PHYSIOCHEMICAL CHARACTERIZATION OF COPTIC JESUS CHRIST ICON [CHURCH OF SAINT MERCURIUS, EGYPT]

BY

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ABSTRACT

[Ar] **التوصيف الفيزيوكيميائي لايقونة السيد المسيح ، كنيسة ابى سيفين ،جمهورية مصر العربية**

قدم هذا البحث التوصيف الفيزوكيميائى لأيقونة قبطية من القرن التاسع عشر من كنيسة القديس مرقوريوس حيث تمثل مثال فريد من هذه الايقونات التي تعود الى العصر القبطي. ولكى يتحقق الغرض من الدراسة تم استخدام بعض الوسائل الفحص والتحليل لشرح وايضاح كل مظاهر التلف مما يساعد في التوثيق الأثري للأيقونة، وقد يعطي ذلك تفسير عن ميكانيكية تلف الأيقونات الأثرية ،كما كشف الفحص البصري أن الأيقونة القبطية تتكون من أربع طبقات: دعامة لوح خشبي ، وطبقة تحضير ، وطبقة طلاء ، وبقية طبقة الورنيش ، وقد عانت كل طبقة من ظروف البيئة المحيطة، وظهر ذلك في العديد من علامات التلف. تم فحص وتحليل العينات المأخوذة من أماكن مختلفة عن طريق الفحص باستخدام الميكرسكوب الإلكتروني الماسح المجهز بكاشف الأشعة السينية المشتت للطاقة (EDS) والتحليل الطيفي بالأشعة تحت الحمراء فورير «FTIR » وحيود الأشعة السينية « XRD». أظهرت نتائج التحليل الطيفي بالأشعة فوق الحمراء للعينة الأثرية أن الطبقة الأرضية تتكون من الجبس والطباشير والغراء الحيواني كمادة رابطة. كما أشارت أطياف «XRD» إلى مصادر الأصباغ المستخدمة في رسم الأيقونة، وتم تحديد المادة الملونة الحمراء من أحمر الرصاص، وبالنسبة لمادة اللون الازرق من الالترامارين ، و المادة الملونة البيضاء من الرصاص الأبيض ، والمادة الملونة البنية كانت من أكسيد الحديد، بالإضافة إلى استخدام صفار البيض كمادة رابطة في طبقة الطلاء والورنيش المستخدم كان من راتنج الشيلاك. ثم تم الكشف عن حالة التدهور، وفقًا لنتائج «SEM »، والتي أظهرت بوضوح وجود بقع وسناج وشمع وتشققات وثقوب في الطبقة السفلية من الأيقونة، وتراكم الغبار وطبقات الورنيش الداكنة على الطبقة العليا.

[EN] In this paper ,we present a physiochemical analysis of a Coptic icon from church of Saint Mercurius that back to the 19th century. Identified deterioration phenomena were illustrated using various examination and analysis tools in order to fulfill the study's objectives. So as to find an explanation for how ancient icons were damaged. The visual inspection revealed that the Coptic icon is made up of four layers: the wooden panel support, the preparation layer, the painting layer, and the remaining varnish layer. Each of these layers suffered from surrounding environment, appearing in various signs of damage in the visual assessment. Samples taken from different places were investigated and analyzed by using scanning electron microscope equipped with an energy dispersive X- ray detector (EDX), FTIR, and X- Ray diffraction. The results of FTIR analysis revealed that the ground layer consists of gypsum, chalk and animal glue. XRD spectra confirmed that the red pigment was red lead, blue pigment was ultramarine, white pigment was white lead, and brown pigment was iron oxide (burnt sienna), in addition to the use of the egg yolk as a binder in the painting layer and the varnish was shellac resin. The state of deterioration was detected, according to the SEM results, which show clearly the presence of stain, soot, wax, cracks and lacunae at the lower layer of the icon, and accumulation of dust and darkening of varnish layers on the upper layer.

KEYWORDS: Icon, St. Mercurius, SEM- EDX, FTIR, XRD, Coptic, church.

I. INTRODUCTION

Saint Mercurius was born to Christian parents during a time of intense persecution, he was an officer in the Mareusian army, and Saint Mercurius was titled «Abi Shefin» because he vanquished the entire Barbarian army with the sword given to him by the Lord's angel while serving as a commander in the Mareusian army. He also rejected the worship of other gods[1]. Numerous churches across the entire nation bear the name of St. Mercurius, who is regarded as one of the most well-known martyrs in the history of the Coptic Church in Egypt's Orthodox churches[2]. The church of St. Mercurius is situated in Tamouh, Giza, and its style components were influenced by the region's environment and climate[3].

Art historians classify the Coptic period as a Coptic art produced by Egyptian Christians in the late Roman, early Byzantine, and early Arab eras[4]. Icon [ηκονα] is a word that refers to a picture or a portrait. It included historical occurrences connected to Biblical history, saints, holy Christians, and figures from Christian theological conceptions[5]. They are usually placed in centers of worship such as monasteries and churches for the worshipers to honor them by touching or adoring gestures and are generally made out of painted wood[6]. Additionally, because it is holy and sanctifying, the icon plays a variety of roles in Christian worship and church[7]. Every conservator finds the archaeological studies of Coptic icons difficult since they are made up of numerous strata with various physical and chemical characteristics, conflicting behaviors, and environmental deterioration factors[8].

The icon artwork can be damaged by a number of deterioration factors, including temperature, light, humidity, air pollution, and insects[9]. Therefore, to understand the technical process by which the artist created the icon[10]. It is required to examine and analyze the icon's constituent parts. Which serve as a reference for the researcher and conservator to determine the extent of damage, the way in which damage occurred, and the elements of icon layers. The technique for Coptic icons painting depends on painting on wooden panels made from one or several planks held together with wooden pegs and supported by wooden traverses, nailed on the reverse with iron nails[11]. which is a well-known technique for Coptic icon painting. Support, ground, paint [pigment and binder] and varnish layers are the icon's fundamental layers.

Characterization of the icon materials gives us crucial knowledge about the condition of the icon and the impact of age and environmental factors.

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[1] SHENOUDA 2019: 3.
[2] HENIN 2022: 128-143.
[3] MORGAN 2016: 14-36.
[4] MEDHAT et al 2015: 152.
[5] SKALOVA & GABRA 2003: 124.
[6] MALATY 1998: 1-10; PUICA 2006: 37-50
[7] BALIGH & SHALABY 2014: 2; PRIESS 2019: 281.
[8] ELSAYED 2019: 241.
[9] YOUSRY et Al. 2015: 492; ISSA et Al. 2015: 72.
[10] MAHMOUD 2018: 197.
[11] MOHAMED et Al. 2019: 4685.

