icon" and "picture"? In the Coptic tradition, the Coptic word is "limni"; that was borrowed from Greek is "εικών", and that was taken from Arabic (coming from Greek) is "iquna". In Ethiopia, the Geez word is "se'el"; the word "ayqunâ" is also found. (Chaillot,2016)

The icon, in its profound symbolic essence, serves as a powerful communicative tool within the devotional life of the Church. It represents a spiritual theology in visual form — a sacred philosophy that reinforces faith and imparts knowledge among believers. For the educated, it expresses truths and emotions that written texts may fail to convey, while for the illiterate, it becomes a visual narrative through which the heroic deeds of saints can be remembered and recounted. By the second century AD, the term *iconography* had emerged, referring to the artistic interpretation and representation of sacred subjects.(Helmi,٢٠٢٣)

Icons serve as aids to worship, wherever an icon is placed, that space is more readily transformed into a setting for prayer. An icon is not an end in itself; rather, it serves as a window that draws the believer beyond the visible world into the realm of spiritual experience. (Elserogy,2019)

Icons help focus the heart and mind during prayer. For instance, if one becomes distracted during the liturgy, it can be helpful to fix one's gaze on the icon of Christ Pantocrator typically found just to the right of the royal doors on the iconostasis in Orthodox churches. This visual reminder reorients the worshipper, evoking the awareness that they stand in the presence of Christ. In doing so, it brings them back to the present moment and renews their consciousness of God's continual presence.(Henin,2022)

Icons could feature prominently in the liturgical service, particularly at Easter, when the clergy and deacons would go in procession around the altar, as they still do, singing hymns and carrying the icon of the Resurrection together with candles, crosses, gospels and censers.113 The images reaffirmed the accepted religious truths that were transmitted both orally (often in front of the icons themselves) and through the large body of written religious texts and hagiographies. As rhetorical constructions, at once 'potency' and 'sign', icons were also designed to tell stories and persuade, for which they required appropriate and effective formal devices. In their portrayals of martyrs and ascetics, Yuhanna's and Ibrahim's use of verbal and visual devices such as those already mentioned will have produced a highly effective imaginative reconstruction of the Coptic Christian past, shaping a conceptual world that perceived itself as still linked to the memory of their Early Christian tradition. (Tribe, 2004)

The icon painters must follow specific rules, that are iconographical canons. The icons are not just artistic paintings but they play a religious and pedagogical role in the Oriental Churches. In principle, one must meditate and pray before painting icons, as they are religious art. Icons are often painted by monks and nuns and even priests. (Chaillot,2016)

The ark or (**Chair of the Chalice**) is a wooden box measuring approximately 10 by 10 by 11 inches (25 x 25 x 30 cm), which always stands in the middle of the altar. The top has a wide round hole, and consists of two folding leaves through which the chalice is placed during the liturgy. The four sides carry paintings of the Last Supper, the Virgin Mary, an angel, and the

saint in whose name the church was consecrated. The ark is the embodiment of various symbolical analogies. It is sometimes called a throne in reference to the majesty of the crucified Christ. Like the ark that was the instrument of salvation to Noah and his family (Gn. 9), the altar ark holds the chalice carrying the life-giving Blood of Jesus Christ (Jn. 6:54). It is also analogous to the Old Testament ark of the covenant. But whereas the old ark used to hold the tables of the law, the new ark holds the chalice of Christ's Blood, God's New Testament with man, the fulfilment of the scriptures of the prophets (Mt. 26:54, 56); and while the old ark included Aaron's rod which budded (Heb. 9:4), the new ark symbolizes the Virgin Mary who gave birth to God, the Word, manifest in the flesh (Jn. 1:1; 1 Tm. 3:16). Finally, the old ark contained the golden pot of manna (Ex. 16:32-34), whereas the new ark holds the true heavenly Manna which gives life everlasting (Jn. 6:57, 58).

It must be stressed here that, in accordance with the practice of the Coptic Church, the ark is to house the chalice only during the liturgy prayers, and not to hold the Precious Body and Blood following their consecration. In the case of persons wishing to partake of Holy Communion who cannot attend the Divine Liturgy either through illness or for other reasons, the Precious Body, moistened with drops of the Precious Blood, may be reserved and conveyed to them in a special silver pyx, called the *artophorion* (Arabic, *huqq al-dhakhirah*), to be administered to them by the priest, while they are still fasting, immediately after the liturgy. The box is then returned empty to the church. (Youssef,2011)

The Chair of the Chalice Icons at the Virgin Mary Church in Haret Zuwaila.

