RESTORATION AND CONSERVATION OF A UNIQUE ARCHAEOLOGICAL CARPET FROM PRINCE MUHAMMAD ᶜALI PALACE MUSEUM IN AL-MANIAL, CAIRO (CASE STUDY)

BY

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[AR] **ترميم وصيانة سجادة آثرية فريدة من متحف قصر الأمير محمد على بالمنيل – القاهرة (دراسة حالة)**

يمثل السجاد التاريخى أحد أكثر الكنوز الفنية التى يجب الحفاظ عليها للأجيال القادمة. لذلك تقدم هذه الورقة البحثية استراتيجيات علمية لصيانة سجادة آثرية فريدة حُفِظت فى ظروف تخزين غير متحكم فيها. السجادة غنية بالزخارف وتعود إلى العصر الحديث (القرن 13هـ/ 19م). وكانت مُخزنة فى متحف قصر الأمير محمد على بالمنيل (القاهرة) تحت رقم 112/90سجل 2. ونظرا للتلف الشديد الذى كانت تعانى منه هذه السجادة كان لابد من وضع خطة علاج مناسبة لترميمها بشكل صحيح وذلك باستخدام التقنيات الميكروسكوبية والطيفية. فقد تم استخدام التحليل الطيفى بالأشعة تحت الحمراء [FTIR] لتحديد أنواع الأصباغ، فى حين تم استخدام حيود الأشعة السينية [XRD] لتحديد المرسخات. كما تم استخدام المجهر البصرى والمجهر الإلكترونى الماسح [SEM] لتحديد نوع الألياف وحالتها وشكلها المورفولوجى. واستخدم برنامج الأوتوكاد [AutoCAD] لتوثيق السجادة بالكامل بما تحمله من زخارف ومظاهر تلف. وقد أكدت النتائج أن الخيوط المستخدمة فى السجادة هى ألياف صوفية، الألياف تعانى من جفاف شديد وتقصف وهشاشية، أيضا احتواء الألياف على شقوق عرضية وترسيبات سميكة على السطح. علاوة على ذلك، تم العثور على أصباغ الفوة، النيلة الزرقاء، والبليحة. وكانت المرسخات المستخدمة هى الشبة، ثانى كرومات البوتاسيوم، وكبريتات الحديدوز. وكان عامل التلف الأتربة بجانب العوامل الفيزيائية الأخرى. وتم معالجة السجادة الآثرية بإزالة أعمال الترميم القديمة الخاطئة، ترطيب الألياف، محاولات للتنظيف الجاف، الغسيل، التجفيف، التقوية عن طريق التثبيت على حامل كتاني جديد تم شده على إطار خشبى (وفقاً لمتطلبات السلامة)، وأخيراً التعقيم بالفضة النانوية.

[EN] Historical carpets represent one of the most artistic treasures, which ought to be saved for the next generations. Therefore, this paper presents scientific strategies to conserve a unique archaeological carpet, which was kept under uncontrolled storage conditions. The carpet is highly decorated and dates back to the modern era, 13th AH/19th AD. It was stored in Prince Muhammad Ali Palace Museum in El-Manial (Cairo) under Nr°.90/112 Record 2. As this carpet suffered from severe damage, an appropriate plan had to be drawn up to restore it properly using microscopic and spectroscopic techniques. Fourier Transform Infra-Red (FTIR) spectroscopy was used to identify the kinds of dyes, while X-ray diffraction (XRD) was used to identify mordants. Optical microscope and Scanning Electron Microscopy (SEM) were used to identify the type of fibers, their condition, and surface morphology. The AutoCAD program was used to document the whole carpet with all its decorations and aspects of damage .The obtained results confirmed that the threads used in the carpet are wool fibers; the fibers suffer from severe dehydration, brittleness, and fragility; also, the fibers have cross-slits and thick deposits on the surface. Moreover, the presence of Madder, Indigo, and weld dyes were found. The mordants used were alum, potassium dichromate, and ferrous sulfate. The deterioration factor was dust alongside the other physical factors .

The treatment of the archaeological carpet was performed by removing old erroneous restoration works, moisturizing fibers, attempts to dry cleaning, washing, drying, consolidating by fixing on a new linen fabric supporter which was stretched on a wooden frame (according to the safety requirements), and finally sterilizing by nano-silver.

KEYWORDS: Oriental rugs, carpets, SEM, FTIR, XRD, restoration, conservation

I. INTRODUCTION

Historical carpets represent one of the most artistic treasures, which ought to be saved for people in the future[1]. All existing Oriental Rugs share the features of being on the pile (Carpet or pile rug) and non-pile (*Kilim*)[2]. The origins of Oriental rug weaving are obscure. Their raw materials (wool, cotton, and silk) are naturally perishable and can only survive for a few centuries, except if held under exceptional conditions. Therefore, by far most of the old and antique rugs still in existence were made during or after the l8th century AD. This makes it practically impossible to chronicle their exact evolutionary development and dispersal throughout the oriental weaving region[3]. The oldest existing carpet dates back to 500 BC, as detected through carbon 14 dating. It was found in 1949 by Soviet archeologists in an ice-filled imperial Scythian burial chamber in the Pazyryk Valley in Siberia[4].

There are three main categories of Oriental carpets, based on origin, being created out of the Persian[5], Turkish and Armenian traditions[6]. Originally oriental rugs were made manually, woven on a usual wooden frame (loom)[7]. Weavers held an ornament in their memory, transferring «from hands to hands». In general, the rugs and carpets have a central area of design bordered several times with geometric patterns[8].

Many factors contribute to a carpet's deterioration. These agents of deterioration can occur naturally, or they can result from external factors[9]. The deterioration can be attributed to the combined effects of external environmental conditions[10], such as humidity, temperature, pollutants, soiling and exposure to light[11], which accelerates the chemical breakdown[12]. Examination and analysis give a clear map of the nature of damage, whether it is workmanships' defects or naturally caused due to aging[13].

Oxidation and fading of colored fibers heavily affect the appearance and mechanical properties of textile artifacts[14]. The unwanted effect is a significant loss of tensile strength and a strongly increased brittleness, resulting in the loss of elastic

[1] ᶜABDEL-KAREEM 2010: 53; SHAHID et AL. 2019: 58.
[2] FORD 1989: 16.
[3] ALLANE 1995: 9.
[4] HAFIZ FOUNDATION 2012: 12.
[5] SERRANO et AL. 2021: 80.
[6] ACKLES 1988: 2.
[7] GRIFFIN 1913: 89; SAKHAI 1995: 16.
[8] ACKLES 1988: 1.
[9] NATIONAL PARK SERVICE 2002: 9.
[10] DING et AL. 2021: 69.
[11] NAFESA et AL. 2021: 137.
[12] ABO EL ENEN 2018a: 36; AHMED & ZIDDAN 2011: 412.
[13] EL-GHAREB 2021: 155.
[14] DEGANO et AL. 2011:2837.

properties[15]. According to many researchers, the effect of wool aging is caused mainly because of alterations in the protein fraction. Particularly, as wool may interact with UV radiation, in form of tryptophan, tyrosine, methionine, and cysteine residues. Furthermore, the photochemical studies on wool mainly focus on the reaction of aromatic amino acids, which react to phenyl radicals and then products of oxidative coupling, e.g., di-tyrosine. It is reported that aging of wool generates singlet oxygen and hydroperoxides. As a consequence, phenols were converted to phenoxyl radicals, leading to the hydroxylation of aromatic compounds such as tyrosine, phenylalanine, and tryptophan. These deteriorations such as products of photo-oxidation are responsible for the yellowing phenomena[16].

