Scientific Methods for Treating and Preserving Manuscripts and Historical Documents

Tedjani Mayata
tedjani-mayata@univ-eloued.dz
University of Eloued
Mohammed Toumi
mohammedtoumi93@gmail.com
University of Eloued

Received: 13-08-2023 **Accepted:** 05-11-2023 **Published:** 21-11-2023

Abstract
This paper delves into scientific methods aimed at the treatment and preservation of manuscripts and historical documents. It underscores the significance of maintaining environmental control within museums, advocating for the integration of sensitive sensors in all rooms to monitor relative humidity and temperature. Additionally, it suggests the adoption of subject-specific climate control within storage cabinets or display cases housing manuscripts. Establishing localized climates stands out as a fundamental approach to safeguarding manuscripts, particularly in cases where comprehensive climate control proves economically burdensome and operationally challenging in archaeological museums. The document also offers references for further reading on this critical topic.

Keywords: scientific methods, historical documents, environmental control, localized climates, archaeological museums.

Tob Regul Sci. ™ 2023 ;9(2): 1245-1260
DOI : doi.org/10.18001/TRS.9.2.76

Introduction

Since its beginnings, the 20th century witnessed modern advancements in various fields such as medicine, physics, chemistry, and others. Additionally, with the development of modern and innovative sciences in the realm of electronics and technology, these sciences have evolved, intricately covering all aspects of human life down to its minutiae. It is only natural that manuscripts, books, and documents receive the attention of scientists and researchers amidst this modern scientific revolution. They deserve in-depth study, treatment, preservation, and action. In the domain of preserving, treating, and restoring manuscripts, books, and documents, science has contributed significantly, prolonging their lifespans and ensuring their safety for long subsequent eras.

Delving into the specifics of manuscripts and books from a material standpoint, their health, so to speak, relies on the nature of the materials from which they are made and the surrounding conditions. Therefore, their treatment, restoration, and preservation do not merely hinge on maintenance and restoration efforts. It heavily relies on creating suitable conditions for their safety and preservation. Consequently, all scientific studies pertaining to the preservation of these cultural assets are based on their natural and chemical properties, as well as the impact of the climatic and non-climatic conditions surrounding them. If we examine manuscripts, we find they are comprised of cellulose materials, represented in paper, proteinaceous materials seen in leather and parchments, adhesive materials like animal glue, starch, and various other adhesives, as well as ink and color media. Collectively, these components are subjected to numerous environmental factors such as atmospheric pollution, fluctuations in temperature, humidity, different types of light, and air-borne elements like fungal spores and insect eggs. All these factors, whether individually or combined, interact with the components of the manuscripts, causing various forms of damage, leaving discernible imprints and clear injuries that can be termed as the imprints of time.

1. **Strengthening Process:**

Undoubtedly, the aim of the strengthening process is to stabilize fragile and deteriorating fibers by interlinking them to attain sufficient physical strength for preservation. In the past, various natural resins were utilized for this purpose, including Paraffin, Coutchouc latex solutions in chloroform mixed with cellulose nitrates or linseed oil. Additionally, natural resins like Glue, Strach, Casein, Gelatin, Beeswax, and Shellac were employed. However, significant scientific advancements in organic chemistry over the years have led to the production of extensive arrays of modern synthetic resins. This development has made the utilization of these materials a practical and widely accepted concept. Among these resins are types that exhibit high efficiency and effectiveness in the field of artifact reinforcement, enabling restoration and maintenance professionals to select those most suitable for their specific needs (1).

1.1. Natural Strengthening Materials:

A - Starch:

Starch consists of two types of multiple sugars, Poly Glucosides, namely Amylose and Amylopectin (2). These vary from one source to another, consequently leading to variations in starch properties. However, starch generally possesses excellent adhesive properties due to its high concentration of hydroxyl groups capable of forming secondary hydrogen bonds that align with the functional groups in cellulose fibers (3).

Pliny mentioned that starch made from a finest types of wheat flour mixed with boiling water was used in the production of papyrus during the Pharaonic era. Nevertheless, no specific example or recognition of starch in papyrus or any other Egyptian material was cited (4). Starch was used in the preservation of a limited number of artifacts, including paper, silk, wood, and bamboo. Additionally, it is used as a secondary consolidant and fixation material, depending on the nature of the artifact and the application method (5).

There are numerous types of starch, such as cornstarch, wheat starch, potato starch, and rice starch. Wheat starch was used for long periods in paper strengthening, and in the Near East, it was employed for several centuries in fortifying weak embroidered antique textiles.

However, both corn and potato starch have proven to be more susceptible to damage during processing, resulting in yellowing. Rice starch, on the other hand, has been found to be less stable than wheat starch concerning natural aging factors (6).