There are many factors that make the process of identifying the icon layers difficult such as the use of small quantities and the lack of sample purity[12]. The purpose of this study is to characterize the components of a Coptic icon painting that the conservator might use while choosing potential conservation methods.

II. Material and Method

1. Sampling

Six samples from each of the four pigments: brown, red, blue, and white were taken, to determine the pigment and binder used in the icon. Samples were collected from the white ground. The previous samples were prepared before examination and analysis by visual examination, SEM, FTIR and XRD. In general Examination and analysis procedures should be done by non-invasive, non-destructive methods, because in most cases, only micro-samples [a milligram] are permitted for analysis[13].

2. Visual Examination

To highlight the artwork and an icon's technical aspects and assess its degree of degradation, numerous photographs were taken of the object under study, to determine its state of damage. And the required restoration in order to keep it in a condition that matches the value and significance of such artifacts.

3. Scanning Electron Microscope [SEM] Equipped with [EDX]

Samples were examined by SEM [scanning electron microscope] using an EDX unit, to characterize the morphological appearance of the layers of the icon. And determine its chemical composition. The instrument was FEL QUANTA FEI Philips– Holland, 3D 200i, coupled with EDX unit Thermo Fisher path finder (conservation lab at the Grand Egyptian Museum in Giza, Egypt).

4. Fourier Transform Infrared Spectroscopy [FTIR]

The device, a Bruker optics model vertex 70 with a mid-infrared source, which has a crystal diamond and does not require sample preparation, measured the spectra of samples in the spectral rang of (4000-400 cm^{-1}). The results were compared to those from the standards data in the lab at the Grand Egyptian Museum in Giza, Egypt.

5. X-ray Diffraction

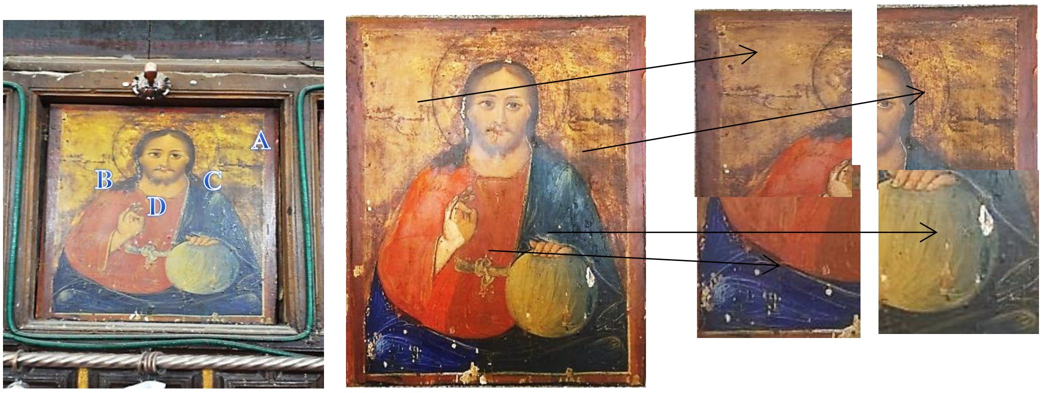
XRD analysis was employed to determine the chemical components of the colored pigments (40kV, 30mA). Measurements were made in 25° with a 0.02° step (Projects Sector Ministry of Antiquities and Tourism, Cairo, Egypt). It was performed by a Philips X'Pert PW3195 Diffractometer, using Cu $K\alpha$ radiation (40kV, 30mA).

[12] Şerifakia et Al. 2009: 303.
[13] Brania 2010: 1-39.

III. RESULTS AND DISCUSSION

1. Visual Examination

The icon has been fixed in the iconostasis's center. The icon was painted in the 19th century by the Jerusalem artist Hafez Shamndi[14]. And is composed of four layers (wooden support layer, ground layer, paint layer, and varnish layer). The varnish was applied in layers over the icon's surface. Traces of unprofessional restoration (over painting). There are also numerous losses in the preparation layer, paint layer, and gilding layer. in addition to strange dark spots covering the paint **[FIGURE 1].**



[FIGURE 1]: Overview of Jesus Christ icon, damage signs and missing parts all over the Coptic icon. ©Done by researchers

2. Scanning Electron Microscope [SEM] Equipped with [Edx]

The SEM photomicrograph and microanalysis data were used to evaluate the damage mechanism, which reflects the Coptic icon's surroundings. The micrograph photo revealed very brittle, cracked, cleaved outer layer contaminated with dirt, and a wooden inner layer, appearing to be in a good state **[FIGURE 1].** SEM-EDX microanalysis of a few samples revealed that Mg was present in most cases. Which, refer to Kaolinite and Chlorite (natural clay compounds accumulated on the pigment samples)[15].

The microanalysis of brown pigment indicated the presence of 3.96 % lead, 0.79 % aluminum, 0.84 % sodium and 0.69 % silica and 39% oxygen. Numerous researchers have demonstrated, that the color may be created by combining ochre yellow, blue ultramarine, and red lead **[FIGURE 2] & [TABLE 1]** Some studies suggested that brown pigment is frequently derived from iron oxide, also known as «burnt sienna»[16]. And the observation of unexpected little percentage of lead may be explained due to impurities from the priming layer which was mainly composed of anglesite ($PbSO_4$)[17].

[14] HENIN et Al. 2022: 133
[15] BARTON & KARATHANASIS 2016: 187-192.
[16] CLARK 2002: 7–20.
[17] ŞERIFAKIA et Al. 2009: 303.

The red pigment spectrum revealed the presence of 4.95 % lead, 2.99 % sodium, 1.01% calcium, 1.89% aluminum, and 6.61% chlorine, which are refer red lead (II) oxide (Pb_3O_4) and some impurities **[FIGURE 3]& [TABLE 2]**. It is noticeable that the lead red was converted to black shades, as a result of to the conversion of red lead (Pb_3O_4) into (Pb_2O_3) by the effect of deterioration factors such as «thermal ageing»[18], and the presence of chlorine salts oxide[19]. The use red lead dates back to the Roman era in the first century AD when it was utilized to paint linen shrouds for burial purposes[20]. Additionally, a wide range of artworks, such as wall paintings, manuscript illuminations, and canvas paintings, were painted with it [21].

Microanalysis of blue pigment revealed the presence of ultramarine blue pigment $(Na,Ca)_8(AlSiO_4)^6(SO_4.S,Cl)^2$, which is proven by the presence of 10.55%sodium, 29.32% calcium, 8.32% aluminum and 10.99% silica, **[FIGURE 4] & [TABLE 3]**.