One of the most important causes of the damage of carpets used as floor coverings is their functional use, as they are greatly exposed to dust and direct friction, causing erosion of the piles, which may lead to their complete loss and the occurrence of tears and cuts. The conservation of carpets includes the entire range of treatment, without tampering directly into the item's structure and changing its shape[17]. Restorations are combined with conservation and represent the methods and procedures which are applied directly, in order to return a carpet into satisfactory form, where its original shape and preserved aesthetic, historical, and physical integrity can be perceived [18]. When preserving historical textiles, remedial measures are taken to support a fragile and damaged fabric in order to make it last longer by making it stronger[19]. Supporting carpets is considered among the range of treatment. Supporting the back of a carpet onto linen would enable the preservation of what was left of both color and design and still keep the carpet safe[20]. Stitching is probably the most widely used treatment method in carpets conservation. It is a versatile technique that can be adapted for several purposes, such as different kinds of damage, retouching, and mounting[21]. Finally, most of the museums control temperature (20-25˚C) and humidity (45-60%)[22].

This paper aims to present the strategy for the conservation of a unique archaeological carpet. To describe the carpet in a precise archaeological manner due to its importance and to assess its condition, the AutoCAD program and specialized sources were used in describing the archaeological carpet. The paper also aims to identify the kind of fibers, dyes, mordants, and different damages in this object through using microscopic and spectroscopic techniques. The paper reports the conservation

[15] ABO EL ENEN 2018a: 36.
[16] Dyer et AL. 2006: 698; DEGANO et AL. 2011: 2838.
[17] DJORDJEVIC et AL. 2017: 94.
[18] ENEN 2018 a: 36.
[19] NILSSON 2015: 1.
[20] ENEN 2018a: 36.
[21] SCHÖN 2017: 1.
[22] SINGH et AL. 2020: 1805.

treatment of the object such as removing old erroneous restoration works, moisturizing fibers, attempts to dry cleaning, washing and drying, consolidating by fixing on a new linen fabric supporter, and finally sterilizing by nano-silver for future protection.

II. MATERIALS AND METHODS

1. Visual Examination

Conventional examination was conducted with the naked eye and with the help of a magnifying lens with scale[23] to identify the weaving structure of the object and the damage aspects that existed on it.

A. Description of the Object

This carpet is a highly valuable example of fine rugs made by Qashqai tribes of southern Iran. The harmony of its coloration and design is typical of Qashqai rugs, which are renowned for their beauty and originality. The carpet was stored in Prince Muhammad ᶜAlī Palace Museum in al-Manial (Cairo) under Nrº.90/112 Record 2. It dates back to the modern era, 13thAH/19th AD century (depending on the ornamental style).

Oriental rugs vary numerously in design and so do Persian rugs[24]. The design features of this carpet are four diamond-shaped medallions, two in beige and two in red, filled with various geometric and semi-floral patterns and roosters' figures. The main decoration design consists of floral and geometric motifs and roosters' figures in blue, beige, and red on a dark blue background and the border has an all-over geometric pattern on a beige ground **[FIGURES 1, 3].**

[FIGURE 1]: Photographic image of the carpet under study © Taken by the researchers

[23] Obtained from organic lab. Faculty of Archeology/Fayoum University.

[24] DIPAOLA 2010: 1.

B. Sampling

Samples from various regions of different colors of the carpet were taken, specifically from damaged and invisible places. They were investigated based on scientific analysis and examination techniques to identify fibers, dyes, and mordants in that era of the carpet, as shown in [**TABLE 1**].

Number of sample	Region of sample	Description of sample	Symbol of sample
1	Main decorative design	Red	1/90/112
2	Main decorative design	Blue	2/90/112
3	Main decorative design	Yellow	3/90/112
4	Main decorative design	Brown	4/90/112

[TABLE 1]. Technical description of selected samples

2. Stereo Microscope

Optical microscope «Carl Zeiss c-2000 stereomicroscope (Germany)» was used[25] to provide the morphological appearance and damage of the raw materials used in manufacturing the object.

3. Scanning Electron Microscope (SEM)

Scanning electron microscopy was used to identify the fibers and characterize their deterioration[26]. The appearance of the fibers was investigated using a *Quanta* 200 ESEM FEG from FEI Scanning Electron Microscope.

4. Fourier Transform infrared spectral analysis (FTIR)

The FTIR spectroscopy represents a valuable tool for the analysis of different types of historical artifacts[27] due to its sensitivity, specificity and non-destructive character[28] FT-IR is an instrument for identifying the molecular structure of organic and inorganic molecules in papers, textiles, fibers, and other materials[29]. Knowledge about the composition and origin of dyes is essential for the preservation, and conservation of the items[30]. The Fourier Transform Infrared (FTIR) Analysis was carried out for samples using FTIR Model Cary 630 FTIR spectrometer produced by Agilent technologies Company, in spectral range (wavenumbers cm^{-1}) from 4000 cm^{-1} to 400 cm^{-1} without any treatment. Infrared analysis was performed on four samples; their colors were red, dark blue, yellow, and brown.

[25] In the conservation lab. Faculty of Archaeology/ Fayoum University.
[26] AMIN 2013: 29.
[27] PÎNZARU et AL. 2008: 31; COLETTI et AL. 2021: 2.
[28] PEETS et AL. 2017: 176; RADITOIU et AL. 2018: 3.
[29] LEE et AL. 2011: 657.
[30] PEETS et AL. 2020: 19.

5. X-ray diffraction (XRD)

X-ray diffraction of fabrics was carried out by Bruker company model D8 (including reflectometry, high-resolution diffraction, in-plane grazing incidence diffraction (IP-GID), small-angle X-ray scattering (SAXS), as well as residual stress and texture investigations).

