THYMOL EFFICIENCY IN CONSERVATION PROCEDURES APPLIED TO INFECTED HANDWRITTEN PAPER ARCHIVE IN THE EGYPTIAN NATIONAL ARCHIVES *DAR-ELMAHFOUZAT*

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ABSTRACT

[AR] تقييم كفاءة الثيمول كاحدى اجراءات الصيانة والترميم تطبيقا على السجلات الورقية المصابة بدار المحفوظات المصرية

دار المحفوظات الوطنية المصرية هى ثاني أقدم دار أرشيفية فى العالم من أجل حماية جميع الوثائق والأوراق الأثرية والتاريخية الرسمية من الضياع والسرقة. و الدار تمتلك بنحو 150 مليون وثيقة أثرية و تاريخية رسمية.الا انه و للأسف الشديد اغلب هذه المواد الأثرية قد تعرضت لتدهور بيولوجى مما أدى إلى خسارة كبيرة. ومن هنا تظهر أهمية استخدام مبيدات الفطريات و قد وقع الاختيار على أحد أكثر المبيدات شيوعا فى مجال الاثار وهو «الثيمول» لدراسة مدى كفاءته تجاه الفطريات عند استخدامه بتركيزات مختلفة. هذا إلى جانب دراسة أولوية الحفظ للأرشيف الورقى المكتوب بخط اليد لعقود الزواج «بمحكمة دمياط» لما له من أهمية كبيرة في إبراز معلومات غاية فى الاهمية وثائقيا وذلك بعد تعرضه لعدوى فطرية. استراتيجيات عمليات الترميم والصيانة التى تمت بالدراسة تتم من اجل الحفاظ على هذا الدفتر الورقى من أجل الحفاظ عليه لما يحويه من معلومات أثرية هامة. كما تم استخدام بعض التقنيات الفحوص والتحليل خلال الدراسة وهى: طريقة حيود الأشعة السينية (XRD) للتعرف على الحبر الكربونى، والتحليل الطيفى للأشعة تحت الحمراء (FTIR) لتحديد المادة الرابطة للاحبارالمستخدمة ومدى بلورة السيليلوزالمكون الرئيسى للورق، حيث أظهرت النتائج أن الحبر الأسود المستخدم فلا الوثائق الورقية بالدفتر عبارة عن كربون وأن المادة الرابطة للحبر هى الصمغ العربي. تم تطبيق عدة خطوات لترميم الدفتر مثل عملية التنظيف، تثبيت الأحبار، فرد الأوراق، إصلاح التمزقات، تدعيم الأجزاء الضعيفة وإزالة الترميمات السابقة غير المناسبة.وعلى هذا تهدف هذه الدراسة إلى إلقاء الضوء على دار المحفوظات الوطنية المصرية وإبراز دورها المهم في حماية وحفظ الوثائق الأثرية والتاريخية فضلا عن تقييم كفاءة الثيمول تجاه الفطريات باستخدام تركيزات مختلفة مع شرح أهم إجراءات الترميم المختارة للدفتر الورقى المكتوب بخط اليد الخاص بعقود الزواج بمحكمة دمياط.

[EN] The Egyptian National Archives *Dar-Elmahfouzat* is the second oldest archive house in the world built in order to protect all the official archaeological and historical documents and papers from loss and theft. It possesses about 150 million official archaeological and historical documents.

Unfortunately, all these archaeological materials are exposed to biological degradation which results in great loss. Hence the importance of using fungicides. The choice fell on one of the most commonly used in the field "thymol" and its efficiency towards fungi in different concentrations. The author gives the priority of conservation to this important handwritten paper archive of the marriage contracts' of Damietta court, because of their great importance to posterity and to highlight such significant historical data threatened by fungal infection. The specific conservation strategies employed to conserve this paper archive were meant to keep them safe and secure and to give us the important archaeological information that they contain. Also some analytical methods were used here: X-ray diffraction (XRD) method for identifying the carbon ink, Fourier Transform Infrared Spectroscopy (FTIR) for determining the ink binder and the paper crystallinity. The results revealed that the black ink was carbon and ink binder was Gum Arabic. Different types of conservation processes were used: Cleaning process; fixing the inks; flattening and crease removal; repairing tears and supporting the weaker parts in completion process; and inappropriate previous repairs removal. This study aims to shed light on the Egyptian National Archives *Dar-Elmahfouzat* and highlight its important role. Also clarifying its importance in protecting and preserving the archaeological and historical documents, explain the thymol efficiency towards fungi in different concentrations and the most important treatment procedures for the selected handwritten paper archive of the marriage contracts of the court of Damietta.

KEYWORDS: Archive, conservation, *Dar-Elmahfouzat*, paper, previous repairs.

I. INTRODUCTION

The Egyptian national archives *Dar-Elmahfouzat* is the second oldest archive house in the world[1]. Its establishment dates back to 1829 by Muhammad ᶜAli Pasha under the name of the *aL-Daftarkhana*; in order to protect all the official archaeological and historical documents and papers from loss and theft. Its name was changed to the Egyptian National Archives *Dar-Elmahfouzat* in 1935. About 150 million official archaeological and historical documents and a rare library that includes 10833 books and all the treaties of Egypt during the Ottoman Empire and 27,500 rare maps for Egypt and the world are housed there.

This building includes:

• **Records:** For all births and deaths all over Egypt.

• **Expense Records**: It includes agricultural lands tax expense from the year 1905.