The churches complex of Ḥāret Zuwaila, located in the heart of Cairo's bustling commercial district—between the Musk Market and Khan al-Khalili—comprises three primary churches. The main church is dedicated to the Virgin Mary, the northern church to St. Mercurius (Abu Sefein), and the upper church to St. George.

Access to the Church of the Virgin Mary is via a descending stairway, which attests to the building's antiquity. Since its probable construction in the 9th century, the surrounding street level has risen approximately six meters. Over the centuries, the church has undergone numerous restorations, making it difficult to discern its original architectural layout. The initial design appears to have been a transept basilica, though few of the original parallel walls remain. According to tradition, the church was built on a site where the Holy Family is believed to have rested during their flight into Egypt. A well within the church is traditionally thought to have been used by the Christ Child, and its water is believed to have healing properties.(Gabra, 2012)

"It has been observed that the iconographer Anastasi Al-Qudsi Al-Rumi was among the most prolific icon painters who depicted episcopal thrones (**Chair of the Chalice**) in Egypt during the 19th century, across various churches and monasteries, for example;

Chalice Chair with icons painted on all sides: The Blessed Virgin carrying the Child, Archangel Michael, The Last Supper and the Archangel Gabriel in the order consisted with the Arabic inscription at the bottom: Remember O Lord Thy diligent servant 'Erian son of Yuhanna el Tawil. Reward O Lord those who have laboured from the Coptic Church of Saint George. Old Cairo **(Fig.1).**

Figure 1. Chalice Chair from the Coptic Church of Saint George. Old Cairo

The painter Anastasi Al-the Rumi, who is regarded as one of the most prominent icon painters of the 19th century. Anastasi al-Qudsi al-Rumi was an accomplished iconographer who worked extensively for the Coptic community in Cairo between 1836 and 1871. He consistently signed and dated his icons in Arabic, reflecting both his authorship and the cultural context of his work.During this period, the honorific title *Muqaddis*—meaning "holy one"—was commonly bestowed upon Christians who had made a pilgrimage to Jerusalem. This title functioned as a Christian equivalent to the Muslim honorific *Hajj*, granted to those who completed the pilgrimage to Mecca.

Al-Qudsi al-Rumi maintained close ties with the Coptic Patriarchate. In the historic Church of Saint Menas, near Old Cairo, he undertook the restoration of works originally executed by Yohanna al-Armani. Notably, the curved wall of the main sanctuary features wood paneling and an iconographic depiction of Christ Enthroned as the High Priest, flanked by Aaron and Moses. This composition underscores a renewed Coptic clerical engagement with the Old Testament tradition during the 19th century.(Henin, 2023)

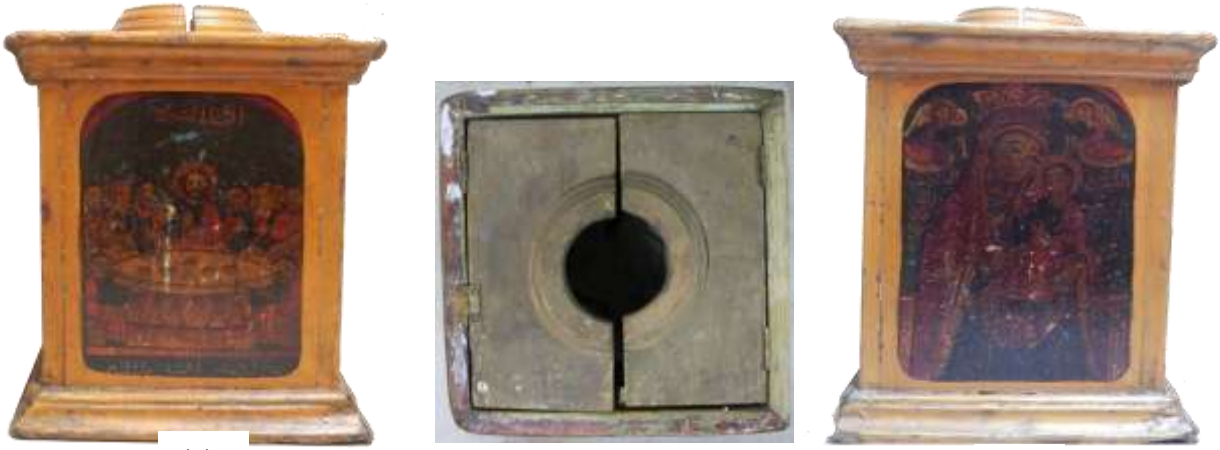
An Art-Historical Study of the Chalice Chair

The chair, which is the focus of this research, is designed as a wooden cube with an upper opening that is closed by two wooden panels, which open outward. In the center of these panels, there is a circular aperture that facilitates the closure of the chair while securing the chalice within it.