6. Testing the stability of dyes and measuring the pH value

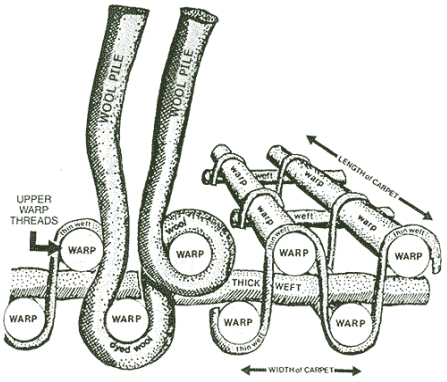
Before starting the treatment steps, the dyes were tested for stability and condition to make sure they are protected while performing the wet cleaning procedure. The test was performed by immersing a piece of cotton wrapped around a wooden stick into the cleaning solutions[31] and placing it in contact with the colored parts of the carpet, each color was individually tested[32].

III. RESULTS OF EXAMINATION AND ANALYSIS

1. Visual Examination

A. Weaving Technique of the Object

The carpet was woven using dyed woolen yarns (wool on wool) by the Persian knot with warp threads on two different levels (open back) **[FIGURE 2]**[33]. The carpet is irregular in dimensions as a result of what it suffered from of loss in its outer frame; the width dimensions of the carpet ranged from 149 to 158 cm, and the longitudinal dimensions of it ranged from 267 to 274 cm.



[FIGURE 2]: The Persian knot used in the carpet with the warp threads on two different levels (open back)

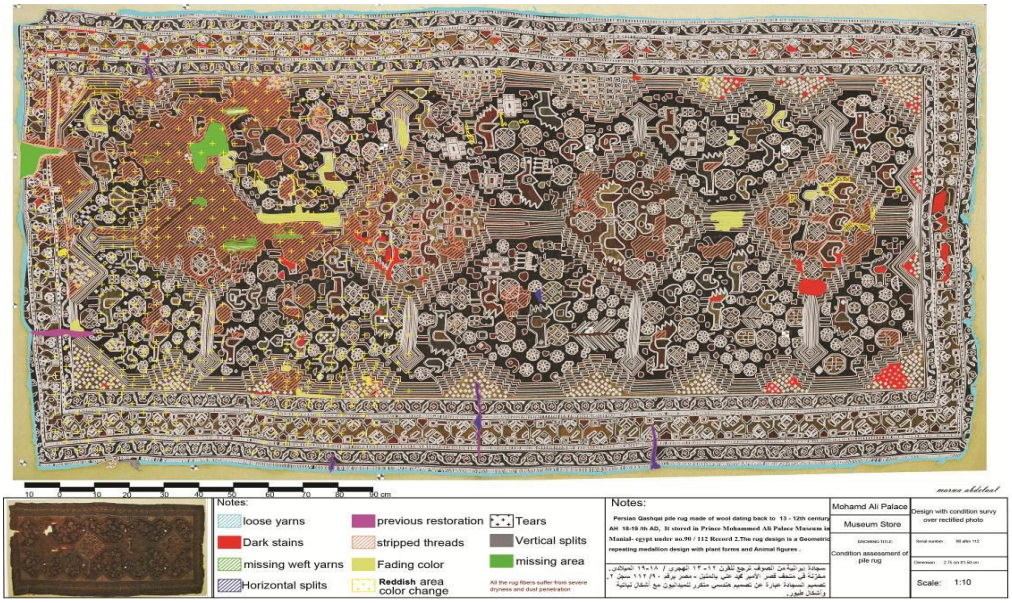
[31] AHMED 2013: 41.

[32] AHMED & ZIDDAN 2011: 415.

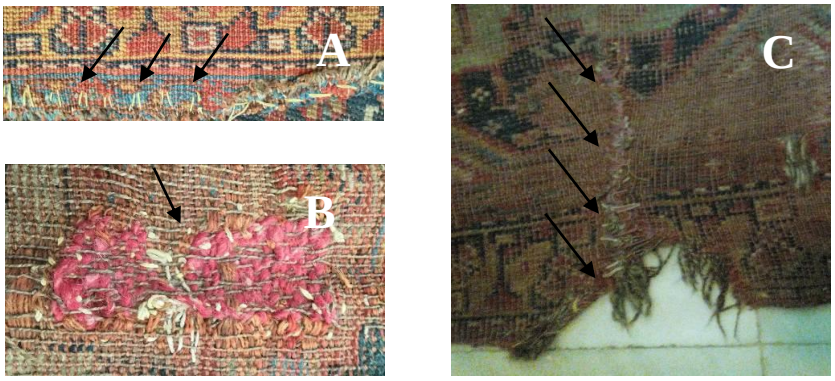
[33] Oriental Rug Knotting & Construction. Pdf. downloaded from: Http://www.kapridjianrugsandcarpets.com/knotting.pdf, (Accessed on March 3, 2021)

B. Condition of the Object

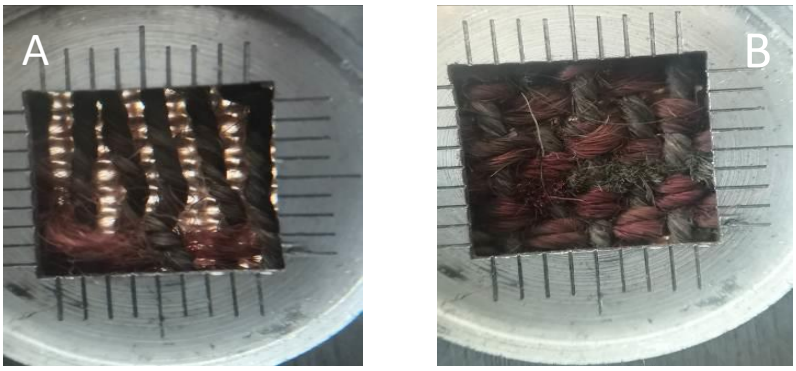
The visual examination showed many signs of damage on this object due to the functional use of the carpet as a floor covering, the natural aging factors, and the improper storage method such as color changes, dark stains, fading colors, stripped threads, loss of all the fringes, and parts of the selvages, tears, vertical splits, horizontal splits, missing weft yarns, the disappearance of some knots, erosion of the pile **[FIGURE 5]** from most of the carpet and previous erroneous restoration works (using threads contrasting in color, restoration of the splits, and missing weft yarns in a remarkable and inappropriate manner, and installing metal rings not isolated and rusted in the object for use in hanging the carpet) **[FIGURES 3-4].**



[FIGURE 3]: The condition assessment of the carpet using the AutoCAD program (© Designed by the researchers)



[FIGURE 4]: Old restoration works (© Taken by the researchers)
A: Sewing the edges of the carpet with different colored yarns. B, C: Restoration the missing weft yarns and the splits in a remarkable and inappropriate manner.