• **The Library:** It includes most importantly 10,833 copies of books e.g. (Newspaper of «The Egyptian Facts» from the year 1885, the «Decreto» or Khedives' decisions, the ambassadors' agreements at the Ministry of the Foreign Affairs, the yearly statistic for the Egyptian cotton from the year 1911, treaties between Egypt and other foreign countries, the old law of Egyptian police, geographic evidence of Egyptian cotton).

• The Other Building (the Archives of *Al-Daftarkhana*) includes a set of documents:

Such as: Records of the money house competent of Legacy; records of births, vaccinations for the Ministry of Health, and records of deaths or death reports[2].

Due to unfavorable conditions of storage the archaeological and historical documents are currently in a bad condition. The most significant types of damage include dirt, stains, tears, loss, biological deterioration, brittleness, folding, creasing, fading of colors and ink damage. If these worthy documents are not treated, they could be lost forever.

A lot of steps of restoration need to be appllied: cleaning, consolidation and ink fixing[3]. Different methods have been developed by conservators and scientists interested in manuscripts to develop techniques in closely related fields (Librarians and owners of special collections)[4]. In the last years a lot of developments have been made in paper conservation[5].

Using thymol is one of the most important phytochemical components against fungal activity because of its pharmacological and bioactive potential effects as an alternative natural anti-parasite. Thymol is a natural product found in *Thymus*

[1] KIAN BYRNE 2020: 1-3.

[2] MINISTRY OF FINANCE DOCUMENTS 2020: 10.

[3] WOODS 2006: 200-224; ABDEL-MAKSOUD 2011: 47-49.

[4] SHAHINE 1990: 217-223; QUANDT 1996: 1-12; ABIGAIL 1996: 1-30; EL-MOSELHY 2012: 184-186.

[5] SHAHINE 1990: 217-223; QUANDT 1996: 1-12; ABIGAIL 1996: 1-30.

kotschyanus. It is a phenol that is a natural monoterpene derivative of cymene. It has a role as a volatile oil component[6].

This study aims to highlight the importance of the Egyptian National Archives *Dar-Elmahfouzat* in protecting different archaeological and historical documents. The study illustrates the restoration and conservation procedures for the handwritten paper archive of the marriage contracts from the court of Damietta through different steps of conservation. Also, analytical techniques were applied in the study: X-Ray diffraction (XRD) for identifying the ink type, Fourier Transform Infrared Spectroscopy (FTIR) for determining the ink binder and paper crystallinity and finally, confirmation on the thymol efficiency in conservation procedures.

II. MATERIALS AND METHODS

Controlling the biological degradation is considered one of the most important procedures of the conservation process. In this study the author used thymol, one of the fungicides which already have been proven effective in the field, after restoration of the handwritten paper archive of the Marriage Contracts' from the Court of Damietta that are preserved in the Egyptian National Archives *Dar-Elmahfouzat*. Some analytical methods have been also done. The author provided the steps as follows:

1. Visual Assessment

The authors used high resolution Nikon camera for documentation process, in order to record the different aspects of deterioration on the paper archive and in addition to the critical eye observations.

2. X-Ray Investigations for Identification of Ink and Determining the Paper Crystallinity

A few milligrams of the ink powder from some fragments was prepared as ink sample then analyzed by X-ray diffraction using Compact X-ray Diffractometer System PW 1840 – Analytical Equipment – Philips – Eindhoven. The sample was studied in Cairo University labs.

For determining the paper crystallinity a very small fragment (the paper sample) was analyzed by Compact X-ray Diffractometer System PW 1840 – Analytical Equipment – Philips – Eindhoven – the Netherlands (Cu Kα radiation with Ni-filter) in Cairo University labs.

[6] JOHN WILEY & SONS, INC. 2021: 1-100; WAFAA HIKAL 2021: 2162.

3. Fourier Transform Infrared Spectroscopy (FTIR) for determining the Ink Binder

Identification of ink binder was done by using total reflectance – Fourier transform infrared (ATR FT-IR) spectroscopy using Fourier transform infrared spectroscopy (JASCO-FT/IR-6100) in Laser Technology Unit (LTU), Center of Excellence for Advanced Sciences (CEAS), National Research Center (NRC), Dokki, Giza, Egypt.

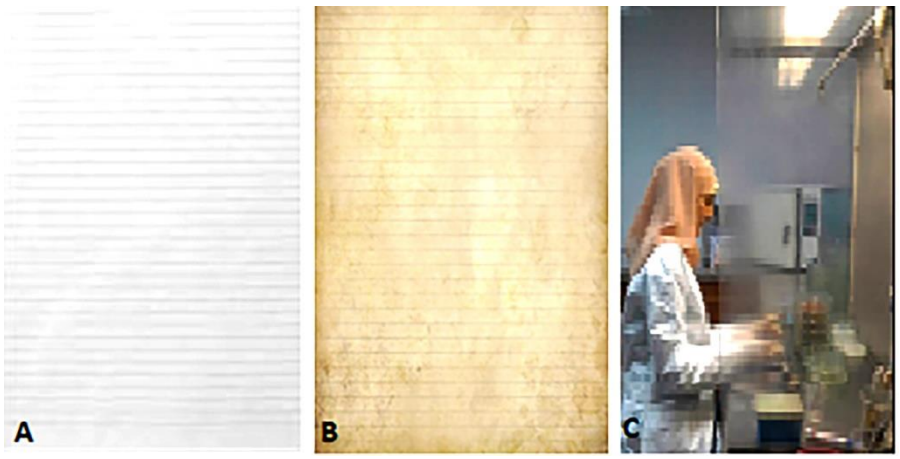
4. Thymol Preparation

Thymol has been selected in the study due to its broad antimicrobial and pesticidal spectrum, also it is commercially available for treatment as it was more economical and effective. Thymol was obtained from the local market: Company of «Sons El-Araby Shama» in Bab El-Khalq – Cairo. Thymol suspensions were prepared according to recommended manufacturer's concentrations: three different concentrations (0.3%, 0.5%, and 0.7%). Thymol traces were dissolved in distilled water or other suitable organic solvents to get the required concentration. In this study thymol came in the form of a white powder and then was solubilized in alcohol 70%.