Even though starch might not meet all modern requirements for restoration and artifact maintenance, there is no adhesive material that can be prepared, controlled, and reclaimed as easily as with starch (7). Thus, starch has continued to be used mixed with glue as a consolidating material over multiple centuries (8).

B - Gum Arabic:

Gum Arabic is a high-molecular-weight polysaccharide weighing 58,000 and comprises complex carbohydrate materials that yield glucose upon breakdown (C H O). It also contains structurally complex salts, organic acids, as well as compounds of calcium, magnesium, and potassium. Gum Arabic is extracted from various types of Acacia trees, with Acacia Senegal considered the most crucial species. Sudan, in particular, stands as the leading country in the production and trade of Gum Arabic (9).

Gum Arabic dissolves in cold water and quickly dissolves in warm water but does not dissolve in organic solvents or melt upon heating. The solution of Gum Arabic is prepared by crushing the gum pieces and converting them into fine powder, adding water, and stirring the mixture thoroughly to create a solution suitable for the desired purposes (10).

Gum Arabic was used in ancient Egypt and remained a commercial commodity for thousands of years (11). Herodotus mentioned its use in binding linen wraps used in wrapping mummies after embalming. He also stated that ancient Egyptians often used it instead of glue (12).

Moreover, Gum Arabic was utilized as a medium in inks and colors and recommended for use as a color fixative. It was also used as an adhesive in paper tapes and labels. Additionally, it was formerly used as a textile adhesive but is susceptible to water degradation and oxidative light damage similar to starch. Additionally, it is prone to biological deterioration (13).

C - Animal Glue:

Animal glue is considered one of the oldest and most well-known adhesive materials, obtained from certain animal materials containing gelatin such as bones, hides, cartilages, and animal tendons through water extraction and concentration via evaporation. It was used in ancient Egypt for various purposes, including wood binding, mortar making, fixing coarse-woven linen with wood and gypsum, as a coating material, and fixing colors (14).

Animal glue is a complex group of compounds known as proteins, consisting of carbon, hydrogen, oxygen, and nitrogen (15). It contains a high proportion of gelatin, chondrine, and a percentage of keratin, with multiple types such as fish glue (16).

It provides high adhesive strength in dry atmospheres but is highly sensitive to moisture. At a relative humidity of 80%, it is prone to biological damage. Protection from fungal and bacterial growth can be achieved by adding substances like mercury chloride and formaldehyde. However, mercury chloride remains a toxic residue, while formaldehyde leads to cross-linking and insolubility, quickly degrading if acidity surpasses pH 3 or alkalinity goes beyond pH 9, along with rapid degradation by enzymes (17).

Animal glue was one of the strongest adhesive materials before the scientific advancements in synthetic resins. Paste of glue and starch was used for relining oil paintings in the 18th century and later in the strengthening and bonding of antique textiles, ivory, bone, wood, paper, ceramics, pictures, and colored drawings (18).

1-2. Industrial Strengthening Materials:

Polyvinyl compounds appeared somewhat early around 1835, when Polyvinyl Chloride (PVC) production was first achieved. However, the production of vinyl polymers did not evolve until the 20th century. Polyvinyl acetate exists as solid powders with various molecular weights, and its properties depend on these molecular weights (19).

Vinyl acetate copolymers are prepared by reacting vinyl acetate monomer with acetaldehyde using polymerization methods such as suspension, emulsion, and bulk (20). Their Glass Transition Temperature (Tg) is within the range of room temperature and exhibits stability under light. Vinyl acetate acetate dissolves in various solvents including dimethyl ether, acetone, toluene, benzene, methanol, xylene, amyl acetate, and others (21).

In 1932, vinyl acetate was first used in artifact preservation as a surface adhesive and binder during the transfer of gypsum frescoes. Subsequently, it was utilized as a glazing material for pottery and cornices, adhesive in oil painting relining, and its application expanded to include various artifact materials (22).

A - Cellulose Acetate (CA):

Cellulose acetate was prepared around 1927 through the reaction of cellulose with acetic anhydride in the presence of concentrated sulfuric acid as a catalyst (23). Cellulose acetate with a degree of substitution (DS) of 2.4 dissolves in acetone and similar solvents. When the substitution degree reaches 3, it dissolves in less polar solvents. CA replaced CN and was used as a strengthening material for textiles, paper, and other substances. Its primary use in artifact preservation was in paper encapsulation (laminating), which commenced in 1934 (24). Varieties of CA with a molecular weight of 18,000 and a low polymerization degree below 200 were used for oil painting varnishes due to their light and heat stability properties (25).