[FIGURE 5]: Fibers under the magnifying lens © Taken by the researchers. A: disappearance of some knots; B: erosion of pile

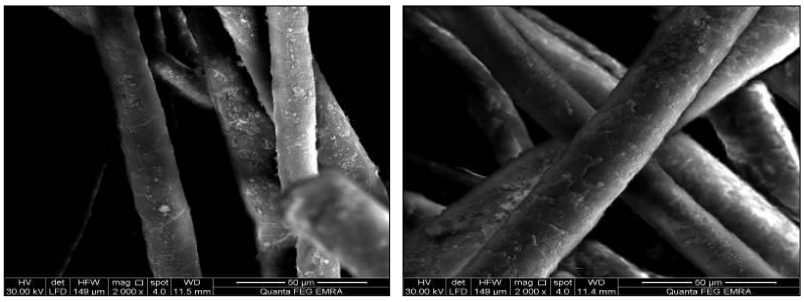
2. Stereo Microscope

The photos showed that fibers suffered from dehydration; brittleness, fading of dyes, and fragility [**FIGURE 6**].

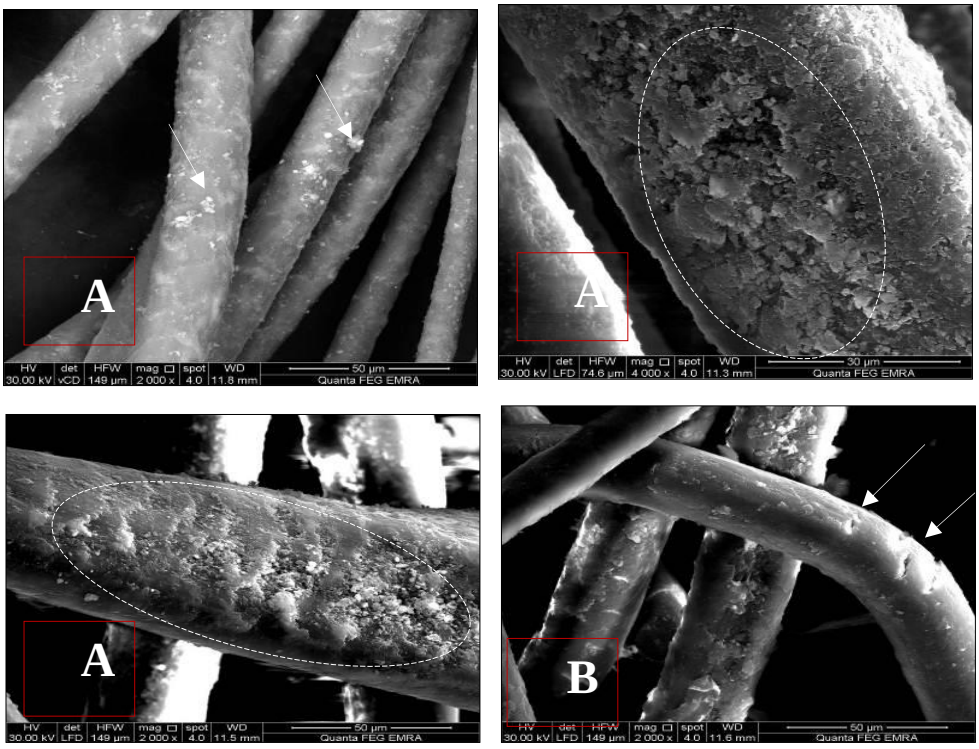
[FIGURES 6]: The fibers under stereo microscope
A, B, C & F. Samples of brown shades; D. Blue sample; E. Red sample

3. Scanning Electron Microscope (SEM)

The morphological images using a scanning electron microscope showed that the threads used in manufacturing this carpet are wool fibers. Moreover, it was clear that the fibers are severely damaged and have cross-slits and thick deposits on the surface **[FIGURES 7-8]**.



[FIGURE 7]: SEM images of the carpet's fibers showing the absence of the morphological properties of raw wool



[FIGURE 8]: SEM images of the carpet's fibers showing deterioration signs A. Many deposits on the fiber surface; B. The wool fibers are extremely damaged, broken with transverse cracking

4. Fourier Transform Infrared (FTIR)

A. Red color (sample 1)

The FTIR spectrum of the red sample fiber; sample 1 **[FIGURE 9/A]** was compared with the results of infrared analysis of natural dyes known as standard[34]. After the comparison, it turned out that the red sample is madder dye. The spectrum of this sample is characterized with a specific broad band at 3432.28 cm^{-1} due to the O–H stretching band of madder dye or N-H stretching vibrations of terminal amino group in wool fibers. A peak at 2925.45 cm^{-1} is because of C=H stretching band and a peak at 1636.88 cm^{-1} is assigned to C=O stretching band, a peak at 1508.23 cm^{-1} is assigned to

[34] DERRICK et AL.1999: 200.

aromatic band and a peak at 1458.18 cm^{-1} is assigned to C-H bending band. As can be seen, a characteristic peak of alizarin from madder dye appeared at 1456 cm^{-1} [35].

The main characteristic peaks of wool fibers appeared between 1000 and 1700 cm^{-1}, which are related to amide I (1644 cm^{-1}), amide II (1516 cm^{-1}), and amide III (1235 cm^{-1})[36]. Other specific peaks are the stretching bands C-O vibration at 1041.18 and 472.41 cm^{-1}.

B. Blue Color (Sample 2)

The FTIR spectrum of the blue sample 2 **[FIGURE 9/B]** was compared with the results of infrared analysis of natural indigo dyes known as standard[37]. After the comparison, it turned out that the blue sample is indigo dye. The spectrum of this sample showed a specific peak at 3421.7 cm^{-1} due to the N–H stretching, a peak at 2926.26 cm^{-1} that is assigned to C-H stretching of wool fibers and O-H stretching of indigo dye. A peak at 1654.26 cm^{-1} is assigned to C=C stretching for indigo, while for wool it is assigned to N-H bending in lysine amino acid[38]. Other specific peaks are the aromatic bands vibration at 1560.03, 1508.23 and 1437.69 cm^{-1} assigned to C-H bending in case of indigo and as C-C stretching of tyrosine amino acid for wool.