Ultramarine was the finest and most expensive blue that could be used by painters[22]. Lapis lazuli has been used as a source of Ultramarine blue pigment in artwork since at least 3000 BC. Paintings were enriched in their artistic value when ultramarine blue was existed on the artist's palette[23]. It was determined via micrographs that several areas of the surface of the pigment sample had accumulated blackness, black soot, and wax. Interact in some way with an oil binder, which affects how its chemistry , According to **[FIGURE 4]**[24].

The white pigment in **[FIGURE 5] & [TABLE 4]** was composed of 53,74% Pb, 20.37 % C, 21.92% O, 1.71% Al and 2% Fe, which are refer to white basic lead carbonate $2PbCO_3{\cdot}Pb(OH)_2$. White lead is a naturally occurring mineral known by the name hydrocerussite[25]. From antiquity until the 19^{th} century, lead white manufacture remained mostly unchanged[26]. On the surface of the white pigment, there were macro and micro cracks of different width and depth[27], Air pollution and the presence of hydrogen sulfate caused white lead pigment to turn into dark lead sulfate[28]. In addition to superficial sandy deposits accompanied by loss of paint[29].

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[18] KUMAR et Al. 1986: 415–418.
[19] ANGLOS 2001: 186-205.
[20] ABDEL-GHANI 2009: 355; WALTON & TRENTELMAN 2008: 845 – 860.
[21] AZE et Al. 2008: 145–154.
[22] LOTUT 2018: 1-18.
[23] ACETO et al 2013: 4184
[24] FRISON & BRUN 2016: 41-55.
[25] GRANT 2001: 4439- 4442.
[26] MAKSOUD et Al. 2020: 102085
[27] LUSSIER & SMITH 2007: 41-53.
[28] GLIOZZO & IONESCU 2022:14-35.
[29] KARYDIS 2006: 1-24; BUDU 2018: 1-9.

Element	Wt%	At %
C k	51.51	61.80
O k	39.45	35.61
Na k	0.84	0.52
Al k	0.79	0.37
Si k	0.69	0.37
S L	0.81	0.37
Ca L	1.94	0.70
Pb M	3.96	0.28

[TABLE 1]: The SEM-EDX micro analysis of brown pigment from archaeological icon.

Element	Wt %	At %
C k	23.02	15.47
O k	63.70	57.01
Na k	2.99	2.33
Mg k	1.01	0.75
Al k	2.85	1.89
S k	2.24	3.51
Cl K	6.61	3.33
Ca k	1.89	4.23
Pb L	4.95	0.43
Fe L	1.37	0.44

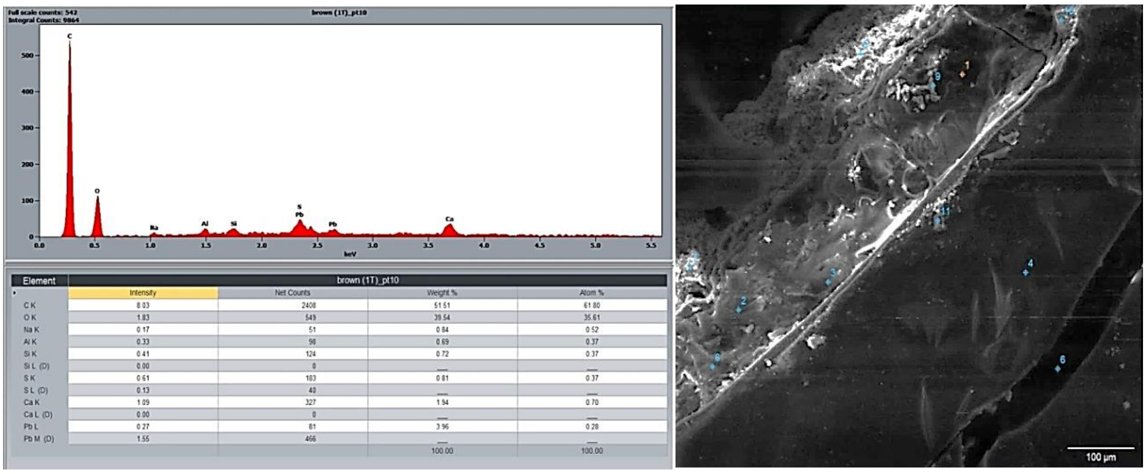
[TABLE 2]: The SEM-Edx micro analysis of red pigment from archaeological icon.

Element	Wt.%	At %
C k	29.32	39.76
O k	40.54	41.26
Na k	10.55	7.47
Al k	8.32	5.02
Si k	10.99	6.37
S L	0.28	0.12

[TABLE 3]: The SEM-EDX micro analysis of blue pigment from archaeological icon.

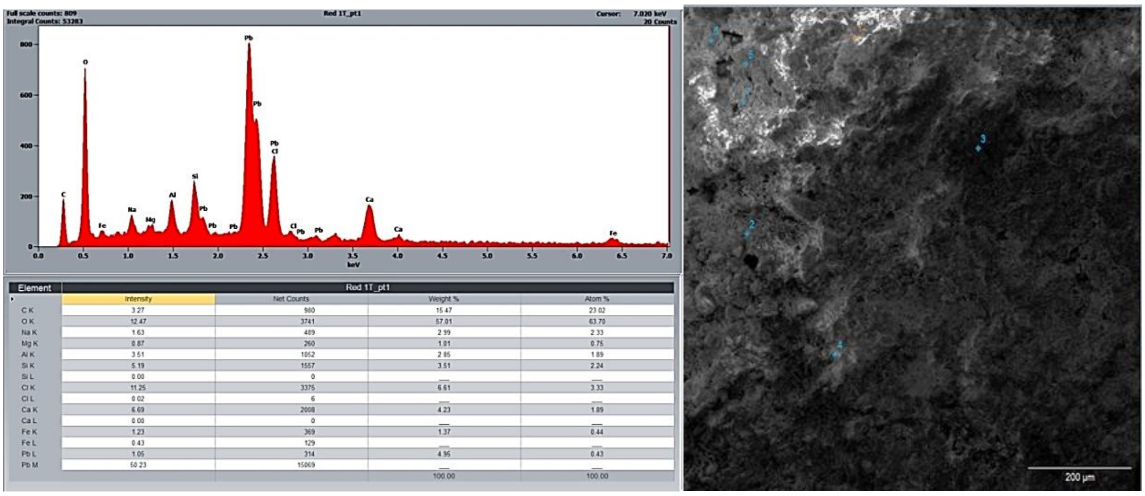
Element	Wt%	At %
C k	20.73	49.93
O k	21.92	39.64
Al k	1.90	2.04
Fe L	1.71	7.51
Pb L	53.74	0.09