B - Cellulose Nitrate (CN):

Cellulose nitrate is considered the first commercial synthetic material, the most famous and oldest derivative of cellulose, commonly used in various industries (26). Its production is credited to Schonbein in 1845. Everett.A mentions the year 1862 while Mills.J states it as 1833. This product evolved in the forties of the 19th century when a new method for treating cellulose with nitric acid was discovered, resulting in the production of cellulose nitrate in 1870 (27,28).

Cellulose nitrate resin is a colorless, brittle, and solid polymer that can be melted and molded at 80°-90°C and flows at 150°C. It is soluble in most polar solvents, alcohols, ketonic ethers, and esters, and exhibits resistance to water and moderate resistance to mild acids and bases but is vulnerable to strong acids and bases (29).

Cellulose nitrate has been used in artifact preservation for a long time (30). It was one of the first resins used for strengthening all artifact materials. Although its solubility is a significant advantage, its drawback includes brittleness and the formation of nitric acid when broken. Posse suggested using Zapon, a solution of camphor and cellulose nitrate in amyl acetate, for paper reinforcement and surface coating of artifacts. However, it was replaced in the 1920s and 1930s with cellulose acetate and polyvinyl acetate (31,32).

C - Hydroxyethyl Cellulose (HEC):

Hydroxyethyl cellulose is produced by the reaction between alkaline cellulose and ethylene oxide. It appears as a white powder, and its properties depend on the length of the base chain and the number of hydroxyethyl groups in the molecule. It exhibits good resistance to organic solvents but is not resistant to water. It is susceptible to biological degradation but retains its adhesive strength in hot and humid conditions. HEC is used for paper, fiber, leather adhesion, and various other applications (33).

It has been used in different forms to increase the viscosity of suspensions to form pastes, as well as for protecting colors used on non-varnished picture surfaces (34). Some types of HEC were reported to cause fiber weakness when used in silk reinforcement (35,36).

D - Methyl Cellulose:

Methyl cellulose, an ethereal cellulose, was first prepared in 1992 from cellulose and methyl sulfate, and its preparation has since evolved to more manageable and less hazardous methods. It appears in the form of a fine or fibrous powder, readily soluble in water and cold soda, while heating can cause clotting. It is also soluble in some organic solvents but requires an ethoxy group percentage exceeding 23% (37).

Methyl cellulose demonstrates good resistance to biological deterioration and is considered more stable than cellulose nitrate. It replaced cellulose nitrate in most applications. It was used as an organic solvent, with a degree of substitution larger than 2.6 in the early forties as a lead oxide coating. Methyl cellulose was also used in water solutions with a 1.5-2 degree of dissolution as an adhesive and paper reinforcement. It was utilized for fixing colors on mural surfaces, as a reinforcement for water-submerged wood, and as an adhesive for textiles. Additionally, it was added to starch and polymer suspensions to enhance their properties and is safely used with silk textiles (38).

1.3. Parylene Consolidation:

Parylene is considered one of the modern polymers used in the conservation of cultural artifacts such as books and manuscripts, especially in cases of strengthening weak and brittle paper affected by high acidity. It appears as a white powder, known for its high flexibility, resistance to oxidative reactions, stability, and resilience against moisture and ultraviolet radiation. It exhibits good resistance against both organic and inorganic materials, chemical substances, strong acids, alkaline solutions, polluted gases, and water vapor.

The process of applying the Parylene layer occurs at room temperature without any chemical interaction with the material intended for reinforcement. Instead, it mechanically adheres after exposure to Parylene gas or vapor, bonding and crystallizing onto the surface, depositing a thin layer (39). Paper can also be immersed in Parylene, penetrating the cellulose fibers deeply, protecting the paper from moisture effects, increasing its flexibility and fiber durability (40).

Parylene is a superior material used in reinforcement processes, particularly for weak and brittle paper. It acts as a barrier against the impact of moisture and water on cellulose fibers, enhancing tensile strength, fold endurance, and durability. However, it cannot be dissolved or reclaimed (41).

2. Restoration Process:

The purpose of restoration (both manual and mechanical) is to preserve and maintain cultural artifacts like manuscripts, documents, rare books, and others for an extended period. It aims to reconstitute these artifacts to a form that closely resembles their original state. Restoration involves repairing any deformities that have affected the manuscripts. This process requires high patience, refined taste, and manual dexterity. Restoration is a globally recognized practice based on fundamental principles followed by all conservation specialists, crucial for ensuring the manuscript's safety.

Several key fundamentals precede the commencement of the restoration process. Among the most important are:

A- Preserving the original form of the manuscript without causing any damage.

B- Preserving the heritage of the manuscript, considering several concepts crucial for maintaining its historical and cultural value.

C- Using natural materials and avoiding industrial materials and substances as much as possible.

D- Ensuring the restoration process is reversible, allowing for removal if necessary.

E- Not completing the missing parts of the written lines in the book.

F- Restraining the use of chemicals to the bare minimum to prevent damage and loss to the manuscript.