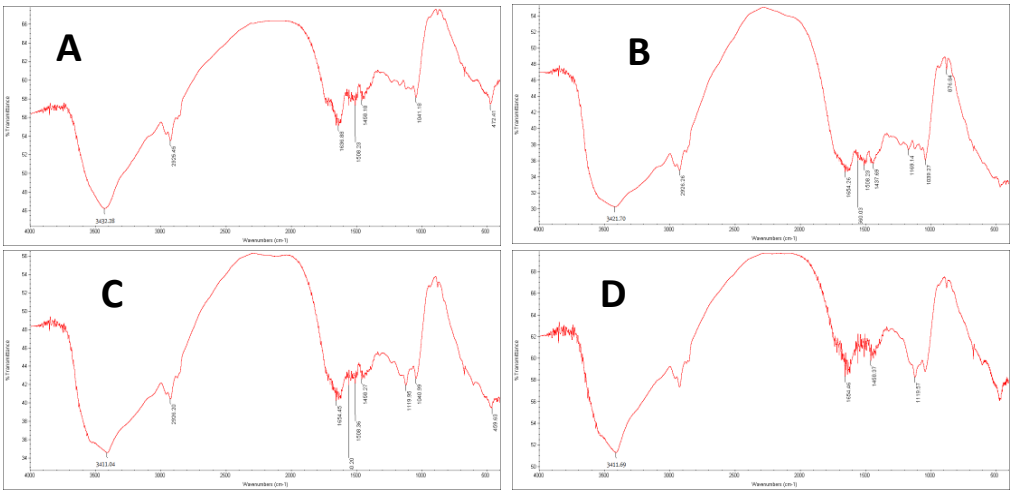
C. Yellow Color (Sample 3)

The FTIR spectrum of the yellow sample 3 **[FIGURE 9/C]** was compared with the results of infrared analysis of natural dyes known as standard[39]. After the comparison, it turned out that the yellow sample is weld dye. The spectrum of this sample is shown with a specific peak at 3411.04 cm^{-1} due to the hydroxyl in benzene, a peak at 2926.20 cm^{-1} assigned to C-H stretching band, a peak at 1654.45 cm^{-1} assigned to carbonyl, 1560.20 cm^{-1} and 1508.36 cm^{-1} are skeleton vibration absorption peaks of benzene, and 1119.95 cm^{-1} and 1040.99 cm^{-1} are stretch vibration absorption peaks of cyclic ether.

D. Brown Color (Sample 4)

The FTIR spectrum of the brown sample 4 **[FIGURE 9D]** was compared with the results of infrared analysis of natural dyes known as standard[40]. After the comparison, it turned out that the brown sample is Madder dye. The spectrum of this sample is shown with a specific peak at 3411.69 cm^{-1} due to the O–H stretching band, a peak at 1654.46 cm^{-1} assigned to C=O stretching band, a peak at 1458.37 cm^{-1} assigned to aromatic bands and C-H bending bands; and a peak at 1119.57 cm^{-1} assigned to the stretching band C-O.

[35] CANAMARES et AL. 2004: 923.
[36] BARANI & CALVIMONTES 2014: 4.
[37] DERRICK et AL. 1999: 197.
[38] OSMAN et AL. 2014: 463.
[39] CHEN et AL. 2017: 22.
[40] DERRICK et AL. 1999: 200.



[FIGURE 9]: A. Spectrum of wool dyed with madder dye; B. Spectrum of wool dyed with indigo dye; C. Spectrum of wool dyed with weld dye; D. Spectrum of wool dyed with madder dye.

5. X-ray Diffraction (XRD)

A. Red Color (Sample 1)

The XRD spectrum detected that the main compounds are alum ($Al\ H_{24}\ K\ O_{20}\ S_2$) ≈ 52% according to code number 1011177, and potassium dichromate ≈ 7.4% according to code number 9008493. On other hand, the spectrum showed the presence of Fe, Zn, and Cu elements referring to dust as deterioration factor **[FIGURE 10/A]**.

B. Blue Color (Sample 2)

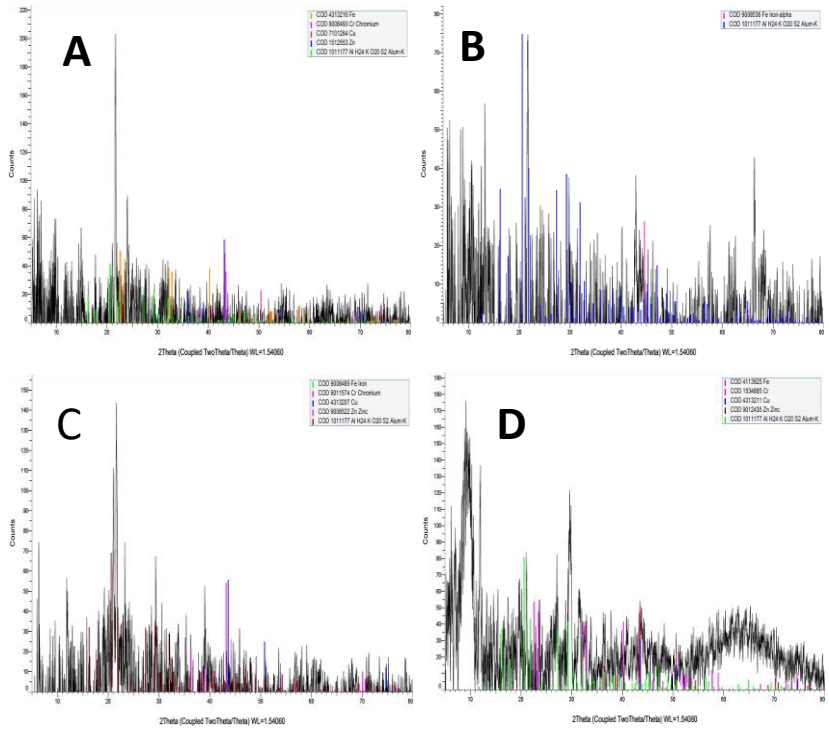
The XRD spectrum showed that the main compound is alum ($Al\ H_{24}\ K\ O_{20}\ S_2$) ≈ 96.7% according to code number 1011177. Additionally, the spectrum showed the presence of dust as deterioration factor due to the presence of iron oxide ≈ 3.3% **[FIGURE 10/B]**.

C. Yellow Color (Sample 3)

The XRD spectrum showed that the main compounds are alum ($Al\ H_{24}\ K\ O_{20}\ S_2$) ≈ 73.7 % according to code number 1011177, and potassium dichromate ≈ 6.5 % according to code number 9011574. Here too, the spectrum showed the presence dust as deterioration factor due to the presence of (zinc, iron, and copper) **[FIGURE 10/C].**

D. Brown Color (Sample 4)

The XRD spectrum showed that the main compounds are alum ($Al\ H_{24}\ K\ O_{20}\ S_2$) ≈ 68.7 % according to code number 1011177, and ferrous sulfate ($FeSO_4.\ 7H_2O$). Again, the spectrum showed the presence dust as deterioration factor due to the presence of (chromium, zinc, and copper) **[FIGURE 10/D]**.



[FIGURE 10]: XRD diffractogram of the tested samples
A. Red sample; B. Dark blue sample; C. Yellow sample; D. Brown sample

6. Testing the Stability of Dyes and Measuring the pH Value

When performing the pH test on all investigated samples it was observed that all the dyes were stable and did not bleed with the wet cleaning solutions. The pH was also measured and turned out to be neutral (pH≈7).