[TABLE 4]: The SEM-EDX micro analysis of white pigment from archaeological icon



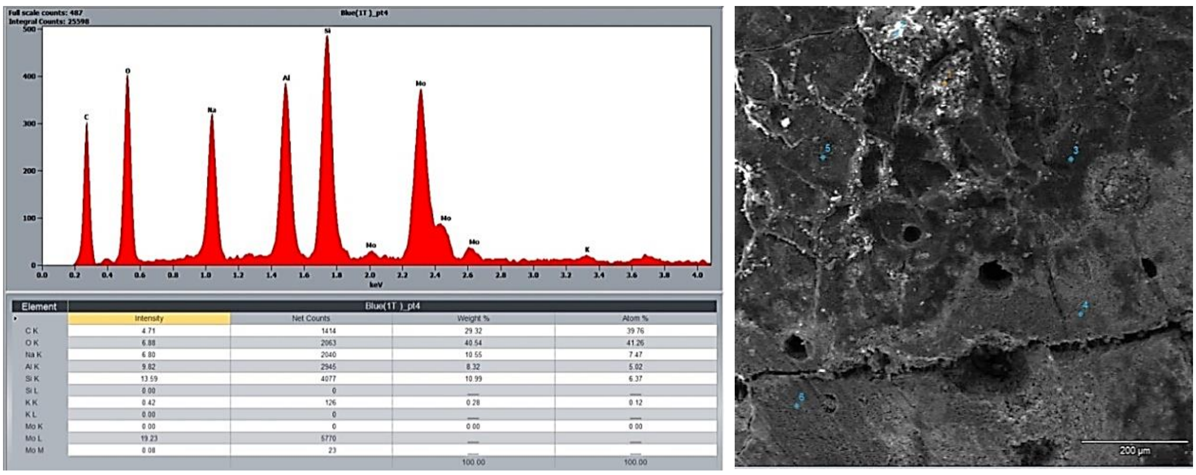
Element	brown (1T)_pt10			
	Intensity	Net Counts	Weight %	Atom %
C K	8.03	2408	51.51	61.80
O K	1.83	549	39.54	35.61
Na K	0.17	51	0.84	0.52
Al K	0.33	98	0.69	0.37
Si K	0.41	124	0.72	0.37
Si L (D)	0.00	0	—	—
S K	0.61	183	0.81	0.37
S L (D)	0.13	40	—	—
Ca K	1.09	327	1.94	0.70
Ca L (D)	0.00	0	—	—
Pb L	0.27	81	3.96	0.28
Pb M (D)	1.55	466	—	—
			100.00	100.00

[FIGURE 2]: SEM- EDX results of brown sample indicate the presence of lead oxides (Pb_2O_3).



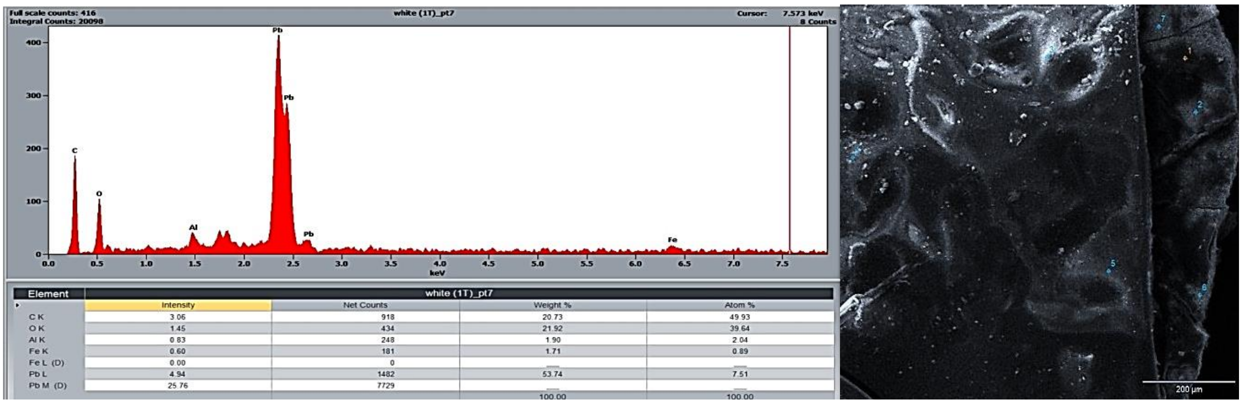
Element	Red 1T_pt1			
	Intensity	Net Counts	Weight %	Atom %
C K	3.27	980	15.47	23.02
O K	12.47	3741	57.01	63.70
Na K	1.63	489	2.99	2.33
Mg K	0.87	260	1.01	0.75
Al K	3.51	1052	2.85	1.89
Si K	5.19	1557	3.51	2.24
Si L	0.00	0	—	—
Cl K	11.25	3375	6.61	3.33
Cl L	0.02	6	—	—
Ca K	6.69	2008	4.23	1.89
Ca L	0.00	0	—	—
Fe K	1.23	369	1.37	0.44
Fe L	0.43	129	—	—
Pb L	1.05	314	4.95	0.43
Pb M	50.23	15069	—	—
			100.00	100.00

[FIGURE 3]: EDX micro-analysis results of red pigment indicate the presence of red lead oxides (Pb_3O_4).



Element	Blue(1T)_pt4			
	Intensity	Net Counts	Weight %	Atom %
C K	4.71	1414	29.32	39.76
O K	6.88	2063	40.54	41.26
Na K	6.80	2040	10.55	7.47
Al K	9.82	2945	8.32	5.02
Si K	13.59	4077	10.99	6.37
Si L	0.00	0	—	—
K K	0.42	126	0.28	0.12
K L	0.00	0	—	—
Mo K	0.00	0	0.00	0.00
Mo L	19.23	5770	—	—
Mo M	0.08	23	—	—
			100.00	100.00

[FIGURE 4]: SEM-EDX microanalysis of blue pigment indicate the presence of ultramarine $(Na ,Ca)8(Al SiO_4)_6(SO_4 S, Cl)_2$.



[FIGURE 5]: SEM-EDX microanalysis results of white sample indicate the presence of basic lead carbonate $2PbCO_3. Pb(OH)_2$

3. FTIR Analysis

Infrared spectrometry is used for identification of coloring pigments, and binders. Yet there are difficulties, due to the identical chemical composition of many organic compounds, like glue, egg white and yolk, and comparable spectra in the IR range[30].