Each of the four sides of the Chalice Chair is adorned with a Coptic icon representing various distinct themes. The distinctive style of Anastasi Al- Rumi is characterized by his practice of framing each icon, with the upper part delineated by an elliptical arch. Additionally, he frames the lower section with an inscription that reads: “The humble Anastasios the Roman, the sacred iconographer, painted this.” On the opposite sides, the inscription states: “May the Lord reward with eternal rest those who have labored in the Kingdom of Heaven,” along with the date of the chair, marked as the year 1567 in the Coptic Calendar.

One of these icons depicts the Last Supper of Christ with His disciples **(Fig.2).** In the scene, Christ is positioned at the center of the disciples around an oval table, with bread and a chalice placed at the center. The twelve disciples are divided into two groups, with six positioned on either side of Christ. Christ is shown with a distinct halo, distinguish him from the disciples

On the opposing panel stands an icon portraying the Blessed Virgin Mary holding the Christ Child. The image depicts the Coronation of the Theotokos: two angels, symmetrically positioned at the top corners, place a crown upon her head. A radiant halo encircles the head of Christ, who, in contrast to Mary, holds a radiant shape in his hand while remaining uncrowned.



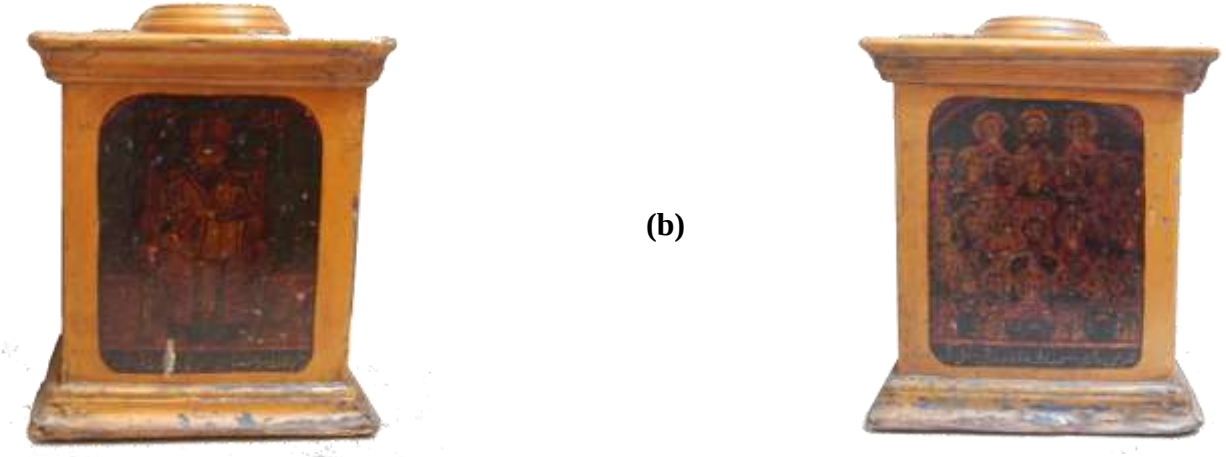
(a) **(b)** **(c)**

Figure 2. (a) The Last Supper of Christ with His disciples.
(b) A top view of Chalice chair
(C) The Virgin Mary holding the Christ Child

On the third side of the Chair of the Chalice, there is an icon portraying Saint Mark **(Fig.3)** seated on a throne. He is depicted wearing patriarchal vestments, crowned. In his right hand he holds a cross, and in his left, the Holy Gospel**.** At the left side of his throne sits a lion at rest**,** symbolizing his Evangelist identity.

On the opposite panel is an icon depicting the Twenty-Four Fathers, arranged in four ascending rows: seven figures in each of the lower three rows, and three in the uppermost row. Each father is depicted with a halo of sanctity**.** Some hold a cross in their right hand, while others bear it in their left. The Twenty-Four fathers are mentioned in the Book of Revelation by Saint John the Evangelist as part of the celestial vision.

(a)



(b)

Figure .3.

(a) The Saint Mark seated on a throne

(b) The Twenty-Four Fathers

The Structure Composition of the Chalice Chair Icons

The chalice chair is composed of four icons, each measuring approximately 24 × 23 cm. Both the top and base of the chair are decorated with a square wooden frame measuring 28 × 28 × 4 cm.