Moreover, there are crucial and necessary specifications that the materials used in the restoration and treatment should meet, including:

1. Not reacting with the original artifact material.
2. Having restorative properties.
3. Being safe when applied and used.
4. Using materials similar to the manuscript material and manufactured in the same manner.
5. Avoiding the use of foreign chemicals in their composition.

Before commencing the restoration process, the following steps must be taken:

- Photograph the manuscript systematically before and after the restoration process. This documentation demonstrates the extent of effort put into restoring the pages, showcasing the precision and skill of the individual conducting the process. Simultaneously, it unveils any potential forgery that might occur during the restoration process.
- Identify all damages and precisely delineate them to determine the method of treatment and restoration.
- In the case of paper parts being detached, the restorer should collect them in an envelope or container for use in restoration and reposition them later.
- Conduct scientific examinations and laboratory analyses to identify the materials used in the making of the manuscript, including pigments, inks, and other components, and to determine their stability and their reaction to treatment solutions applied for acidity removal, neutralization, and various cleaning methods

For the restoration of books and manuscripts, there are two methods: manual restoration and automated restoration. It's important to delve a bit into history to understand the reality of this practice, who initiated it, and began working on it. When delving into history, we find that the budget of Dar al-Hikmah, established by the ruling Fatimid Caliph by Allah's order in Cairo in 395 AH, included an allocation for the restoration of manuscripts that were subject to damage and injuries. This indicates an early scientific and cultural awareness, a significant aspect of interest in manuscripts, and a commitment to their preservation. It also indicates that the origin of this craft is purely Arab-Islamic. In the past, the methods employed were extremely primitive, relying on the adhesion of torn papers and mending of leather without considering the distortions and new damages caused by these repairs to the manuscripts.

In our modern era, these restoration processes involve precise artistic operations with aesthetic standards that demand a high sense of taste, extreme sensitivity, considerable patience, in addition to manual skill and scientific expertise.

The field of restoration and maintenance, like other sciences, has evolved and been updated. Its methods, techniques, types, and the materials used have varied. We can categorize it into the following three types:

- Manual Restoration
- Automated Restoration
- Thermal encapsulation using foils.

Each of these types possesses different characteristics in terms of execution, application, and the nature of the materials used.

3. **Restoration Methods:**

3.1. Manual Restoration:

This process involves purely manual techniques that demand a great deal of caution, patience, extensive expertise, precision, and highly refined manual skills from the restorer. The restorer mends various damages and injuries using specific tools such as scalpels, forceps, brushes, and a light table, among others, in the restoration of delicate historical documents, rare manuscripts, and books severely damaged. This method involves the use of Japanese tissue paper and various adhesive materials like methyl cellulose, carboxymethyl cellulose, hydroxyethyl cellulose, among others (42). Additionally, it employs equivalent, pure paper resembling the original manuscript paper, prepared to fill in the missing parts. The restorer works on repairing various aspects and conditions of damage, including:

- ***Softening and Flattening Hardened Papers:***

This process is essential for papers exposed to dry climatic conditions, leading to the loss of their moisture content and resulting in cracking and warping. When paper loses its moisture due to low ambient humidity, it becomes dry. To counter this dryness, special softening solutions are utilized. These solutions consist of mixtures of alcohol and glycerin in varying proportions. Additionally, 2% thymol is added to these solutions as a preservative. Based on the degree of paper dryness, the softening solutions are categorized as follows:

- Dry Paper: 480 cm^3 Ethanol + 50 cm^3 Glycerin + 20 cm^3 Water + 20 cm^3 2% Thymol
- Moderately Dry Paper: 450 cm^3 Ethyl Alcohol + 50 cm^3 Glycerin + 20 cm^3 Water + 20 cm^3 2% Thymol
- Severely Dry Paper: 425 cm^3 Ethyl Alcohol + 75 cm^3 Glycerin + 20 cm^3 Water + 20 cm^3 2% Thymol

- **Separating Stuck and Hardened Pages:**

Manuscripts are affected by environmental and climatic factors, causing the manuscript pages to adhere to each other. This occurs due to excess moisture exposure over time. The presence of dust and dirt within the folds creates a suitable biological environment for the growth of insects and

fungi, weakening the paper's structure (43). These conditions can cause the papers to stick together and harden, forming a solid mass where fungi and bacteria proliferate after the pages have absorbed excessive moisture from poor storage conditions. Consequently, this weakens the papers, leading to tearing while attempting to separate them.
Therefore, we require scientific and appropriate methods to separate them, relying on the restoration specialist's skill and control to avoid any tears or damage during this process.