The spectrum of archaeological medium was compared with the proposed material's reference. The FTIR spectrum showed the presence of amide groups of proteins by observing the NH bending band (between700-1500 cm^{-1}) combined with the C=O bond at the band 1645 cm^{-1}, and CH_2 bond of the methylene group (1500 and1700 cm^{-1}) and C=H methyl group band at the band 2920 cm^{-1}), This proved the use of egg yolk as a medium for pigments[31] **[FIGURE 6]**. The band at 1171 cm-1 is suggested to be a characteristic sign of shellac resin[32] **[TABLE 5].**

Calcium carbonate ($CaCO_3$) produced a strong signal, at the absorption band 1450-1400cm^{-1} , assigned to C=O stretch group, and gypsum ($CaSO_4.2H_2O$) (calcium sulfate) gave a signal at absorption functional group at 983 cm^{-1}, which is assigned to (SO_4)[33].

Furthermore the presence of animal glue as a binder is highlighted by the strong absorption bands in the region of 3401 cm^{-1}, 2920 cm^{-1}, ascribed to amide I (C=O stretching) and amide II (C-N stretching and N-H bending), as well as the peaks connected to methylene groups at band 2929 and 2850 cm^{-1}**[FIGURE 7]**.

Due to thermal ageing, calcium sulfate is thought to occur when preparation layers contain cracks and have missing pieces. The sulphation processes that cause the ground layer to deteriorate, due to the presence of sulphur dioxide (SO2) gas acts as an oxidant and a catalyst, reacting with calcium carbonate to form calcium sulphate when there is a high relative humidity[34]. The FTIR spectra of the Coptic icon's preparation layer showed that it is made of calcite, gypsum, and animal glue **[TABLE 6].**

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30 BERG et Al. 2002: 22-27.

31 VAHUR et Al. 2016: 3373-3379; KHASAWNEH & ELSEROGY 2019: 85-91.

32 DERRICK et Al. 1999: 190; GHANI 2015: 23 - 37.

33 ANBALAGAN et Al. 2009: 226-230

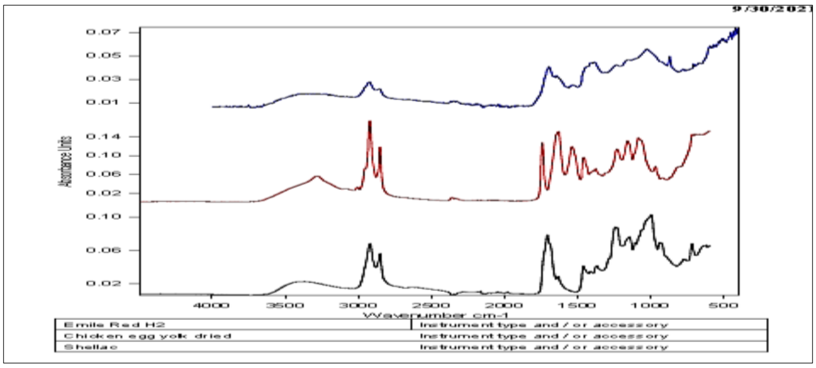
34 PAVLIDOU et Al. 2006: 709-717

Functional group	Egg yolk	Shellac
-CH- stretch	2900cm^{-1}	3100 cm^{-1}
C=O stretch	1750cm^{-1}	1650 cm^{-1}
C-H bending	1380 cm^{-1}	1480cm^{-1}
C-O stretch	-	1171cm^{-1}

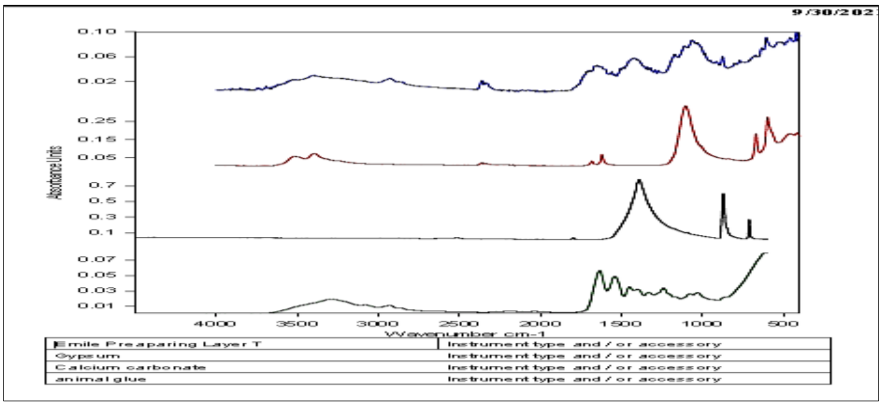
[TABLE 5]: FTIR spectra of a red pigment indicate the presence of egg yolk medium, and shellac varnish.

Functional group	Animal glue	Calcite	Gypsum
-CO- bending	-	875 cm^{-1}	-
-SO_4- stretch	-	-	1140cm^{-1}
S-O bending	-	-	669 cm^{-1}
C=O stretch	1450 cm^{-1}	1425 cm^{-1}	-
-NH- stretch	3401 cm^{-1}	-	-
-CH- Bending	2920 cm $^{-1}$	-	-

[TABLE 6]: FTIR spectra of a ground layer and medium indicating the presence of gypsum, calcite and animal glue as a binder.



[FIGURE 6]: FTIR spectra of archaeological red sample which show egg yolk as a medium binder, shellac as a varnish.



[FIGURE 7]: FTIR spectra of ground layer sample indicate that it consists of gypsum, calcium carbonate, mixed with animal glue as a binder.

4. X-RAY Diffraction Analysis

Ground layer and pigmented samples were used to conduct this investigation; the outcomes of the XRD studied have demonstrated that the ground layer is composed entirely of calcite, gypsum, and animal glue as a binder[35]. XRD pattern of a brown pigment reveals the presence of brown lead **[FIGURE 8]**[36]. XRD spectrum of red pigment as seen in **[FIGURE 9]**, shows that it consists of red lead. The use of ultramarine is seen in the XRD spectrum [FIGURE 10], refers to blue pigment, and the XRD spectra of white pigment showed , that it was composed of calcite **[FIGURE 11]**[37].

It is apparent that the preparation layers are abundant in calcite and quartz. The changes in temperature and relative humidity, mechanical stresses, and the physiochemical characteristics of the sample (mineral content) lead to the conversion of preparation layer components into anhydrite phase, which is weaker and brittle. it results in loss of the preparation layer components, contains large porous areas, flaking of the outer surface layer, and ultimately loss of the original painting structure. Dark areas and cracks can be noted on the surface[38].