The structure of the four icons, arranged from bottom to top, consists of the following layers **(Fig.4):**

- Wooden Support
- Ground Layer (Preparation Layer)
- Paint Layer
- Varnish Layer

Figure 4. The Structure Composition of the Chalice Chair Icons

STATE OF THE CHAIR OF THE CHALICE ICONS

Icon deterioration could be attributed to the aging of materials, tangential carving of the board of which the panel is made up, the aging of the glue as well as unintentional human damage. No icon escapes the process of aging, which over time leads to a change in its appearance. This phenomenon of degradation affects the whole structure of the painting. Due to their delicate components, icons are frequently subjected to damage. (Elserogy,2018)

- A dark varnish layer is present, significantly obscuring the fine details of the paint layer. This is likely due to prolonged exposure to smoke and high temperatures, particularly during liturgical ceremonies and rituals in which incense is used.
- Partial loss of the paint layer is evident, especially in the icon of Saint Mark the Evangelist. This damage is attributed to varying levels of heat and humidity, as the chalice chair is located within the sanctuary, where both temperature and humidity levels tend to be elevated.
- Several holes and losses in the wooden support are observed, particularly along the edges, corners, and even the central areas of the icons. These structural weaknesses may accelerate susceptibility to insect infestation.
- Additionally, a layer of modern paint covers the outer frame of the four icons, as well as the top and base of the chair. This alteration is likely the result of well-meaning, yet misguided, restoration efforts by individuals responsible for maintaining church artifacts—interventions that, unfortunately, contribute further to the deterioration of the objects rather than their preservation.

Documentation Prior to Conservation

Before initiating the conservation process, a thorough documentation phase was carried out using high-resolution photographic techniques. Initial imaging was conducted with a specialized NIKON D550 camera to capture general views of the icons. This was followed by

detailed imaging using a Keyence VHX-900F digital microscope, which allowed for the visualization of various deterioration features with enhanced precision and clarity **(Fig.5).**

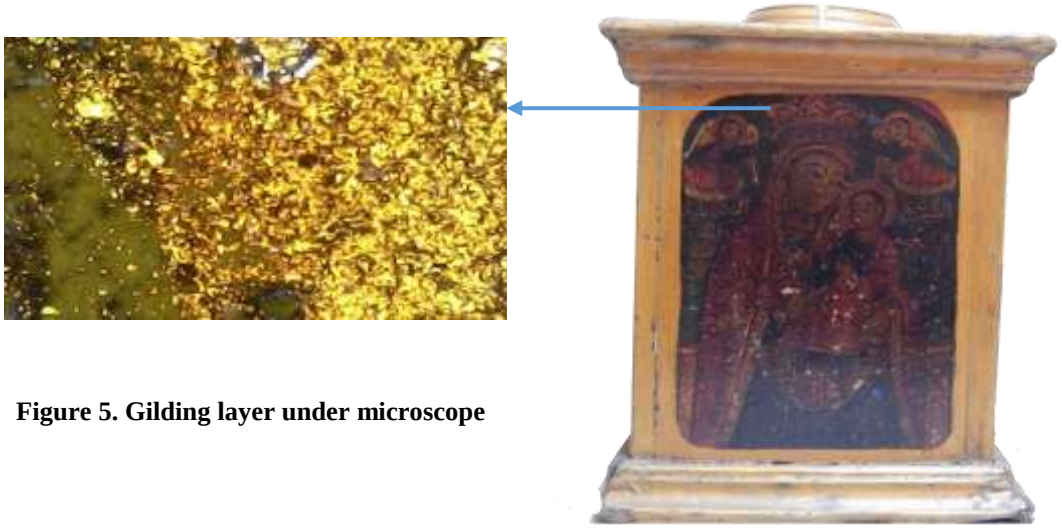


Figure 5. Gilding layer under microscope

In addition, an optical microscope **(Fig.6)** was employed to examine the degradation phenomena affecting the paint layer and to analyze the artistic technique of the iconographer Anastasi Al-Rumi. This examination was conducted using a Leica S9I stereo zoom microscope, equipped with a built-in camera. The imaging was performed in the following format and settings:
Resolution: 720p (1280 × 720), Aspect Ratio: 16:9**,** Exposure: 151.0 ms, Gain: 5.0×, Gamma: 0.45.

Figure 6. Deterioration aspects under the optical microscope.