Indirect Moistening Method:
This process involves placing stuck pages between two layers of blotting paper. Then, wrapping them with a piece of cloth moistened with distilled water, followed by encasing the entire assembly in a nylon bag and compressing it under a glass panel with a weight on top for half an hour. The aim is to gently separate the pages from each other without exposing them to excessive moisture, which may lead to disintegration and ink damage.

For Slightly Stuck Pages:
In this case, gently press and manipulate the manuscript back and forth, holding it from the spine side until the pages loosen from each other. Carefully and cautiously, separate them one by one by hand or with a scalpel.

Steaming Method:
This method requires experience and precise judgment. It involves exposing the stuck pages to water vapor by heating a certain amount of water in a wide container. Holding the manuscript vertically over the container at an appropriate height, allowing the water vapor to penetrate between the pages. Then, cautiously attempt to separate the pages and leave them to dry between blotting paper (44).

As an efficient and time-saving alternative, a steaming device is employed. Many stuck books and manuscripts are placed within the device, which emits water vapor for a short period, followed by an attempt to separate the pages (45).

Alternatively, soaking the pages in a solution comprising alcohol, water, and glycerin in proportions of (2:1:1) is a reliable method. Glycerin permeates the paper fibers, strengthening them, facilitating their separation without damage.

- ***Restoration of torn pieces:***
  These tears result from the removal of sharp tools such as scissors or different blades. The cuts are either in a straight or diagonal line and are characterized by the absence of fibers on the edges of the cuts. They are restored by using neutral transparent paper or Japanese paper on one or both sides in a very narrow and thin strip along the cut. The strips are cut by hand as we need the fibers on the edge of the strip.

- ***Restoration of diagonal and curved cuts:***
  These are a result of tearing by hand and are characterized by the presence of fibers on the edges (46). They are restored by applying adhesive on the fiber edges from both sides and then aligning, joining, and integrating them back into their original state.

- ***Restoration of fragmented or torn papers:***
  This destructive phenomenon is due to the high acidity in the papers. Restoration is done by stabilizing the torn and fragmented text on paraffin paper after matching the letters and spaces by using adhesive. Subsequently, it is sprayed with a sizing solution and left to dry. Then, a piece of Japanese paper is placed over it, and adhesive is applied from the center towards the edges in a uniform manner over the entire text. Another layer of paraffin paper is placed on the coated surface and smoothed by hand. It is then flipped, and the previous paraffin is slowly and carefully removed. Following this, missing parts of the old paper are added with new paper of suitable thickness and color. The paper is left to dry, placed under a press to flatten, and becomes smooth without wrinkles.

- ***Restoration of corners and margins:***
  The process involves selecting suitable paper for the original manuscript to be restored. It is then cut larger than the missing part of the paper. The edges and missing margins are coated with adhesive on both the missing paper and the new paper. With the help of an illuminated table, the used paper is cut to match the shapes present in the old paper, using hands or a scalpel to obtain the necessary fiber for integrating the manuscript's paper with the new one. After the cutting process, the contact area is lightly coated with adhesive, and the fibers are merged using a scalpel (47).

- ***Restoration of the entire paper edges "frame method":***
  This is done when only the middle part of the manuscript paper remains. The restoration process includes selecting a suitable pulp paper for the worn and eroded paper in terms of thickness, color, and area. Subsequently, both papers are applied to each other, taking into account an illuminated table to ease the completion process. The outlines and borders of the old paper are lightly drawn with a pencil on the new paper. Then, the drawn shape is cut using a scalpel to create fibers on the edges of the cut-out area in the middle of the paper. Following this, adhesive is applied to the eroded paper's borders, and the new paper is accurately glued onto it, ensuring that all edges and features of both papers match each other. The fibers are integrated using adhesive and a scalpel.

- ***Repairing holes resulting from insects and rodents:***
  The various shapes and appearances of holes in manuscript papers caused by different pests vary depending on the infesting insect. Some holes are circular, others are elongated, or irregular in shape (48). Often, repairing these holes using restoration paper is challenging. Therefore, we resort to repairing them using paper pulp dough. With the aid of a scalpel, we fill the holes with paper pulp dough without any excess protruding beyond the hole's boundaries, to avoid covering letters or lines of writing (49).

To prepare the paper pulp dough, a small quantity of the paper used for restoration is cut into small pieces and soaked in distilled water for 24 hours (50). The soaked quantity is then placed in a blender and thoroughly mixed for 20 minutes, adding a small amount of methyl cellulose. After the mixing process, the excess water is filtered out from the fibers. A little methyl cellulose is then sprinkled over the prepared fibers and left for absorption. Following this, a small amount of glycerin is added to provide the necessary flexibility to the dough, along with a few drops of formalin as a preservative. All ingredients are thoroughly mixed until the dough is well blended and ready for use (51).