A. Paper Sample Preparation

After thymol concentrations were prepared, the paper sample was prepared. A sheet of paper was chosen from the surplus of the dilapidated records used in the place of study (*Dar-ELmahfouzat*) in order to be the closest to the document under study and application, as these records have the same chemical and structural composition. Then the sheet of paper was aged in calibrated condition room (heat oven) at the National Institute for Standards with conditions of temperature (70°C) and relative humidity RH (50%) for 8-16 days[7]. This sheet of aged paper was treated with thymol by spraying according to the areas (A/0.3%, B/0.5%, C/0.7%, D/control (210 X 279 mm)). The infected sheet with identified microbial spores of *Aspergillus sp.* (as this family is the most common in affecting the archaeological papers) was placed inside a vacuum chamber and incubated under optimum conditions at 28-30°C [8] as showed in [**FIGURE** 1]. The antifungal activity of the thymol used was tested according to growth zone (%) of the treatment aged sheet of paper. The sheets treated with thymol in different concentrations were compared with the control sheet of aged paper. The percentage of fungal growth inhibition was calculated according to the Pandey *et al.* (1982) formula: Growth inhibition% = [(growth in the control — growth in the sample)/growth in the control] × 100.

[7] JIM REEB & MIKE MILOTA 1999: 66-74.
[8] ORLITA 2004: 157-163; PANGALLO et AL. 2007: 87-94.



[FIGURE 1]: The sheet of paper before and after ageing and after treated with thymol and infected with fungi inside the vacuum chamber: A- the sheet of new paper; B- the sheet of paper after ageing; C- treatments of the aged sheet of paper inside the vacuum chamber.

III. RESULTS AND DISCUSSION

1. Visual Assessment and Historical Background

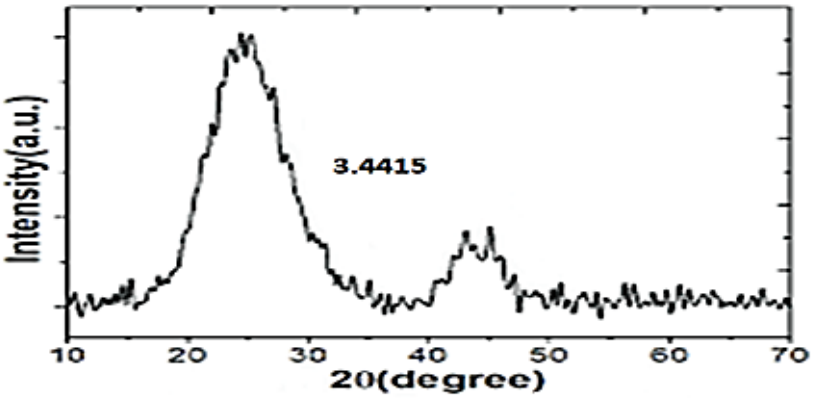
A handwritten paper archive of the marriage contracts of the court of Damietta that preserved in The Egyptian National Archives *Dar-Elmahfouzat*. Its contents were written in black ink and the numbers are in red ink. The storage conditions of the paper archive are unsuitable which resulted in different deterioration aspects. Documentation process for the condition survey was done by using high resolution camera. The results revealed some dirty moist dust on the surface, contraction in different places, embrittlement of some parts, loosening in the stitching, warping of some parts of the edges, stiffness and lack of flexibility of the edges, inappropriate old restoration, and loosening in some parts which resulted in separation of small parts from the sheets [**FIGURE 2**].

[FIGURE 2]: Visual Assessment of the paper archive showing different aspects of deterioration on the paper sheets: 1- Inappropriate old restoration, some dirty moist dust found on the surface and warping of some parts of edges; 2- Contraction in different places, embrittlement of some parts and loosening in the stitching; 3- The loosening in some parts resulted in separation of small parts from the sheets.

2. X-Ray Investigations

A. Identification of Inks by X-Ray Diffraction (XRD)

The results showed that the black ink was made of carbon ink (which appeared in 002Θ=25.86° which refers to 3.4415 Å) **[FIGURE 3].** Carbon inks were made from lampblack or soot mixed with a binder, commonly Gum Arabic which keeps carbon particles in suspension and adhere to paper[9].