Analytical Study for Material Identification

Restoration of icons are based on scientific analysis for their chemical composition. This will lead to avoid any potential of incompatible of the added materials with the original. (Elserogy,2019)

To non-destructively identify the elemental composition of the pigments and the preparation layer, a handheld X-ray fluorescence (XRF) spectrometer was employed. This technique ena

The purpose of the analysis was to identify the basic components of the icons, characterize the materials used in their preparation and to diagnose the nature of the damage to the icons before treatment and restoration. Prior to discussing and interpreting the resulting spectrum, it is worth mentioning that the selected spectrums are the most significant. Bled in-situ analysis of the constituent elements without causing damage to the artwork. (Elserogy,2018)

The results obtained from the analytical techniques revealed the following composition of the colorants used in the icons **(Fig.7):**

- The blue pigment was identified as ultramarine blue, with the chemical composition: $(Na,Ca)_8(AlSiO_4)_6(SO_4.S.Cl)_2$.
- The white pigment was found to be lead white, with the chemical composition: $2PbCO_3 \cdot Pb(OH)_2$.
- The red pigment was determined to be a mixture of cinnabar (HgS) and red lead (Pb_3O_4).
- The yellow pigment was identified as orpiment, chemically represented as: (AS_2S_3).
- The green pigment was found to be a mixture of orpiment (As_2S_3) and ultramarine blue $(Na,Ca)_8(AlSiO_4)_6(SO_4 \cdot S \cdot Cl)_2$.
- The black pigment was identified as carbon black.
- The brown pigment was a mixture composed of red pigments (cinnabar (HgS)) and (red lead (Pb_3O_4)) combined with carbon black**.**
- The analysis of the ground layer revealed that it is composed of a mixture of calcium carbonate ($CaCO_3$) and hydrated calcium sulfate (gypsum) ($CaSO_4 \cdot 2H_2O$).

Figure 7. The most famous Pigments in the Chalice Chair Icons

https://www.mindat.org/min-2330.html https://www.mindat.org/gm/1052

In addition, a Fourier Transform Infrared Spectroscopy with Attenuated Total Reflectance (FTIR-ATR) system was used, operating within a spectral range of 400–4000 cm^{-1}**.** This analysis allowed for the identification of the binding medium used in the paint layer, the binder material within the ground layer, and the varnish applied as a protective isolating coating against environmental factors.

The analytical results indicated that egg yolk was used as the binding medium for the pigments. Additionally, animal glue was identified as the adhesive material used in the preparation of the ground layer. Furthermore, shellac varnish was applied as a protective coating over the paint layer **(Fig.8).**

Figure 8. (a) Lac on host plant, (b) Scraped lac, (c) Lac dye, (d) Seedlac, (e) Shellac and (f) Button lac and other products (value-added) obtained from lac. (Thombare.2022)

CONSERVATION METHODOLOGY:

Before any intervention of conservation and restoration of icons on wood, it is necessary to make a scientific documentation containing physical, chemical and biological analyses, consolidation and cleaning tests, as well as a written, photographic and drawn 2nd International Scientific Forum, ISF 2014 11-13 December 2014, Tirana, Albania Proceedings 117 documentation. The documentation must be revealing the scientific nature of the restoration, and also highlight the technological aspects of icons, the state of preservation and the conservation - restoration methodological operations performed on the studied objects. (Pădureț u,2014)

Consolidation Process

It was observed that the paint layer in several areas of the icons exhibited severe flaking, with some sections nearly detached from the ground layer. This condition posed a high risk of pigment loss in the form of detached flakes. Therefore, consolidation was carried out as a preliminary step prior to any mechanical cleaning, to ensure the cohesion of the paint layer and prevent the loss of original material.

The consolidation process was performed using a **7**% gelatin glue solution treated with a fungicide**.** Tissue paper was applied to assist in securing the flaking areas during treatment. In certain sections of the icons, gelatin glue was also injected to reinforce the adhesion between the paint layer and the wooden support **(Fig.9).**

Figure 9. During Consolidation Process and fixing of fragments

Mechanical Cleaning Process

During this stage, unwanted surface deposits were carefully removed from the paint layer using soft camel hair brushes, which possess specific properties that help avoid scratching or abrading the painted surface. The primary goal of this process was to break the adhesion between the surface dirt and the paint layer. Mechanical cleaning is considered one of the safest cleaning methods, as it does not induce any chemical alterations or visual changes to the pigments in the paint layer.

The Use of Green Solvents as a Modern Technique in Varnish Removal

Chemical cleaning was undertaken to remove the aged, discolored shellac varnish layer**,** which had lost much of its original optical and protective properties. The varnish had darkened to a deep brown tone and had accumulated significant amounts of dust and soot**.** In some areas, the soot was found in compact masses fused with the varnish layer, obscuring underlying decorative details and iconographic features.