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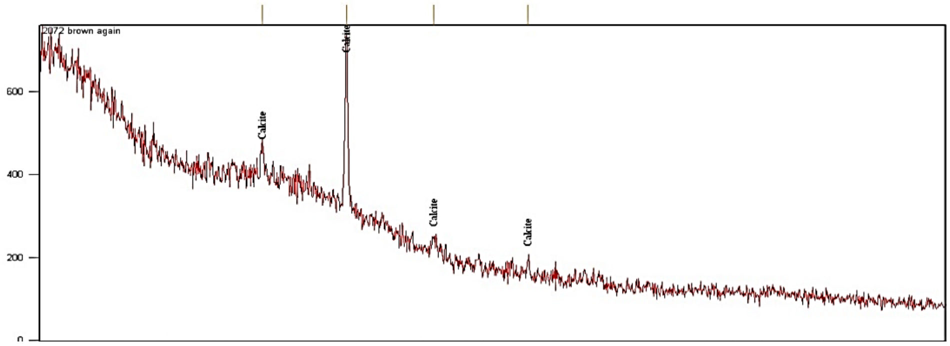
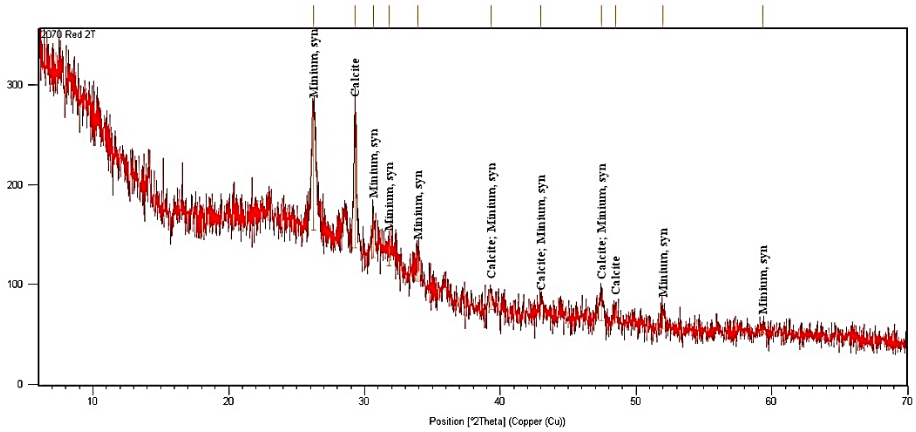
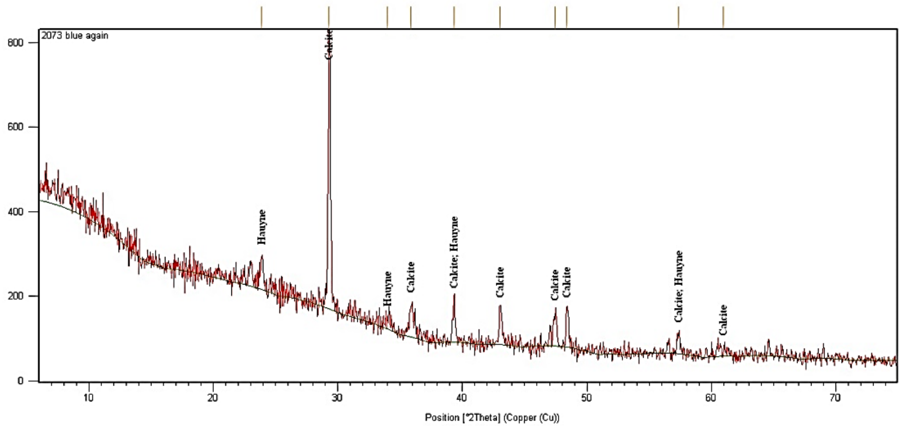
[35] MEDHAT et Al. 2015: 151-161.
[36] HRADIL et Al. 2003: 223–236; HELWIG 2007: 38-109.
[37] BERNARD 1971: 33-121; MAHMOUD 2013: 82; GONZALEZ et Al. 2016: 43-49.
[38] SALLAM 2016: 493-500.



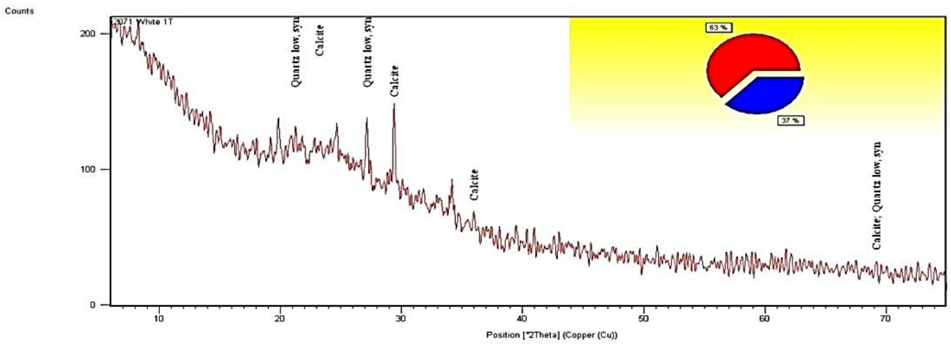
[FIGURE 8]: XRD results of brown pigment indicating the existence of calcite and iron oxide.



[FIGURE 9]: XRD results of red pigment indicating the existence of calcite and red lead.



[FIGURE 10]: XRD result of blue pigment indicated to the existence of calcite.



[FIGURE 11]: The spectra of archaeological white pigment, which prove the use of calcium carbonate, and in addition to quartz.

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	01-072-1937	34	Calcite	-0.100	0.728	$CaCO_3$
*	00-041-1493	23	Iron oxide	-0.139	0.654	Fe_2O_3

[TABLE 7]: Results of XRD spectra of brown pigment.

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	01-072-1937	34	Calcite	-0.100	0.728	$CaCO_3$
*	00-041-1493	23	red lead	-0.139	0.654	Pb_3O_4

[TABLE 8]: Results of XRD spectra of red pigment.

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	01-072-1937	58	Calcite	0.000	0.941	$CaCO_3$
*	00-020-1087	16	ultramarine	0.000	0.126	$Na_{6-8}Al_6Si_6O_{24}S_4$

[TABLE 9]: XRD analysis of blue pigment ,which revealed the presence of calcite in the ground layer and ultramarine pigment.

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	01-086-2334	17	Calcite	0.000	1.001	$CaCO_3$
*	01-083-2472	19	Quartz low, syn	0.000	0.559	SiO_2

[TABLE 10]: XRD analysis of white pigment.

IV. CONCLUSION

The physical and chemical analysis of a holy Jesus icon was described in this work. The icon is a part of the collection of Coptic icons, that can be found in the main sanctuary of the Mercurius church in Giza. Four pigments were found to have been employed to decorate the Coptic icon. SEM-Edx, FTIR, and XRD techniques were used for analysis.

SEM-EDX and XRD microanalysis results reveal that the brown color is made up of iron oxides, while the red, blue and white pigments are made up of red lead, ultramarine, and calcite, respectively.