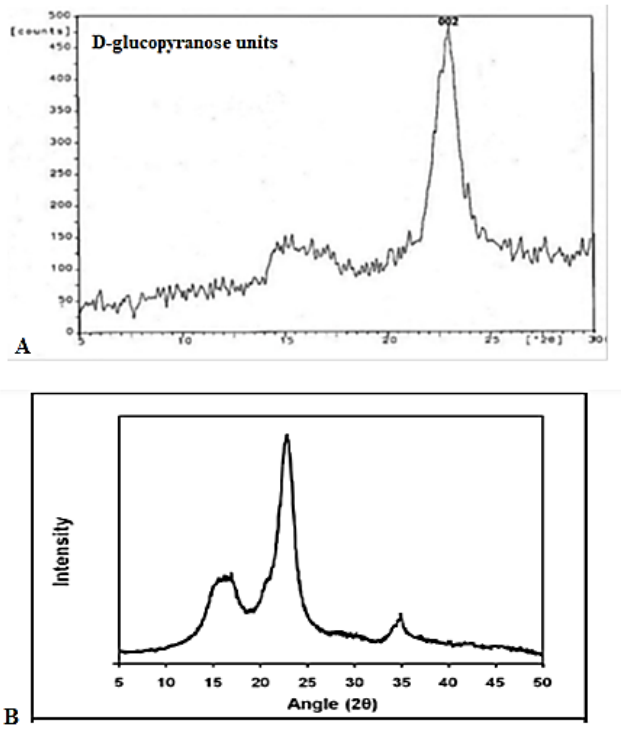


[FIGURE 3]: Identification of carbon ink by X-ray diffraction (XRD) of the paper archive.
© Done by researcher

B. X- Ray Diffraction Analysis for Determining the Paper Crystallinity

Cellulose is a high molecular weight linear polymer composed of D-glucopyranose units linked by β-1,4-glycosidic bonds. The repeating unit of cellulose is called cellobiose. Hydroxyl groups present in cellulose macromolecules are involved in a number of intra- and intermolecular hydrogen bonds that result in various ordered crystalline arrangements. This appeared in the peak 002 compared to the other parts of the chart in **[FIGURE 4]** which are a result in the ageing cycle with larger amorphous contributions.

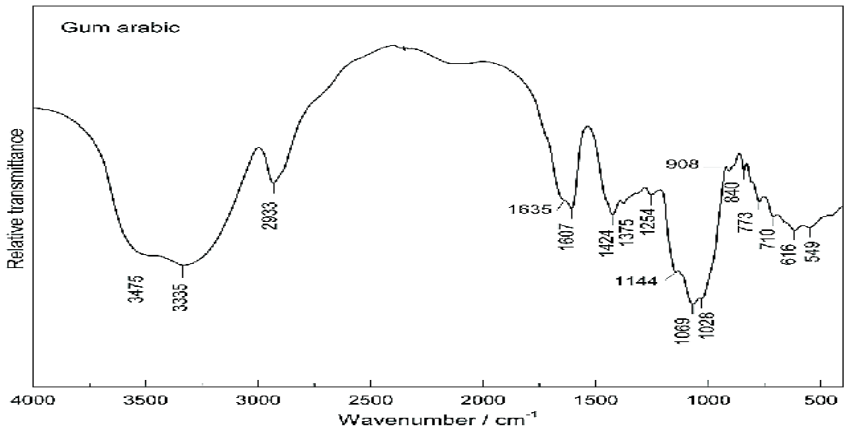
[9] SIMMONS et AL. 2007: 129.



[FIGURE 4]: A- X-ray diffraction pattern of archaeological archive paper (done by researcher) compared to B- the standard X-ray diffraction spectra of cellulose crystallinity[10]

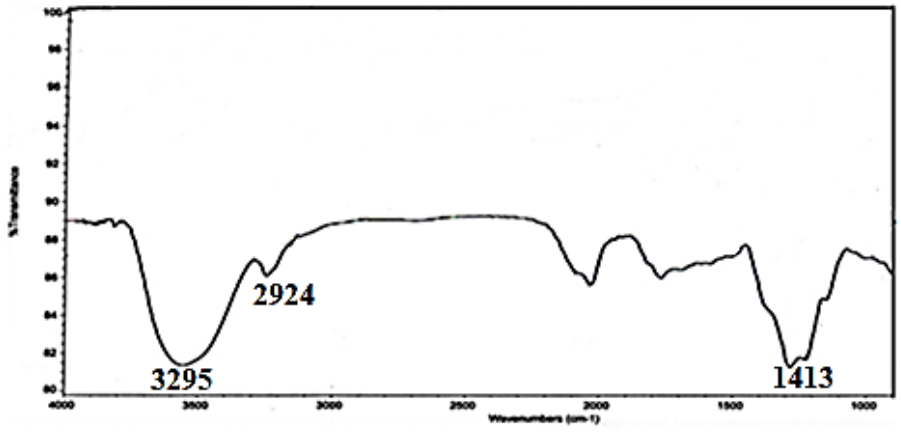
3. Fourier Transform Infrared Spectroscopy (FTIR) for determining the Ink Binder

The results reveal that the ink binder is Gum Arabic compared to the standard chart **[FIGURES 5 & 6]**. The FTIR *spectra* of Gum Arabic showed a broad and strong absorption band in the range of 3400 to 4000 cm^{-1}. Very strong band at 1300-900cm^{-1} due to C–O and O-H stretching band at 3600 - 3200cm^{-1}, which indicated the characteristics of polysaccharides.



[FIGURE 5]: Standard FTIR Spectrum of gum Arabic· ŽELJKA 2017: 18.