Therefore, the removal of this deteriorated layer was essential to recover the visual clarity of the icon and prepare the surface for the application of a new protective varnish.

Prior to cleaning, solubility tests were conducted to assess the sensitivity of the paint layer to the proposed solvents. This step ensured the selection of the most appropriate cleaning agents that would not cause any negative effects on the original pigments.

The growing concern over both actual and potential health risks faced by conservators across all areas of cultural heritage has emphasized the need to develop new strategies for replacing

toxic solvents with alternatives that are virtually non-toxic. Particular attention has been given to replacing traditional organic solvents with more environmentally friendly substitutes**.**

In recent years, the conservation sector has shown increasing interest in formulating green solvents specifically designed for the removal of aged varnish layers. This shift reflects a commitment to adhering to European Union directives on hazardous chemicals, and to promoting safer, more sustainable practices in conservation treatments.

Green Solvents Used for Varnish Removal in the Chalice Chair Icons

Based on a review of several studies concerning the application of green solvents in varnish layer treatment, two solvents were selected for their proven effectiveness and safety—both for the artifact, the conservator, and the environment. These solvents have been validated through multiple experiments in the conservation field.

The selected solvents are Dimethyl Carbonate (DMC) and Ethyl Lactate, both recognized for their low toxicity and environmental compatibility. A test model was prepared, replicating the same materials and structure of the chalice chair icons, in order to evaluate the performance of these solvents prior to their application on the original artwork (**Fig.10**).

Figure 10. The Application of the selected green solvents on a test model

<u>Dimethyl Carbonate</u>

Dimethyl Carbonate (DMC) is a highly versatile and environmentally benign compound that offers a sustainable alternative to traditional reagents such as methyl halides (including dimethyl sulfate) and phosgene, typically used in methylation and carbonylation reactions. Its chemical reactivity is notably tunable: at moderate temperatures (around 90 °C), DMC primarily facilitates methoxy carbonylation, while at elevated temperatures, it effectively promotes methylation of a wide range of nucleophiles.

One of the key advantages of DMC lies in its remarkable selectivity**,** particularly in reactions involving substrates prone to multiple alkylations—such as CH_2 -active compounds and primary amines—where it enables highly selective mono-C- and mono-N-methylation**.** Furthermore, DMC is now industrially produced through clean, sustainable processes, and it is recognized for its low toxicity, biodegradability, and minimal environmental impact**,** making it an exemplary green solvent for pollution-preventive chemical synthesis. (Tundo,2002)

Dimethyl Carbonate (DMC) is an acyclic alkyl carbonate that is industrially synthesized via the catalytic oxidative carbonylation of methanol**,** utilizing a green production process developed by Enichem (Italy) and UBE Industries (Japan)**.** Over the past few decades, DMC has gained significant importance in the chemical industry due to its exceptional versatility as both a reagent and a solvent, as well as its favorable safety and environmental profile**.**

DMC is fully biodegradable, non-irritating**,** and exhibits no mutagenic effects through either dermal contact or inhalation. These characteristics contribute to its classification as a low-toxicity compound with minimal health and environmental risks. Notably, in 2009, the U.S. Environmental Protection Agency (EPA) officially excluded DMC from the list of volatile organic compounds (VOCs)**,** recognizing its negligible photochemical reactivity and minimal role in the formation of photochemical smog. (Samorì,2015)

Ethyl Lactate

In recent years, the synthesis of alkyl esters of lactic acid (alkyl lactates) has attracted much attention because they can be obtained from renewable resources. They are currently produced from lactic acid and alcohols (methanol, ethanol, butanol) using mineral acids as catalysts, with the consequent technological and environmental hazard **(Fig.11).** Several works describe the synthesis by heterogeneous catalysis using Amberlyst 15, Dowex 50W and heteropolyacids, but the process is equilibrium-limited reaching conversions of just 35% [1–3]. Alkyl lactates are high boiling point liquids used as solvents and plasticizers for cellulose plastics and vinyl resins, among other many applications. They also take part in cosmetic and herbicidal formulations and are used as skin whitening products. In particular, ethyl lactate (EL) is widely used as a green solvent to replace chlorinated hydrocarbons. It presents environmental, technological and economic advantages for many industrial applications. It is biodegradable, harmless, recyclable and non-corrosive. In addition to the above-described uses of alkyl lactates, EL is used in pharmaceutical formulations for the treatment of acne and seborrhea. (Pighin,2016)