SEM images revealed numerous deterioration features on the painted icon's surface, including fractures, flaking, blackness, and accumulating layers of soot and dust. According to the XRD analyses, the preparation layers contain gypsum and calcite [calcium carbonate] [calcium sulphate]. According to FTIR spectra, the preparation layer is made up of calcite, gypsum, and animal glue, and the medium used is egg yolk. The analysis of the coloring pigments revealed the existence of several minerals, which may have been the primary factor in the archaeological icon's ability to absorb water and exert pressure on its exterior layer[39].

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[39] ALI & YOUSSEF 2020: 37-52

BIBLIOGRAPHY

ABDEL GHANI, H.:« A Multi-instrument Investigation of Pigments, Binders and Varnishes from Egyptian Paintings (AD 1300-1900): Molecular and Elemental Analysis Using Raman, GC-MS and SEM-EDX Techniques», PhD Thesis, chapter 12, University of Bradford, 2009.

ACETO,M., AGOSTINO, A., FENOGLIO, G. & MARCELLO, P.: « Non-invasive Differentiation between Natural and Synthetic Ultramarine Blue Pigments by means of 250–900 nm FORS Analysis», *Analytical Methods* 5/16, 2013, 4184-4189, DOI: 10.1039/c3ay40583d

ALI, M. & YOUSSEF, M .:« An Analytical Study of a Mural with Colorful Geometric Decoration, Coptic museum, Cairo, Egypt: a case study», *Scientific Culture* 6/3, 2020, 37-52.

ANBALAGAN, G. et al: « Infrared, Optical Absorption, and EPR Spectroscopic Studies on Natural Gypsum», *Vibrational Spectroscopy* 50/2, 2009, 226-230.

ANGLOS, D.: «Laser-Induced Break- down Spectroscopy in Art and Archaeology», *Applied Spectroscopy* 55/6, 2001, 186-205.

AZE, S. VALLET, M. DETALLS, V. GRAUBY, O & BARONNETA.: « Chromatic Alterations of Red Lead Pigments in Artworks: A Review», *Phase Transitions* 81/2-3, 145-154, 2008, DOI: 10.1080/01411590701514326

BALIGH.R & SHALABY.M.: « A Comparison between Coptic Icons in Christian Churches and the Icons of the Monastery of St. Catherine in Sinai », *Bulletin of the Center Papyrological Studies* 31/1, 2014, 1-27, DOI: 10.21608/bcps.2014.24309

BERG, K. J. et Al.:« Darkening and Surface Degradation in 19th- and early 20th Century Paintings–an Analytical Study», In book: *ICOM Committee for Conservation 13th Triennial Meeting*, 2002, 22-28.

BERNARD, K.: «X-Ray Diffraction and the Composition of Lead White», *Studies in the History of Art* 4, 1971-1972, 121–133. https://www.jstor.org/stable/42617728

BRANIA, A.: «Characterization of the Mamluk Painting Materials in Cairo, Egypt: El-Ashraf Bersbay Madrasa (826 A.H/ 1423 A.D)A case study», *Mağallaï Al-Itiḥād Al-ʿām Lil Aṯārīyin Al-ʿarab* 11, 2010, 1-39, DOI: 10.21608/jguaa.2000.2747

BUDU,A.: « The Deterioration and Degradation of Icons with Revetments. Case Studies », Conference: *Sustainable Preservation of Cultural Heritage Collections*, Romania, 2018, 1-9.

CLARK, R.:«Pigment Identification by Spectroscopic Means: an Arts/science interface», *Comptes Rendus Chimie 5/1*, 2002, 7–20, https://doi.org/10.1016/S1631-0748(02)01341-3

CHITALE. A.:« Production & Characterization of Brown Coloured Pigment from Trichoderma Viride», *Electronic Journal of Environmental, Agricultural and Food Chemistry* 11/5, 2012, 529-537.

DERRICK, M. R., STULIK, D., LANDRY, J. M.: *Infrared Spectroscopy in Conservation Science*, Los Angeles (The Getty Conservation Institute) 1999.

ELSAYED.Y.: « Conservation of a Historic Panel Oil-painting Coated with an Ancient Varnish Layer », *Shedet* 6, 2019, 238-256, DOI: 10.21608/shedet.006.14

ELSEROGY,A. MAHMOUD, G. & ALAWNEH, F.:«The Conservation of the Byzantine Icon from Georgios Church, Jordan », *Annales d'Universite 'Valahia' Targoviste*, Section d'Archeologie et d'Histoire, vol. Tome XX, 2018, 53-69.

FRISON, G., & BRUN ,G.:« Lapis Lazuli, Lazurite, Ultramarine 'Blue', and the Colour Term 'Azure' up to the 13th Century », *Journal of the International Color Association* 16, 2016, 41-55.

GHANI, M.:« Dating a Coptic Icon of Anonymous Painter by Spectroscopic Study of Pigment Palette», *Mediterranean Archaeology and Archaeometry* 15/1, 2015, 1-16, DOI: 10.5281/zenodo.15002.

GLIOZZO, E., IONESCU, C.: « Pigments—Lead-based Whites, Reds, Yellows and Oranges and their Alteration Phases», *Archaeological and Anthropological Sciences* 14, 2022, 14-35.

GONZALEZ, V., CALLIGARO, T., WALLEZ, G., EVENO, M. & TOUSSAINT, K.: «Composition and Microstructure of the Lead White Pigment in Masters Paintings using HR Synchrotron XRD», *Microchemical Journal 125*, 2016, 43-49.

GRANT, R.: *Lead Production*, in *Encyclopedia of Materials: Science and Technology*, 2001, 4439-4442.

HAMED, S., Ali, M., El Hadidi, N.:« Using SEM in Monitoring Changes in Archaeological Wood: A review», *Current Microscopy Contributions to Advances in Science and Technology*: A. MÉNDEZ-VILAS (ed.), 2012, 1077-1085.

HELMI, F. M. & ATTIA, M. A.: «Non–Destructive Study of an Oil Painting from 19th Century Egypt »,vol.1, In: 3rd international conference on non–destructive Testing, Micro Analytical Methods and Environment Evaluation for Study and Conservation of Works of Art, Instituto Centrale del Restauro, Roma, 1992, 738.

HELWIG, K.: *Iron Oxide Pigments*, BERRIE, B. H. (ed.), *Artists' Pigments, A Handbook of Their History and Characteristics*, vol. 4, Washington (National Gallery of Art) 2007.