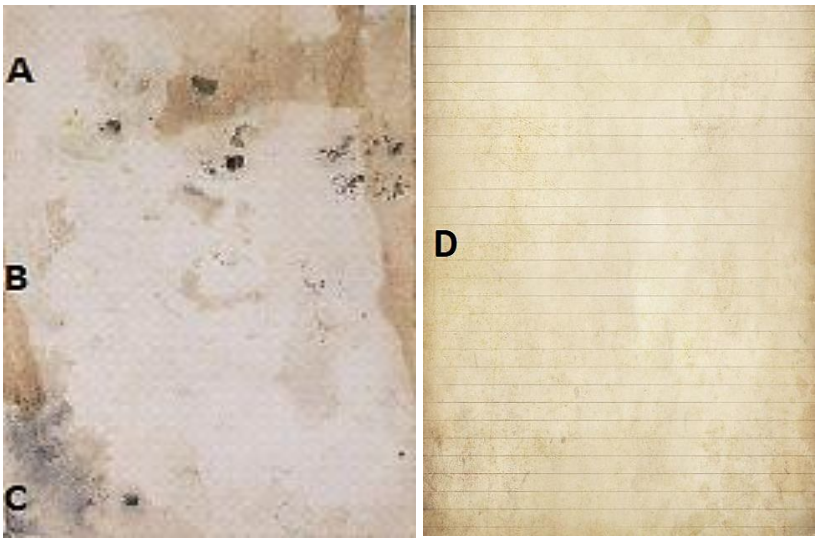
[10] SUNKYU et AL. 2010: 3-10.



[FIGURE 6]: Fourier Transform Infrared Spectroscopy (FTIR) for determining the ink binder © done by researcher

4. Thymol Efficiency in Conservation Procedures

After observation of the aged sheet paper which was treated with different concentrations (0.3%, 0.5%, and 0.7%) throughout a period of four weeks, it was noticed that the presence of fungal activity in the area of low concentration 0.3% was less than the area of 0.5% concentration (A and B region) and in the region of higher concentration 0.7%, where the fungal activity was much less in the area (C area) illustrated in **[FIGURE 7]**.



[FIGURE 7]: Observation of the aged sheet paper which was treated with different concentrations in different areas (A/0.3%, B/0.5%, and C/0.7%, compared with the D/control area) after being infected with fungi.

The antifungal activity of thymol which were observed in the plates of the aged paper sample was explained in table 1 as follows:

Time	Concentration/ Growth inhibition (%)			
	A/0.3%	B/0.5%	C/0.7%	D/Control
Week 1	0	0	0	100
Week 2	1	0	0	100
Week 3	1.5	0	0	100
Week 4	2	1	0.5	100

[TABLE 1]: Antifungal activity of thymol which was observed in the aged sheet of paper areas compared with control. © done by researcher

IV. DISCUSSION

The investigations of the paper archive with the visual assessment which were explained in detail above revealed that the storage conditions of the paper archive were unsuitable which resulted in a lot of deterioration aspects. Damage processes left it suffering from weakness and susceptible to mechanical damage[11].

Carbon-based materials, such as carbon black inks in manuscripts have various structures ranging from amorphous to crystalline, with a high degree of graphitization and crystallinity.

Many researchers studied the structure of the carbon based materials and paper archive using various analytical tools, such as XRD which has been most widely employed for quantitative analysis[12]. The analysis in the study approved that the black ink was made of carbon ink which is referred to in the interplanar distance of 3.4415 Å. Moreover, the FTIR proved that the binder of the ink was Gum Arabic, which includes a broad and strong absorption band in the range of 3400 to 4000 cm^{-1} after comparing with the standard chart of Gum Arabic. Gum Arabic is used commercially as most common old poly-saccharine[13].

All the different aspects of deterioration which appeared in the paper archive require different treatment and conservations procedures, that were applied by the author including the disinfection process, loosening of the binding, numbering the sheets of paper and cleaning process, fixing the inks, inappropriate previous repairs removal, flattening and crease removal, repairing tears, supporting the weakened parts and reassembling the separate small parts from the sheets, and finally the completion process for the missing parts.

[11] KIRSTY 2020: 8, 83.
[12] SANG-MIN LEE et AL. 2021: 153.
[13] HAJER ADAM et AL. 2013: 174.

V. TREATMENT AND CONSERVATION PROCEDURES

Different materials and techniques were used to complete the procedures of the study. First using the alcohol for disinfection, and then using soft brushes in mechanical cleaning to remove dust. Subsequently, chemical cleaning of stains and rust, followed by the use of Klucel G for fixing the ink. Also flattening and crease removal and then completion process by using dyed tissue paper 7 g/m^2 and Klucel G 2% to offer support to paper in order to keep it safe and strong enough for handling and transport and inappropriate previous repairs removal as explained in the following steps:

1. Disinfection Process

The disinfection step can be applied before or after conservation steps[14]. There are a lot of obtainable physical and chemical methods of fungal damage disinfection[15]. In testing antimicrobial products' effectiveness, a 70% solution has far superior efficacy performance than the higher or lower concentrations. The most used forms in alcohols are isopropyl alcohol and ethyl alcohol (ethanol and alcohol). Alcohols have been used for years in sanitizing sprays; wiping agents to remove possible existent residues from contact surfaces; cleaning agent products (ethyl alcohol only), and fulfill the criteria of low toxicity to man and to the environment. Also thymol has a good relationship with collagen materials which promote the growth of micro-organism, it is transparent, colorless and thus does not change the color of the paper surface or produce any unwanted optical effects; and it has a long service of life[16].

Ethanol was used commonly in microbiology as a disinfectant as it has a good toxic effect on fungi if the contact time is at least 2–3 min[17]. So the author used ethanol (98%) applied by spray techniques on the paper archive then left it to dry in the room temperature **[FIGURE 9]**. Also the author applied thymol in the successful concentration (0.7%); its efficacy has been previously tested for future antifungal preservation by spraying technique.

[14] ABDEL-MAKSOUD 2006: 58-67.
[15] ALLSOPP 2004: 25
[16] ARTHUR 1998: 14
[17] NITTÉRUS 2000a: 101-115.