- ***The restoration using the splitting technique:***
  In this method, it's possible to address various types of previous damage in a single process by splitting the manuscript paper into two sheets. Subsequently, a delicate restoration paper is placed between the two sides and then rejoining them onto the restoration paper to recreate a single sheet as it was before the split.

  This method is carried out as follows:

  Both sides of the paper intended to be split are uniformly coated with a special adhesive, either a gelatinous adhesive or a cellulose adhesive. Then, the two pieces of the sheet are joined on their sides and placed under a press to dry.
  Once the drying process is complete, the edges of the adhered sheet are gently and cautiously pulled apart, causing the paper to split into two.
  The split page is then separated from the adhesive by placing it in a solution of water and alcohol.
  A suitable, delicate restoration paper is chosen in the required dimensions and placed between the torn pages. They are then reattached using an appropriate adhesive, thus creating a single sheet.
- ***Fiber-Based Restoration Technique:***
  This method is considered modern and innovative, relying on completing the missing parts of manuscript paper using paper fibers of various colors, lengths, and sizes. Notable features of this technique include ensuring complete uniformity between the old paper and the restored area in terms of texture, feel, and color. Additionally, it yields excellent results in restoring unblemished and unaffected paper edges. This method has two advantages in this case: a. It does not add any thickness in repairing the adjacent paper edge. b. It significantly shortens the restoration process time.
  This process requires cellulose fibers of different colors to accomplish. The restorer determines the desired color degree from the fibers, matching it to the color of the manuscript paper. The desired color is produced from a mixture of several colors in specific proportions. These are thoroughly blended using a water distiller for 20 minutes (52). Subsequently, they are placed inside a plastic container with a plastic tube to extract the fibrous liquid onto the damaged area of the manuscript paper using a specialized device for this type of restoration. This method can be utilized in various restoration procedures.
- Etching and Plate Removal Method: This method is used when dealing with damaged thick paper containing gilded etchings or plates, and the process proceeds as follows:

- After thorough drying, the fabric layer is peeled off, along with the gilded etching layer that can be used and restored by placing it onto a new suitable restoration paper matching the manuscript page or plate size. It can be separated from the fabric using a solution of water and alcohol.
- The etchings are affixed onto the new paper using the adhesive substance utilized in the restoration process.

3.2. Mechanical Restoration:

Mechanical restoration is widely employed in the realm of print restoration and to a lesser extent in manuscript and document restoration. For this type of restoration, a specialized device is utilized, housing a basin equipped with a plastic mesh where the papers intended for restoration are placed on a layer of organza cloth. Pure cellulose fibers, previously prepared and mixed with water, are poured over the papers with great care to ensure even distribution, covering the entire paper's surface area. Subsequently, the water present in the device's basin is vacuumed, causing the fibers to directly settle on the surface of the incomplete and missing papers. The fibers accumulate in areas of holes and deficiencies, the fiber quantity being suitable and calculated by weight and area based on the severity of the paper's damage, while considering the required paper color and thickness. The paper is swiftly removed from the device and spread onto an acid-free cardboard panel. Following this, the paper is subjected to appropriate pressure to ensure complete drying, thereby achieving the final result of the mechanical restoration process.

Mechanical restoration is considered a highly significant process that should be present in every exhibition house, library, cultural center, or any institution dealing with valuable and crucial paper consciousness. Hence, driven by the enthusiasts of cultural heritage, several experiments and attempts at mechanical restoration have been conducted over the years.

- ***The Evolution of Mechanical Restoration:***
  The genesis of mechanical restoration coincides with the stabilization of Europe post-World War II, where governmental entities began recognizing the significance of preserving cultural legacies documented on paper, be it manuscripts, printed materials, or invaluable documents. The idea of restoring documents through suspended paper pulp was born in the document maintenance section of the National Library in Saint Petersburg, Russia, in 1950 (53). Upon assessing the sheer magnitude of this cultural heritage and its dire need for maintenance and salvage, there arose an urgent demand to expedite the restoration and conservation processes. This demand prompted the innovation of specialized techniques and machinery, leading to the introduction of the mechanical restoration system using suspended paper pulp fibers. This system has remarkably evolved over the years, becoming the forefront of intricate restoration tasks involving insect-inflicted gaps, rodent or fire-induced damages, and reinforcing fragile or torn papers. From the early '70s until today, this system has undergone a significant and remarkable qualitative advancement, achieving precision, expertise, and speed fifty times faster than manual restoration.
  The mechanical restoration system requires:

- ✓ A leaf casting device, globally known as the Leaf Casting apparatus.

- ✓ Pure and neutral cellulose fibers.
- ✓ Subjecting these fibers to a precise calculation system based on fiber standards in water.
- ✓ Skill, precision, and swiftness in execution to prevent ink damage by avoiding prolonged immersion in water.