IV. DISCUSSION

The visual assessment of the samples using the magnifying lens with scale showed disappearance of some knots and erosion of the pile from most of the carpet; also the morphological examination using scanning electron microscope showed that the fibers are severely damaged and have cross-slits and thick deposits on the surface; that indicated the bad condition in which the object was preserved. This explains the presence of many deposits on the surface of dyed fiber as «Tertsch» mentioned: «Alizarin often combines with calcium to form precipitates and therefore dyes best in hard, calcium-rich water»[41]. The presence of many deposits on the surface of fibers are due to a large amount of dust penetrating the carpet fibers and its accumulation on the surface.

FTIR analysis spectra showed that the red color is madder dye, the yellow color is weld dye, the blue color is indigo dye, and the brown color is madder dye. These results

[41] TERTSCH & ZIB 2014: 3.

agree with the dyes used by Iranian weavers, as they used madder dye to obtain the red color in its shades and the brown color in its shades using different mordant[42]. They also used weld dye to obtain the yellow color for dyeing carpet yarns; and indigo dye to get the blue color in its miscellaneous shades[43].

The results of X-ray diffraction (XRD) clarified the following: the presence of alum ($Al\ H_{24}\ K\ O_{20}\ S_2$)[44] in all samples as the main compound. Besides, chromium was found in a relatively high percentage in both the red and yellow samples, as well as the presence of iron with the brown sample. The results also showed the presence of some elements referring to the chemical composition of the dust, as a result of neglect, lack of ventilation, and absence of regular cleaning.

To sum it up, it can be concluded that alum was used in all samples as a mordant for wool fibers before dying[45], chrome was used as a mordant with madder dye to obtain the red garnet color and with weld dye to obtain the golden color and iron was used with madder dye to obtain the brown color[46]. The presence of other foreign elements represents the chemical composition of the dust minerals in Cairo[47].

From the aforementioned results, it can be suggested that the appropriate treatment plan for the condition of the carpet under investigation is the following: Removing old erroneous restoration works[48], cleaning[49] and sterilizing the object for future protection[50], and finally consolidating the object by fixing it on a new linen support which was stretched on a wooden frame[51] (according to the safety requirements). The carpet is so threadbare so it is not possible to complete the lost threads by planting new threads because this will cause stress on the original threads of the carpet and a greater loss.

[42] GHAZIZADEH 1979: 29.
[43] GHAZIZADEH 1979: 32.
[44] KŘÍŽOVÁ 2013: 324.
[45] SCHWEPPE 1986: 5; *THE MAIWA GUIDE TO NATURAL DYES*: 7.
[46] [c]ABDEL-KAREEM 2012: 86.
[47] [c]ABDEL-KAREEM 2010: 55.
[48] AHMED & ZIDDAN 2011: 415.
[49] KAMAL & MANSOUR 2017: 95; DJORDJEVIC et AL. 2017: 94; AMIN 2019: 6.
[50] PIETRZAK et AL. 2016: 1.
[51] ABO EL ENEN 2013: 34; ABO EL ENEN 2018b: 20.

V. CONSERVATION PROCESSES

1. Removing old Restoration Works and Moistening the Object

Wrong old repair works were removed **[FIGURE 11]**, and the dry fibers of the carpet were softened by spraying distilled water once a day and covering it with polyethylene; taking into consideration many precautions to prevent any future microbiological decay **[FIGURE 12]**.

[FIGURE 11]: A. The removal of inappropriate old restoration;
B. Parts separated from the object after removal of old restorations © Taken by the researchers

[FIGURE 12]: During topical hydration © Taken by the researchers

2. Wet Cleaning

Attempts for topical cleaning using some organic solvents (ethyl alcohol 95%, and acetone 99% from El-Salam for Chemical Industries) were done, but no good results were obtained, due to the extreme dryness of the fibers of the object.

3. Washing Stage

Before starting the washing process, primary support was applied to the carpet by placing it between two layers of gauze as a sandwich, sewing them together by running stitches, using appropriately thin needles and fine threads to protect the vulnerable parts of the carpet from disintegrating during the washing process **[FIGURE 13]**. A suitable washing basin was prepared (designed in cooperation with the museum's staff) and the carpet was washed using pure water and «Cetaphil» neutral soap. The ratio was one part «Cetaphil» neutral soap to 100 parts of distilled water.

The carpet was immersed in the washing bath for 20 minutes, with little pressure

by hand and brushes **[FIGURE 14]**, so that the water would penetrate between the fibers to release the dust particles out. Then the carpet was rinsed three times for 15 minutes to ensure that the neutral soap had been completely removed **[FIGURE 15]**.

[FIGURE 13]: Covering the carpet with gauze as a sandwich © Taken by the researchers

[FIGURE 14]:. While washing the carpet © Taken by the researchers

[FIGURE 15]: Samples from carpet's wash baths © Taken by the researchers

4. Drying Process

The object was dried with tissue paper and then placed on a stainless steel stand, and left in the atmosphere of the restoration laboratory in the museum until completely dry.

5. Consolidation Process

A. Preparation of a Wooden Frame

Wooden support was equipped; its size is larger than the size of the carpet by about 10 cm from each side; its size was 175 cm x 285 cm. The wooden support was then isolated from the surrounding environment by using shellac, to which «pure para-chlorobenzene» as an insecticide was added; the wooden frame was covered with four layers of the previous mixture and was left until completely dried.

B. Preparation of Linen Support

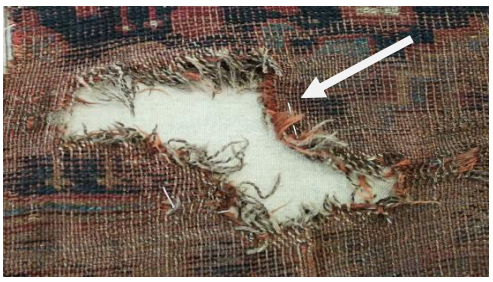
A cloth of natural linen was boiled in pure water to get rid of the gum and undesirable or dusty materials; and after drying it was ironed.

C. Fixing the Textile Support on the Wooden Frame

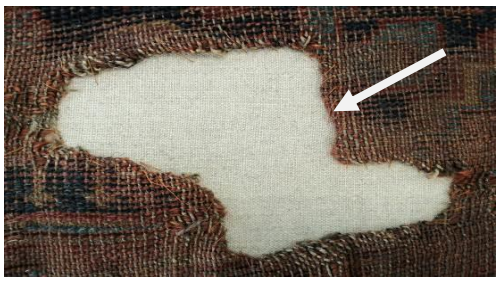
Natural linen was stretched from the four sides on the wooden frame by using pins of isolated stainless steel; taking into account the tension of the linen to the appropriate extent.

D. Fixing the Carpet on the Support and Repairing it

After the carpet treatment was completed, it was permanently fixed and completely restored by using a thin needle and natural thin yarns whose color tones are suitable for the colors of the carpet. In the beginning, the four edges of the carpet were fixed on the support by sewing with a small stitch, blanket stitch technique. The splits and tears in the carpet were repaired by couching stitches. The inside of the carpet was also fixed using the running baste stitch **[FIGURES 16-26]**.