[FIGURE 9]: The disinfection process applied by spray techniques.

2. Detaching the Binding, Numbering the Sheets of Papers and Cleaning Process

In order to obtain a better cleaning process of all parts of the archive paper document, the binding of paper should be detached then the sheets of papers must be numbered. Dirt and soiling were found on the surface of the paper archive. This resulted in physical damage to the document by abrading the fiber structure and inks. It had destroyed the aesthetic value of the document that lead to deformation of the other parts. The danger of the dirt is that it attracts moisture, atmospheric pollutants such as sulphur dioxide and hence forming sulphuric acid. Moisture could encourage mould growth as the spores are often found in the surface dust and disserve the visibility of decorations, inscriptions or information in the document[18]. Cleaning (mechanical and chemical) [19] is an essential and vital technique of removing foreign materials from different sources for aesthetic reasons or reduction of superficial soil, grime or other types of dirt and deposits[20].

The author used the following steps in cleaning: For the safest intervention cleaning should be applied by gentle brushing for removal of the spots of loose surface dirt. Dust was collected from the document pages with a very soft brush[21]. White vinyl eraser to remove the sticky dirt[22] in some areas where no writings are present[23], but in the case of soil/dust a soft brush was first, followed by a sponge rubber. Also the scalpel was used slightly. After dry cleaning with brush and eraser, absolute isopropyl alcohol was used away of ink writing. Soil deposits were removed by wet cleaning using a mixture of

[18] ABDEL-MAKSOUD 2011: 47-49
[19] MOURA 2008: 86-90.
[20] SHAHINE 1990: 217-223; WOODS 2006: 200-224; CROSSMAN 2010: 18.
[21] MUNN 1989: 8.
[22] ARTHUR 1998: 14; CROSSMAN 2010: 18; ALLSOPP 2004: 25.
[23] CHAHINE 1996: 363-369.

alcohol/ water 3:1[24]. After each cleaning step the document was flattened and pressed with a light weight[25].

According to WÄCHTER & LYDIA there are some notes that should be taken into consideration:

- The brush used should be very soft in order to prevent any scratching in the document especially in near places of inks.
- The cleaning process should be carried out from the center to the edges of the document in order not to get the dirt inside the document's tissue.
- The scalpel (if used) should not be used sharp so as not to "hurt" the fibers' tissue.
- Also the magnifying glass should be used during all the cleaning steps to get accurate work[26].
- In chemical cleaning, water should not be used alone but must be mixed with an organic solvent. Mechanical cleaning methods are safer than chemical cleaning methods[27] **[FIGURE 9]**.

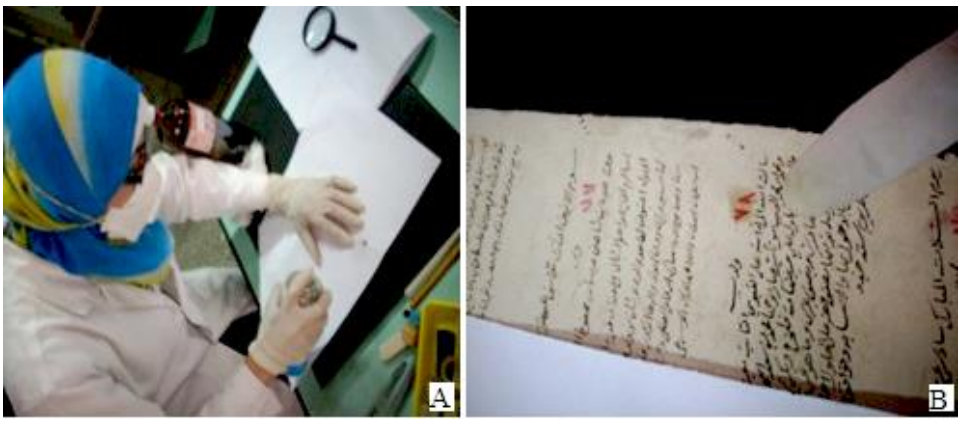
[FIGURE 9]: Some of the conservation producers: A- numbering the sheets of paper before loosening the binding; B-mechanical cleaning using different tools between the lines and on the edges under magnifying glass.

3. Fixing the Inks

Fixing inks is an important step of conservation treatments to secure the water-sensitive ink found, while the aqueous conservation treatment is carried out. The sensitivity of the inks with the different chemicals must be measured[28]. One of the most common materials used in that process is Klucel G (hydroxypropylcellulose) in ethanol at 0.5% applied with a very fine brush[29]. The pH value should be also measured[30]. The

[24] ABDEL-MAKSOUD 2009: 69-87.
[25] ABDEL-MAKSOUD 2011: 47-49.
[26] WÄCHTER 1962: 22–26.
[27] EL-MOSELHY 2012: 184-186.
[28] WOODS 2006: 200-224; EL-MOSELHY 2012: 184-186
[29] DOBRUSINA 1994: 209; QUANDT 1996: 1-12; CHAHINE 1996: 363-369; WOODS 2006: 200-224.

author found that red inks used in numbers in the paper document are sensitive to alcohol so the author used a very fine brush to fix the ink with Klucel G by spraying technique **[FIGURE 10]**.



[FIGURE 10]: Fixing inks in some parts of the document (the sensitive red inks): A, B-covering the other parts surrounding the sensitive red inks in the document then spraying technique.