The adoption of this system has spread more extensively and rapidly in Western countries than in Arab nations for several reasons, the most significant being:

- ✓ The high cost of the mechanical restoration device.
- ✓ The expensive nature of pure cellulose fibers and the difficulty in importing them from abroad.
- ✓ The complexity of repairing these devices due to their intricate mechanical and electrical systems, with maintenance services usually only available in the originating country, rendering the system impractical.
- ✓ The scarcity of trained experts proficient in handling these devices.

- ***The Adhesive Materials Used in Mechanical Restoration:***

It is crucial to ensure that the adhesive materials used are of good quality and suitable for restoration work, as the safety and durability of the restoration depend on their type. Therefore, they should possess the following specifications:

- ✓ High adhesive capability.
- ✓ The adhesive should form a flexible, transparent layer on the restored paper's surface.
- ✓ It should be easily removable from the paper in case the restoration process needs adjustment.
- ✓ There are various types of adhesives used in restoration processes. For instance:

A. Methyl Cellulose: The adhesive is prepared in a concentration of 5-3.5% by dissolving 4 grams of methyl cellulose in 100 ml of cold distilled water. After stirring for 10-15 minutes, it becomes ready to use. It is the easiest adhesive to prepare and lasts for approximately one month. It has good specifications suitable for various restoration types.

B. Starch: Starch offers good adhesive properties and is used in leather and other restoration processes. The adhesive is prepared by dissolving 40 grams of starch and 0.5 grams of arrowroot in 500 ml of distilled water. The mixture is placed in a water bath until well blended, then 10 ml of glycerin is added to provide the necessary elasticity and 5 ml of formalin as a preservative.

C. Wheat Paste: This is a good adhesive made from wheat flour, but its preparation is time-consuming. Additionally, it needs to be heated in a water bath when required for use. It is prepared by drying the flour first in an oven at 55°C to eliminate moisture and potentially kill insect eggs, followed by preparation using the following ingredients: 80 grams hot flour, 10 grams gelatin, 100 ml glycerin, 50 ml formalin, and 1 liter distilled water.

Conclusion:

There are several factors that assist in preserving manuscripts and ensuring their long-term maintenance in good condition. For instance, a dry climate impedes microbiological damage, while lower temperatures hinder chemical breakdown and assist in preventing the growth and proliferation of living organisms.

Among the most important methods applicable in a museum environment include the following:

- Complete climate control by establishing storage rooms with specific specifications based on excellent insulation through the construction of thick walls.
- Comprehensive climate control using air conditioning systems with centralized environmental control within the museum. All rooms contain sensitive sensors for relative humidity and temperature.
- Subject-specific climate control within storage cabinets or display cases for manuscripts.
- Creating localized climates is an essential means of protecting manuscripts, especially when comprehensive climate control becomes economically costly and challenging to implement in some archaeological museums.

References

1) [1] Tarraca .G. Synthetic materials used in the conservation of cultural property, in conservation of properties, UNESCO, 1979, pp. 303 – 331
2) [1] Tarrara .G. Synthetic materials used in the conservation of cultural property, in conservation of properties, UNESCO, 1979, pp 301- 331
Mills .J. and White .R. Op, Cit, P.316
3) [1] Masscheiein – Kleiner. L. , Ancient binding media, varnishes and adhesive, translated by Bridgland, J. , ICCROM . Rome .1985,pp. 51 – 52
4) [1] - ipid.
5) [1] Wills.P, the manufacture and use of Japanese whrst starch adhesive in the treatment of for Eastern pictorial art, in adhesives and consolidants. The international institute for conservation of historic and artistic work, London ,1984, pp. 123 – 126
6) [1]Horie , C.V . " Material for Conservation , Organic Consolidants , Adhesives and Coating" Butterworth & Co. Pdt London 1987 , p. 140 – 141
7) [1] Wills. P. Op.Cit, pp. 123 – 126
8) [1] Horie. C. Op. Cit. p.141
9) [1] حربي عز الدين ـ دراسة في علاج وصيانة المنسوجات ذات الزخارف الكتابية، ، كلية الآثار، جامعة القاهرة، 2002، ص125 .
10) [1]Miller , E .J. and Gaym S." Collagen : Overview " Methods in enzymology 82,1982 . P77
11) [1] حربي عز الدين ـ المرجع السابق ـ ص 125
12) [1] Mills, J. and White. R. Op. Cit, P.77
13) [1] - ipid
14) [1] - ipid
15) [1] Horie . C. Op, Cit, P. 143
16) [1] Petrie E. , Hand book of adhesive and sealants. Mc. Graw – Hill , U.S.A, 2000, P.411
[1] Everett .A. Materials , 5th cedition, longman Scientific and technical, London, 1994, p.234
17) [1] Horie, C. Op. Cit, p.144
18) [1] Wills, J and White .R. Op, Cit, PP.130 – 132
19) -Grcev.S, Determination of molecular weight and size distribution branching and branching characteristics of PVAC by means of size exclusion chromatography multi- angllaser light scattering SEC/MALLS. In polymers, vol. 45, issue.1 ,2004, pp 39- 48