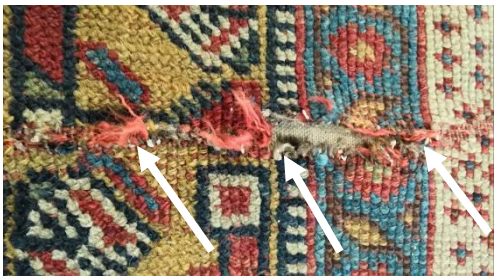
[FIGURE 16]: Bleeding of threads before restoration
© Taken by the researchers



[FIGURE 17]: Bleeding of threads after restoration
© Taken by the researchers

[FIGURE 18]: A slit before restoration
© Taken by the researchers

[FIGURE 19]: The slit after restoration
© Taken by the researchers



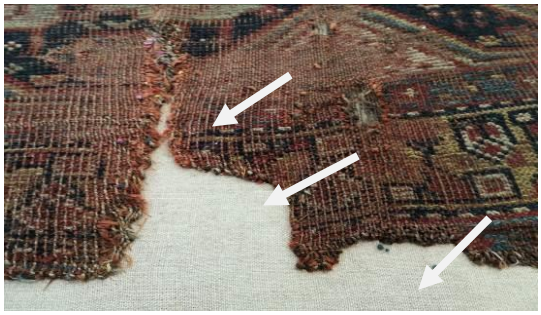
[FIGURE 20]: A slit before restoration
© Taken by the researchers

[FIGURE 21]: The slit after restoration
© Taken by the researchers

[FIGURE 22]: Tears before restoration
© Taken by the researchers

[FIGURE 23]: The tears after restoration
© Taken by the researchers

[FIGURE 24]: Tears and slits before restoration
© Taken by the researchers



[FIGURE 25]: The tears and slits after restoration
© Taken by the researchers

[FIGURE 26]: The Carpet after restoration and after fixing it on a new linen supporter
© Taken by the researchers

6. Preventive Conservation

The carpet was treated with a solution of nano-silver dissolved in distilled water for future protection, as the carpet may be exposed in future to a biological decay due to its organic composition.

VI. CONCLUSION

The successful restoration and conservation of important unique artifacts requires precise examination and analysis of the object, using microscopic and spectroscopic techniques, for designing an appropriate treatment plan depending on the condition of the object. This paper presents a case study of a unique archaeological carpet preserved at the Manial Museum, in which it followed the treatment and conservation strategies to preserve it for future generations, as it is considered a valuable model that represents the skill of ancestors in one of the fine arts.

After the examination and analysis of the object under study, it became clear that the carpet was woven with dyed woolen yarns (wool on wool) by the Persian knot with the warp threads on two different levels (open back). The carpet is irregular in dimensions as a result of what it suffers from a loss in its outer frame. Dyes used in the carpet are madder, weld, and indigo with mordant (alum, chrome, and iron). The fibers have been largely damaged and had cross-slits and thick deposits on the surface, and this indicated the bad condition in which the object was preserved. The presence of many deposits on the surface of dyed fiber is what «Tertsch» reported: «Alizarin often combines with calcium to form precipitates and therefore dyes best in hard, calcium-rich water». Also, the presence of many deposits on the surface of fibers is due to a large amount of dust penetrating the carpet fibers and its accumulation on the surface.

The appropriate treatment plan for the condition of the carpet was the following: Removing old erroneous restoration works, cleaning and sterilizing the object for future protection, and finally consolidating the object by fixing it on a new linen support which was stretched on a wooden frame.

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BIBLIOGRAPHY

[c]ABDEL-KAREEM, O.: «Conservation and Restoration of a Rare Large Persian Carpet», *E-conservationthe Online Magazine* 17, 2010, 53-63.

[c]ABDEL-KAREEM, O.: «History of Dyes Used in Different Historical Periods of Egypt», *RJTA* 16/4, 2012, 79-92.

ABO EL ENEN, E.: «Preservation and Restoration of a Piece of Textile at the Egyptian Textile Museum», *EJARS* 3/1, 2013, 29 – 37.

ABO EL ENEN, E.: «Technical Investigation and Conservation of a Tapestry Textile from the Egyptian Textile Museum, Cairo», *Scientific Culture* 4/3, 2018, 35-46.

ABO EL ENEN,E.: «Conservation of A Gauze Textile From the Tulunid Period in Egyptian Textile Museum, Cairo», *International Journal Of Conservation Science* 9/1, 2018, 13-24.

ACKLES, S.F. *Symbols and their Meanings in the Carpets and Prayer Rugs of the Turkish-Armenian and Persian traditions*, 1988.

AHMED, H.: «Identification and Conservation of a Rare Islamic Textile Decorated with Metallic Yarns», *EJARS* 3/1, 2013, 39 – 45.

AHMED, H. & ZIDDAN Y.: «A New Approach for Conservation Treatment of a Silk Textile in Islamic Art Museum, Cairo» *Journal of Cultural Heritage* 12, 2011, 412–419.

ALLANE, L., KILIMS: *A Buyer's Guide*, Hong Kong (Thames & Hudson) 1995, 9.

AMIN, E.: «Preservation and Restoration of a Piece of Textile at the Egyptian Textile Museum», *EJARS* 3/1, 2013, 29 – 37.

AMIN, E.: «The Documentation and Treatment of a Coptic Child's Tunic in Egypt», *EJARS* 9/1, 2019, 1-11.

BARANI, H. & CALVIMONTES, A.: «Effects of Oxygen Plasma Treatment on the Physical and Chemical Properties of Wool Fiber Surface», *Plasma Chemistry and Plasma Processing*, 2014, New York

CANAMARES, M. V., GARCIA-RAMOS J. V., DOMINGO C. & SANCHEZ-CORTES S.:«Surface Enhanced Raman Scattering Study of the Adsorption of the Anthraquinone Pigment Alizarin on Ag Nanoparticles», *Journal Of Raman Spectroscopy* 35, 2004, 921–927.

CHEN, C., ZHAO W., LIU W., ZHANG Y., TANG H., XU D. & ZHENG, C.: «Research of Dyeing Thermodynamics and Supramolecular Structure of Luteolin on Wool Fabric», *World Journal of Engineering and Technology* 5, 2017, 19-28.

COLETTI, F., ROMANI, M., CERES, G., ZAMMIT, U. & CESTELLIGUIDI, M.: «Evaluation of Microscopy Techniques and ATR-FTIR Spectroscopy on Textile Fibers from the Vesuvian area: A Pilot Study on Degradation Processes that Prevent the Characterization of bast Vibers», *Journal of Archaeological Science*: Reports 36, 2021, 1-11.