4. Inappropriate Previous Repairs Removal

Removing inappropriate previous repairs is important in order not to lead to further deterioration aspects. Past repair techniques were carried out using new paper patches adhered with adhesive. The cases require removing when it causes damage or obliterate parts of the document. Inappropriate previous repairs can be removed by mechanical or wet methods. The author used topically alcohol/water solution with a piece of wet blotter in some parts and adhesive residue was removed with a micro spatula. Additional methods can be used by using poultices or humidified swabs[31] such as a topically humidifying by putting the adhesive with a micro spatula, then trying to remove the outsides edges of the old repairs under the magnifying lens with the fine needle and spatula. Gore-Tex (polyester web) was used to absorb the moisture and put the slight weights to flatten the parts. The author used a metal sink of water for soaking the archive paper sheets, placed between Reemay (white, non-woven polyester fabric) for preserving the sheets from rush of water, and removing the old inappropriate repairs. The author recommends using this technique **[FIGURE 11]**, which was useful as water naturally will work as deacidification agent. Besides, water adjusts the degree of pH of the papers and releases the fibers themselves after ridding the papers of impurities and contaminations.

[30] DOBRUSINA 1994: 209; QUANDT 1996: 1-12; CHAHINE 1996: 363-369.

[31] MUNN 1989: 8; DOBRUSINA 1994: 209; BOTTI 1996: 563-581.

[FIGURE 11]: Inappropriate previous repairs removal: A- putting the sheets between Reemay; B- moving the water by brush as Reemay preserve the sheets not to be hurt by the rush of water; C & D- remove the old repairs (different types of old deteriorated papers).

5. Crease Removal

Removing creases was determined according to the state of the case of paper[32] by raising its moisture content[33]. Alcohol has a lower surface tension than water so Alcohol-Water mixture is isotropic as both components will evaporate simultaneously which causes the fibers less shrinkage[34]. The warped parts of the document were folded with a spatula after adding a small amount of HPC to humidify the area, then small pieces of Plexiglas (or Perspex as light weights) were placed on the outer perimeter of the part then left to dry. The process was repeated all over the warped parts of the paper document[35]. The author added another method by using a hot digital spatula. It should be noticed that the paper sheets should be placed above the Teflon (plastic material polytetrafluoroethylene (PTFE) which is not affected with the heat of the spatula **[FIGURE 12].**

[32] KOLAR 2001: 135–138.
[33] EL-MOSELHY 2012: 184-186; SINGER 1992: 40-45.
[34] QUANDT 1996:1-12; EL-MOSELHY 2012: 184-186.
[35] EL-MOSELHY 2012: 184-186; LAURA 1992: 540-590.

[FIGURE 13]: Flattening and crease removal: remove the creased parts by using hot digital *spatula*.

6. Repairing Tears, Supporting the Weakened Parts and Reassembling the Separate Small Parts

Cruicksbank (2004) and Wills (2001)[36] described the importance of supporting the weakened parts after the first stage of the flattening process. Tear repairs are an important step of conservation. Tears should be fixed in order to improve the appearance, prevent lengthening, separating, and make a document safer to handle. Using a proper adhesive is essential[37]. The author used Klucel G (hydroxyl propyl cellulose (HPC)) which is highly recommended for its solubility in water, ethanol, and methanol also has a low-medium viscosity-grade[38]. Additionally, the author used a sheet of Japanese paper (9g) divided into wide strips using a needle in order to obtain small or narrow strips. These strips were picked up with a tweezer and placed over the tears, then adhesive was applied in a low concentration (1%)[39]. Finally, a piece of Gore-Tex was put on the top of the repair area (to absorb excess moisture and adhesive), then pieces of light weight glass were placed, and the paper was left to dry. After drying the excess tissue was cut off.

Then pressed, using a 1% solution of Kucel G (hydroxyl-propyl-cellulose) (dissolved in ethanol) sprayed on the verso of the document. It is also noteworthy that reassembling the separate small parts from the paper sheets together was done by using the hot digital spatula under the magnifying glass with thin strips of thermoplastic polymer **[FIGURE 14].** Some notes should be taken into consideration:

- These steps should be carried out from one side, but if the part was so weak and the tear was so long it could be carried out from two sides like a sandwich.
- This process should give the document strength during handling.
- The materials in that case should be transparent enough not to obliterate any part of the document or the writing lines.

[36] WILLS 2001: 51-62; CRUICKSHANK 2004: 63-70.
[37] EL-MOSELHY 2012: 184-186
[38] CLARKSON 1992: 27-30.
[39] WOODS 1995: 221-239; LARSEN 1997: 39-68; WILLS 2001: 51-62; CRUICKSHANK 2004: 63-70.

- A soft brush should be used and applied from the center to the edges in order not to contain any bubbles of air or an extra adhesive.
- Approximately 1cm was allowed to extend beyond the edge of the paper to protect the document from future adverse contact[40].
- After finishing the extra pieces should be cut out in a horizontal way not to make any distortions after drying[41].