20) [1]Zhao.K., the formation mechanism of poly vinly acetate poly buty acrylate core/shell latex in tow stage 2nd semi- continuous straved emulsion polymerization process. In European polymer journal , vol.40, Issue.1. 2004, pp.89-96
21) [1] Hamilton .D. adhesives and consolidants. Op, Cit, p.17
22) [1] Horie .C, Op, Cit, p.94
23) [1] عادل محمد سويلم، اللدائن: ماهيتها ـ أنواعها ـ طرق تصنيعها وتشغيلها، دار الكتب المصرية، القاهرة، 1994، ص13
24) [1] Horie , C. Opm Cit, p.130
25) [1] Masschelein – Kleiner L , Op, Cit, P.55
26) [1] Reilly, J. Celluloid opjects: their chemistry and preservation in , JAIC, vol.30, No2, article 3, 1991, pp. 154- 163
27) [1] Everett, A. Op, Cit, pp. 251-264
28) [1] Mills, J. and White .R, Op, Cit, p.74
29) [1] Shahaua. Y, Degradation of cellulose nitrate adhesive , in Studies in conservation, 37, 1992, pp.113-119
30) [1] Hamilton, D. adhesive and consolidants, Op, Cit, P.20
31) [1] Wheat Croft. A, Adhesives and coating, Science for conservation, Vol.3 the conservation unite the museum and galleries commission, London, 1992, pp.49-50
32) [1] Horie. C, Op, Cit, p.133
33) [1] محمد زهير الحمصي ـ موسوعة اللدائن (البلاستيك)، مطبعة الهندي، دمشق، ط1، 1993، ص208
34) [1] Horie. C, Op, Cit, P,128
35) [1] - محمد زهير الحفصي، مرجع سابق، ص 208.
36) [1] Masschelein – Kleiner. L, and Bergiers.F, Opm Cit, pp.70-73
37) [1] محمد زهير الحمصي، مرجع سابق، ص 306
38) [1] Horie.C, Op, Cit, P.128
39) [1] Henry A, Carter., The Chemistry of Paper Preservation Part3. The Strengthening of paper, Augustana University, College , Camrose. AB, Canada. 1996, p.160.
40) [1] عبد السلام محمد العسيلي، دراسات تجريبية وتطبيقية في علاج وصيانة وترميم المخطوطات وتقويتها بالبولميرات، ، جامعة القاهرة، 1996.ص114
41) [1] Bruce. J. Hamphrey., Vaporphase consolidation of booke with the parylene polymers, " Parylene gas phase consolidation : an overiew" , ICCROM, Vol.25, No1.1990, P.133 – 135
42) [1] Kathlin smith., New Study Examines Preservation in Academic Library, Vol26, No4, Abbey Newsletter, 2003, p.13
43) [1] Jozef Stenfan, Nanometric Size Control and Treatment of Historic Paper, Manuscript and Prints of laser Light, Berlin, 2004, pp. 379 – 3.
44) [1] Nicholas Hadgrft, Stuart Welch., Vaccum Packing and its Implication for Conservation Materials, No.89 , 1999
45) [1] Alison Walker., Op, Cit, 3 – 14
46) [1] ـ مصطفى السيد يوسف، صيانة المخطوطات علما وعملا، الهيئة المصرية العامة للكتاب، القاهرة، 2002،ص 22 – 24
47) [1] سماء زكي المحاسيني ـ حفظ التراث العربي ـ وسائل حماية الوثائق القديمة في المكتبات العربية، المجلة المغربية للتوثيق، الرباط، 1983، ص114
48) [1] www.nrich.go.kr/eng/cons/bio.
49) [1] Bill Minter., Eraser Crumbs of staedtler mans plastic and Eberchand Faber, Magic Rub; Abbey Newsletter, vol25, No5. 2002
50) [1] Murnay Lachapelle , R. Canadian International, Development Assistant in the field of Archives and Record management, Archivum, 1999, pp.221-234

51) [1] www.librarypreservation.org/mee/preservation/basicremedial.html
52) [1] Coates, P.R.JICPA .Survery of conservation Facililies and experts in Africa. International preservation News, 2001, pp. 30-39
53) [1] وفيقة نصحي وهبة، علاج وصيانة الستارة الملكية المعروضة بالجناح الجمهوري بقاعة الاحتفالات بجامعة القاهرة، مؤتمر الفيوم الخامس، الجزء الأول، 2005 ص 150