Numerous studies have demonstrated the effectiveness of this green solvent in comparison to conventional petroleum-based solvents. It has been successfully applied in various industrial and conservation contexts, including graffiti removal**,** cleaning of metal surfaces, and the efficient elimination of greases, oils, and adhesives**.** Furthermore, it has proven to be safe and effective for cleaning artworks, both when used neat and applied via swab**.** Its performance as a cleaning agent is notable for leaving minimal to no residues or surface films**,** making it an ideal solvent for delicate surfaces**.** (ELattar,2022)

Figure 11. Illustration of Ethyl lactate lifecycle

By applying the solvent in the form of a gel, it is possible to control the solvent's interaction with the surface, thereby reducing the solvent's penetration into the paint layer. This approach minimizes the risk of solvent absorption by the paint, enhancing the safety and precision of the cleaning process.

Dimethyl Carbonate (DMC) and Ethyl Lactate solvents, both at 99% purity, were procured from LOBA CHEMIE PVT. LTD. Several agar gel compress at a concentration of 1.5% were prepared, incorporating each solvent at varying concentrations of 30%, 50%, and 70%. This work was conducted in collaboration with the National Research Centre.

The gel compress was applied in square shapes measuring 4 × 4 cm onto the targeted areas. Sandbags were placed on top to exert gentle pressure, and the compress were left in place for ten minutes. Afterwards, the gel was carefully removed using metal spatulas, followed by surface cleaning with a 30% ethanol solution in distilled water **(Fig.12).**

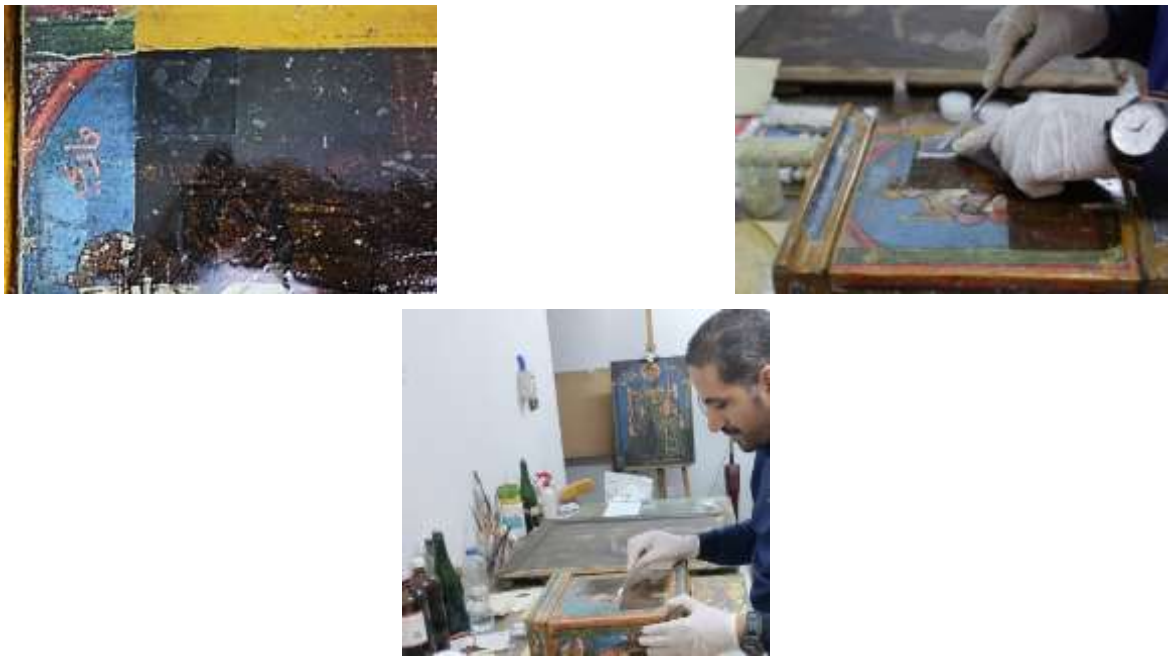


Figure 12. During the cleaning by green solvent with Compress

Completing of the Ground Layer

Based on the analytical results previously conducted on the ground layer of the icon, it was determined that the original material consisted of calcium carbonate combined with animal glue as the binding medium. Accordingly, the same composition was prepared using calcium carbonate and 5% animal glue**,** in order to reintegrate and reconstruct the missing areas of the ground layer **(Fig.13)**.