DEGANO, I., BIESAGA, M., COLOMBINI, M.P. & TROJANOWICZ, M.: «Historical and Archaeological Textiles: an Insight on Degradation Products of Wool and Silk Yarns», *Journal of Chromatography* A, 1218, 2011, 5837– 5847.

DERRICK, M.R., STULIK D.C. & LANDRY J.M.: *Infrared Spectroscopy in Conservation Science*, Los Angeles, 1999, 197-200.

DING, L. & et AL.: «Non-invasive Study of Natural Dyes in Textiles of the Qing Dynasty Using Fiber Optic Reflectance Spectroscopy», *Journal of Cultural Heritage* 47, 2021, 69–78.

DIPAOLA, S., DALVANDI, A. & BEHBAHANI P.A.: «Exploring Persian Rug Design Using a Computational Evolutionary Approach», *Conference: Electronic Visualisation and the Arts (EVA)*, 2010, 121-128.

DJORDJEVIĆ, D. & UROŠEVIĆ, S.: «Textile protection through conservation and restoration», *ZastitaMaterijala* 58 /1, 2017, 94–99.

DYER, J.M., BRINGANS, S. & BRYSON, W.G.: «Characterization of Photo-oxidation Products within Photo yellowed Wool Proteins: Tryptophan and Tyrosine Derived Chromophores», *Photochemical and Photobiological Sciences* 5/7, 2006, 698-706.

FORD, P.R.J.: *Oriental carpet design*, London (Thames & Hudson) 1989, 16.

GHAZIZADEH,P.: «Persian Rugs: Analysis of Selected Designs», Ma Thesis, Faculty of the Graduate College/Oklahoma State University, 1979.

GRIFFIN, G.: *The practical book of oriental rugs*, 2nd (ed.), Philadelphia – London, (J.B. Lippincott Company) 1913, 89.

HAFIZ FOUNDATION: *Jazz from paradise: Miri Creation Contemporary Carpet Masterpieces from The Farjam Collection*, Dubai (Hafiz Foundation) 2012, 12.

KAMAL, N. & MANSOUR M.: «Conservation and Restoration of Archaeological Textile at Coptic Museum, Cairo», *IJTRD*, Proceedings of International Conference on Arts, Science & Technology, 20-22 December 2017, Dubai, 93-96.

EL-GHAREB, K.: « Microstructure and Damage Assessment of Some Ptolemaic Pottery Objects at Tell Abu Yasin in Sharkia, Egypt: Case Study», *JGUAA2*, 6/1, 2021, 154-174.

KŘÍŽOVÁ, H.: *Natural Dyes: their Past, Present, Future and Sustainability, in Textile Dyeing-Theory and Applications*, 1st ed., 2013, 317-334.

LEE, J., CEGLIA A., KIM K. J. & LEE, Y.: «Characterization of Dyed Textiles Using TOF-SIMS and FT-IR», *Surface and Interface Analysis* 44/6, 2011, 653–657.

NAFESA, E., EL-SHAMY & OTHMAN, M.: «Analytical Study of the Archaeological Leather Document Preserved In Egyptian Museum And New Proposal For Museum Exhibition», *JGUAA2* 6 /1, 2021, 136-153.

NATIONAL PARK SERVICE (NPS), APPENDIX K.: *Curatorial Care of Textile Objects, Museum Handbook,* Part I, (NPS Museum) 2002.

NILSSON, J.: «Evaluation of Stitched Support Methods for the Remedial Conservation of Historical Silk Costumes», *E-conservation Journal*, 2015, 1-20.

Oriental Rug Knotting & Construction. Pdf. downloaded from: http://www.kapridjianrugsandcarpets.com/knotting.pdf, (Accessed on March 3, 2021).

OSMAN, E. ZIDAN Y. & KAMAL, N.: «Using The Microscopic and Spectroscopic Techniques to Identify and Characterize Archeological Artifacts», *IJCS* 5/4, 2014, 459-468.

PEETS, P., LEITO I., PELT J. & VAHUR, S.: «Identification and Classification of Textile Fibers Using ATR-FT-IR Spectroscopy with Chemometric Methods», *Spectrochimica Acta Part A Molecular and Biomolecular Spectroscopy* 173, 2017, 175–181.

PEETS, P., VA & et AL.: «Instrumental Techniques in the Analysis of Natural Red Textile Dyes», *Journal of Cultural Heritage* 42, 2020, 19–27.

PIETRZAK, K. et AL.: «Antimicrobial Properties of Silver Nanoparticles Against Biofilm Formation by Pseudomonas *Aeruginosa* on Archaeological Textiles», *Applied Environmental Biotechnology* 1/2, 2016, 1-9.

PÎNZARU, S.C., POP D. & NEMETH, L.: «FT-Raman and FT-Infrared Investigations of Archaeological Artifacts from Foeni Neolithic Site (Banat, Romania)», *Studia UBBGeologia* 53 /1, 2008, 31 – 37.

RADITOIU, V. & et AL.: «Application of Fourier Transform Infrared Spectroscopy (FTIR) for the Study of Cultural Heritage Artifacts», *VR Technologies in Cultural Heritage VRTCH*, 2018, 3-9.

SAKHAI, E.: *Oriental carpets: A buyer's guide,* London (Moyer Bell Ltd) 1995.

SCHÖN, M.: «The Mechanical and Supporting Effect of Stitches in Textile Conservation», (Graduating Thesis, BA/Sc), University Of Gothenburg, 2017.

SCHWEPPE, H.: *Practical Hints on Dyeing with Natural Dyes: Production of comparative Dyeings for the Identification of Dyes on Historic Textile Materials*, Washington, Smithsonian Institution, 1986, 5.

SERRANO, A. & et AL.: «A Non-invasive Imaging Approach for Improved Assessments on the Construction and the Condition of Historical knotted-pile carpets», *Journal of Cultural Heritage* 47, 2021, 79–88.

SHAHID, M. & et AL.: «Analytical Methods for Determination of Anthraquinone Dyes in Historical Textiles: A Review», *Analytica Chimica Acta* 1083, 2019, 58-87.

SINGH, P., SHARMA, E. & FATIMA, N.: «A Descriptive Survey Study on Conservation of Textile Artifacts in the Selected Museums of Uttar Pradesh», *Journal of Critical Reviews*, 7/8, 2020, 1799-1811.

TERTSCH, L. & ZIB D.: «Natural Dyeing – Fabric Dyeing with Madder», Comenius project-biology, 2014, 3. Pdf downloaded from:https://www.academia.edu/24482692/Natural_Dyeing_Fabric dyeingwith_ Madder, (Accessed June 4, 2021).

The Maiwa Guide to Natural Dyes, Maiwa Handprints Ltd.Pdf. downloaded from: Http://www.box19.ca/ maiwa/pdf/Guide_To_Natural_Dyes.pdf , (Accessed June 4, 2021).