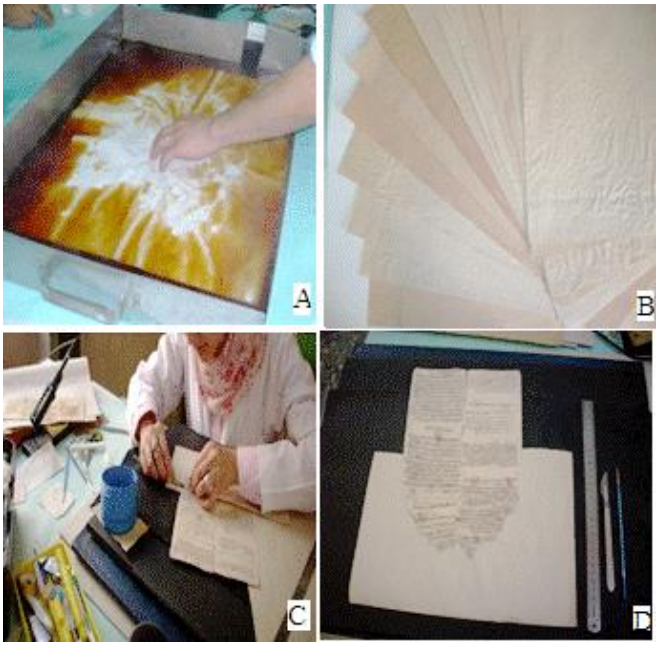
Any adhesive used for mending tears should be characterized with strength, no tendency to discolor and reversibility[42]. To minimize damage, repairs are performed using adhesives with the least amount of moisture required for the specific task[43].

[FIGURE 14]: Reassembly of the separate small parts from the sheets: A-collecting the separate parts; B-reassembling the separate small parts with the sheets under the magnifying glass; C-Reassembling the separate parts using hot digital spatula with thin strips of thermoplastic polymer.

7. Completion Process of Missing Parts

The author prepared the dyed sheets, that will be used in the completion process, with natural dyes (tea with different concentrations). CMC (carboxy methyl cellulose) was used as adhesive with fine brush and sharp metal scalpel for the peeling steps **[FIGURE 15]**[44].

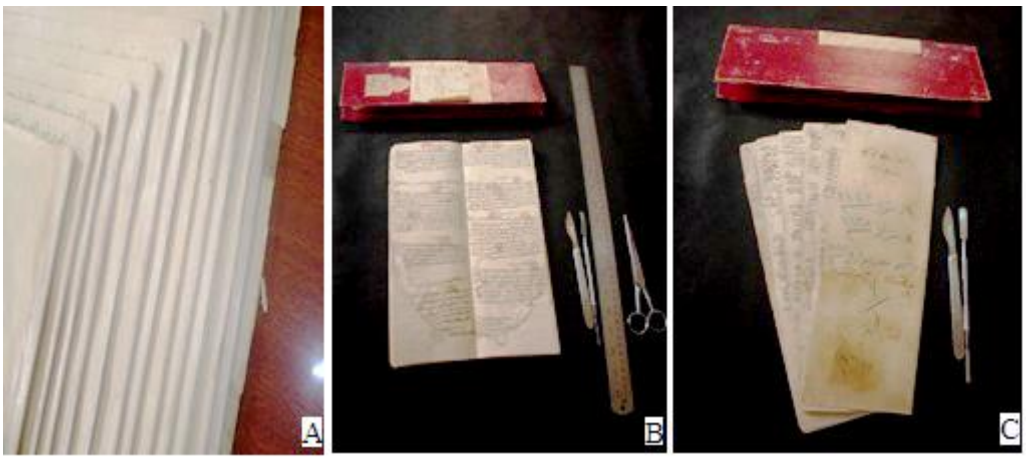
[40] CAINS 1983: 15-23; JOHN 2007: 48-57.
[41] EL-MOSELHY 2012: 184-186
[42] HANSEN 1992: 325–342.
[43] LAURA 1992: 540-590; CATHLEEN 2010: 7.
[44] BLANK 1997: 39-45.



[FIGURE 15]: Completion process of missing parts: A & B- preparing the dyed sheets of papers that are used in the completion process; C & D- putting CMC adhesive with fine brush then using sharp metal scalpel for the peeling steps and the sheet after finishing the process.

8. Finishing Procedures

Preservation procedures play an important role in keeping archaeological materials in good condition, after completing the steps for restoration. If the conditions are not favorable; a chain of reactions will start to damage the objects. The adverse effects of air pollutants and micro-organisms are greater in unfavorable climatic conditions. Controlled climate, particularly controlled temperature and humidity keep the objects in good shape[45]. As a final step of the conservation process, the handwritten paper archive of the marriage contracts' from the Damietta Court was finished by reassembling the sheets of papers together into folders, then the total archive was sewn and rebound **[FIGURE 16].**



[FIGURE 16]: Finishing procedures: A- reassembling the sheets of papers together into folders; B & C- the archive folders after sewing and rebinding process.

[45] ABDEL-MAKSOUD 2000: 212-222.

IV. CONCLUSION

The Egyptian National Archives «*Dar-Elmahfouzat*» is the second oldest archive house in Egypt which has an important role in protecting and preserving archaeological and historical documents. Most of them were not preserved in good conditions. Consequently, the author selected the handwritten paper archive of the marriage contracts of the court of Damietta and explains the thymol efficiency in different concentrations towards biological deterioration. Examination techniques have been also applied in order to determine the ink type and its binder, in addition to cellulose crystallinity. Explaining also the most important treatments procedures for the paper archive.

The conservation strategies employed to conserve this paper archive are as follows: disinfection process; detach the binding, numbering the sheets of papers and cleaning process; fixing the inks; inappropriate previous repairs removal; flattening and crease removal; repairing tears, supporting the weakened parts and reassembling the separate small parts from the sheets; completion process of missing parts; finishing process. The study emphasizes the necessity of applying the mentioned method of using the Gore-Tex/Reemay technique in removing inappropriate previous repairs, in addition to the lack of modern equipment in «*Dar-Elmahfouzat*» compared to other modern conservation laboratories.

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