Figure 13.the object during and after the filling process process

Retouching Process

Following the complete drying of the reconstructed ground layer, the retouching process was carried out using Winsor & Newton water colours, a widely recognized European brand known for its high pigment density and color stability. This particular type of watercolor was selected based on the analytical results of the inorganic pigments identified in the original iconography.

Winsor & Newton Ltd. has been one of the main fine art products providers since its establishment in1832, being responsible for the manufacture of a wide assortment of materials ranging from oils and pigments to brushes and papers. All the items produced over the years have been indexed in a comprehensive historical archive. Original Winsor & Newton handbooks are a powerful resource which can offer insight into the world of artists' materials,

and knowledge of artists' choices through the identification of substances employed to obtain particular colors **(Fig.14).** (Pozzi,2013)

For the retouching application, the Italian "Tratteggio" technique was adopted, which is considered the most appropriate method for this case. This technique—also referred to in Arabic as *"*tahsheer*"* or parallel hatching—involves applying color in fine, linear strokes to visually reintegrate losses while maintaining visual differentiation under close inspection. The retouching was executed with careful attention to tonal transitions, starting with light, cool tones and gradually building up to darker, warmer tones (light to dark, from cold to warm), in accordance with conservation best practices.

Figure 14. Retouching Process by Tratteggio technique

Varnishing Process

The application of a varnish layer serves as a protective shield for the painted surface, safeguarding the pigments from environmental fluctuations. Additionally, re-varnishing contributes to the optical reintegration of the icon by providing a visually unified surface and enhancing color saturation through the refractive properties of the varnish layer.

Given these objectives, it was essential to select a suitable varnish that fulfills both protective and aesthetic requirements. Based on the results obtained from the experimental phase, Dammar varnish was identified as the most appropriate choice **(Fig.15).** It is a natural resin varnish widely used in the conservation of artworks across Europe and the United States, due to its favorable aging characteristics and compatibility with traditional painting materials.

Figure 15. During the varnishing of the object

Dammar varnish was introduced into Europe and America during the nineteenth century, but the chronology of its use in various countries is still imperfectly understood. New information from unpublished manuscripts shows that dammar was used by painters in the United States by the middle of the nineteenth century—one American painter wrote that dammar was 'much used in the United States' in 1851—and by 1860 it was available from at least three American color men. The use of dammar may have been more widespread in the

United States at this time than it was in Britain, perhaps because of connections between German and American painters **(Fig.16).** (Mayer,2002)

https://www.shutterstock.com/image-photo/resin-dammar-gum-flowing-trunk-agathis-1184379979?dd_referrer=https%3A%2F%2Fwww.google.com%2F

Figure 16. Dammar tree and gum shape

Figure 17. The Chalice Chair icons before and after the Conservation process

After the maintenance and restoration work, it is always deemed necessary for every object of historical importance to be kept in a place with regulated conditions, for its further survival in time, whether it is a museum or a storage space or a temple **(Fig.18).** (Stavroula,2024)

Figure 18. Reuse OF Chalice Chair In religious rituals

CONCLUSION

This study highlights the effectiveness of adopting green chemistry principles in the field of cultural heritage conservation, through the successful use of ethyl lactate and dimethyl carbonate for the removal of a deteriorated varnish layer from a 19th-century chalice chair of significant liturgical and historical value. These green solvents, formulated in a gel matrix, allowed for controlled application and safe cleaning action, minimizing solvent penetration and mechanical stress on the aged wood surface. The gel system proved essential in localizing the treatment area, enhancing the precision of the cleaning process, and ensuring the stability of the underlying original materials.

The adoption of these environmentally responsible materials not only contributed to the sustainability of the conservation process but also demonstrated the feasibility of replacing traditional toxic solvents with safer, biodegradable alternatives—without compromising on the efficacy or the aesthetic outcome of the treatment. No negative physical or chemical effects were observed on the artifact following the intervention, confirming the suitability of these green solvents for sensitive heritage objects.

Moreover, the conservation process restored the object's functionality and spiritual value. After meticulous treatment and stabilization, the chalice chair was reintegrated into active liturgical use within the church, allowing the artifact to reclaim its original role in the religious and cultural life of the community. This reinforces the importance of combining scientific innovation with traditional context, ensuring that restoration efforts not only preserve material authenticity but also respect the intangible heritage and continued ritual significance of the object.

In conclusion, this study serves as a model for future conservation practices, where sustainable materials, gel-based delivery systems, and a context-sensitive approach can together provide effective, ethical, and environmentally sound solutions for the preservation and revitalization of religious heritage artifacts.

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