HENIN. E, ABDELAAL. S, FAHIM. N, & ELMALEK.W.: «Conservation and Preservation of Jesus Christ Icon Dating Back to 19th Century at Saint Mercurius Monastery at Tamouh, Giza, Egypt», *International Journal of Advance studies in World archaeology* 5/1, 2022, 128–143, DOI: 10.21608/ijaswa.2022.230400

HRADIL.D, GRYGAR.T, HRADILOVA.J. & BEZDICKA.P.: «Clay and Iron Oxide Pigments in the History of Painting», *Applied Clay Science* 22/5, 2003, 223–236, https://doi.org/10.1016/S0169-1317(03)00076-0.

ISSA, Y.M. ABDEL-MAKSOUD, G. & MAGDY. M.:« Analytical Study of Saint Gregory Nazianzen Icon, Old Cairo, Egypt», *Journal of Molecular Structure* 1100, 2015, 70-79, https://doi.org/10.1016/j.molstruc.2015.07.004

KARYDIS, C.: «The Fabric Support in Portable Icons Deterioration, Documentation & Conservation», International Meeting, Athens 12 ,2006, 1-24.

KENDIX, ELSEBETH L., SILVIA PRATI, EDITH JOSEPH, GIORGIA SCIUTTO & ROCCO MAZZEO: « ATR and Transmission Analysis of Pigments by Means of Far Infrared Spectroscopy» *Analytical and Bioanalytical Chemistry* 394/4, 2009, 1023-1032.

KHASAWNEH, S. ELSEROGY, A.:« Conservation and Restoration of Church Icon from Baptism Museum, Jordan, Case Study» *Mediterranean Archaeology and Archaeometry* 19/1, 2019, 85-91.

KUMAR, U. SHARON, M. JAWALEKAR, S.: « Characterization of Pb3O4 Films by Electrochemical Techniques», *Bulletin of Materials Science* 8/3, 1986, 415–418.

LOTUT, Z.:« Blue in Eighteenth-Century England: Pigments and Usages», *La Couleur* 75, 2018,1-18, https://doi.org/10.4000/1718.1214

LUSSIER, S.& SMITH, D.: «A Review of the Phenomenon of Lead White Darkening and its Conversion Treatment», *Studies in Conservation* 52, 2007, 41-53.

MAHMOUD, H.: «Analytical Study of Coptic Wall Paintings in Egypt, El-Bagawat Necropolis, Kharga Oasis: A Case Study» *Periodico di Mineralogia* 82/1, 2013, 25-40, DOI: 10.2451/2013PM0002.

MAHMOUD. M.: «Using Examination and Analysis Methods to Determine the aspects of Deterioration for Oil Painting (A Case Study) », *International Journal of Multidisciplinary Studies in Architecture and Cultural Heritage* 1/1, 2018, 197 – 221.

MAKSOUD. G, IBRAHIM.M, ISSA.Y & MAGDY, M.: «Investigation of Painting Technique of Coptic Icon by Integrated Analytical Methods: Imaging, Spectroscopic and Chemometric Methods», *Journal of Archaeological Science: Reports* 29, 2020, 102085, https://doi.org/10.1016/j.jasrep.2019.102085

Malaty.T.: *the Coptic Iconography, Introduction to the Coptic Orthodox Church*, 1998, 10, 1-10, https://ukmidcopts.org/kotob/Fr%20Tadros%20Malaty/12-3_Coptic_Iconography.pdf Accessed on 30/06/2022

MEDHAT, A. ALI, M & ABDEL-GHANI, M.: «Analytical Investigation on a Coptic Wooden Icon from the 18 Century Using SEM–EDX Microscopy and FTIR Spectroscopy», *Mediterranean Archaeology and Archaeometry* 15/1, 2015,151-161, DOI: 10.5281/zenodo.15048.

MORGAN .S.: «Shaker's Typological Classification of Coptic Orthodox Church Design An Application on Historic Coptic Churches of Old Cairo and Fustat», *Engineering Research Journal* 151, 2016, A14-A36.

MORKOS. M.: «Factors and Signs of the Damage of Coptic Icons and Suggestion for Treatment: Application on a Chosen Model», 1St International Conference of Coptic Studies at Bibliotheca Alexandrina, Entitled: *Life in Egypt during the Coptic period Towns and Villages*, Laymen and Clergy, Bishops and Dioceses, 2010.

PAVLIDOU, E. ARAPI, M. et Al.: «Onoufrios, the Famous XVI's Century Iconographer, Creator of the «Berati School»: Studying the Technique and Materials used in Wall Paintings of inscribed Churches», *Applied Physics A* 83/4, 2006, 709-717.

PRIESS. M, CHAILLOT. C.: «The Role of Images and the Veneration of Icons in the Oriental Orthodox Churches: Syrian Orthodox, Armenian, Coptic and Ethiopian Traditions, Aethiopica», *International Journal of Ethiopian and Eritrean Studies* 22, 2019, 280–281.

PUICĂ,I. : «Biblical Elements in Coptic Icon», *European Journal of Science and Theology* 2/2, 2004, 37-50.

REFAAT.A , ATTA.D , OSMAN.O , MAHMOUD.A, EL-KOHADARY.S , MALEK.W, FERRETTI.M , ELHAES.M & IBRAHIM.M.: «Analytical and Computational Study of Three Coptic Icons in Saint Mercurius Monastery, Egypt», *Bio interface Research in Applied Chemistry* 9/6, 2019, 4685 - 4698

SALLAM, A. ZHAO, Y. HASSAN, M. TOPRAK, M. MUHAMMED, M. & UHEID A ,A.: «Studies on the Deterioration of Coptic Mural Painting in the Monastery of Martyrs and the Luxor Temple», *International Journal of Conservation Science* 7/2 ,2016, 493-500.

ŞERIFAKIA, K. BÖKEA, H. YALÇINB, S. & IPEKOĞLU, B.: «Characterization of Materials Used in the Execution of Historic Oil Paintings by XRD, SEM-EDS, TGA and LIBS Analysis», *Materials Characterization* 60/4, 2009,303.

SKALOVA, Z. & GABRA, G.: *Icons of the Nile Valley*, Giza (Egypt. Internat. Publ) 2003.

VAHUR, S. et Al.:« ATR-FTIR Spectral Collection of Conservation Materials in the Extended Region of 4000-80 cm -1», *Bio Analysis Chemistry Journal* 408, 2016, 3373-3379.

WALTON, M. & TRENTELMAN, K.: «Romano-Egyptian Red Lead Pigment: A Subsidiary Commodity of Spanish Silver Mining and Refinement », Archaeometry 51/5, 2008, 845–860.

YOUSRY, M ., ABDEL-MAKSOUD.G.& MAGDY, M.: «Study of the Effect of Environmental Conditions on the Red Color of Saint Yehnes Cama Icon, Mallawi, Egypt», International Hournal of Research in Pharmacy and Chemistry, IJRPC, 5/3, 2015, 491-497.