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The Mechanism of Deterioration, Treatment and Display of Historical Decorated Silk Textiles

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ABSTRACT

This paper explores the deterioration aspects were found due to suffering from several degradation factors during the previous museum exhibition for an archaeological Silk piece. The textile with tow face, multicolored, and was exhibited in Applied Art museum in Egypt, Cairo, in case m.s 120/4. Also, treatment and conservation method have been done successfully such as cleaning the piece, supporting of the deteriorated areas on new linen fabric and the museum display have been done by using a wood frame and Acrylic sheet. But many deteriorated, degradation aspects were investigated by using recent technologies such as Scanning electron microscopy with energy-dispersive X-ray microanalysis (SEM/EDAX) is the most frequently used analytical technique to determine the chemical composition. The X-rays can be analyzed with an energy-dispersive system (EDAX), and they provide qualitative and quantitative information. The SEM images provide a characteristic surface morphology and are useful for judging the surface structure of the investigated sample, its fiber quality as well as its damage aspects, FTIR was used to identify the kinds of dyes, and the Stereo Microscopy was used to investigate the weave structure.

Keywords: Historical Silk, acrylic sheet, deterioration, morphology, dyes, weave structure

1. Introduction

Archaeological and historic silk textiles form a valuable part of the collections in many museums, but as silk is a natural proteinaceous fiber (Kim et al., 2008); consists of two types of self-assembled proteins: fibroin and sericin (Gong et al., 2013). Sericin is largely formed of amino acids which prevent long-range ordering of the polymer and impart a solubility which allows sericin to be removed from fibroin by a thermo-chemical treatment (Garside et al., 2014; Qi et al., 2017). A large protein, fibroin consists of a heavy chain, light chain. Twelve domains were identified in the heavy chain molecule. The 12 domains that form the crystalline regions, are linked with each other by the amorphous areas. The crystalline regions compose the β-sheet structure (Zheng et al., 2015); in which strong hydrogen bonds and Van der Waals forces generate a thermodynamically stable structure it does not dilute in water, acids and alkali (Koperska, 2015). The light chain and some regions in the heavy chain formed the amorphous regions of fibroin. Because the major components are polar amino acid residues, the amorphous regions are less organized in a looser structure and are much more easily damaged than the crystalline regions. Furthermore, different from the amorphous regions in the heavy chain, the light chain is an independent sub-unit (only connected to the heavy chain by few disulfide bonds) and exhibited less stable properties, including more hydrophilic character, water uptake ability and degradation rate. The amorphous regions of silk, especially the light chain, would degrade rapidly. Over long time degradation, crystalline regions would first be free crystal groups and progressively turned into invisible molecular residues (Li et al., 2015, Luxford, 2009). Unfortunately, improper storage can cause permanent damage to an object. Storage on a wooden shelf or drawer (Saines, 1998); in out-of-sight places, resulting in years of neglect, deterioration, and sometimes complete loss of important cultural material (Sullivan, 1990); due to exposed to the high level of relative humidity in relation to temperature of the surroundings, insects, microorganisms, pH value and air pollution (Lech et al., 2015, Fawzy et al., 2015).

This paper explains the mechanisms of deterioration in this object, which is stored in the Applied Art Museum in Egypt. The paper aims to report the conservation treatment of the object such as cleaning, supporting the object on a new linen fabric, fixing separate parts and making a new display.

2. Description and Condition

2.1. Historical Context

The object was stored in the Applied Art Museum under no. m.s 120/4. The piece with size 50X65 cm with two faces stitched together with Casting over stitch, the two was waved by 1/1 plain weave technique. No. of the first part warp is 23. No. of the weft 28. No. of the second part warp is 23. No. of the weft 27. The first part with dark red color embroidered with plant decorated with yellow and black silk thread and the bottom of the piece decorated with geometric straight lines with black and yellow silk threads interchangeably along the piece of the thickness of 7 cm. While the second face with purple color embroidered with flowers which have 8 papers surrounding a circle by buttonhole stitch with purple silk threads, and the top and bottom of the piece is decorated with Horizontal tape has a decoration with x shaped thickness 7 mm and beside it plant decoration of 4 cm thickness (Figure 1.).

Figure 1. The studied decorated historical silk textile with two faces.

2.2. Visual Investigation

The initial visual examinations showed that there are many signs of damage on this object from the two faces such as, on the first face there are: missing area, many separated parts, many stains and, separated threads, missing weft threads, missing warp threads and missing decorative yellow threads, bleeding the black color of the decoration plant and the fabric very brittle (Figure 2.A,B,C). On the second face there are: missing area, discoloration of the purple waved silk, which fades and became gray in many places, there are many stains, ravel the warp and weft threads (Figure 3. A. B. C.).

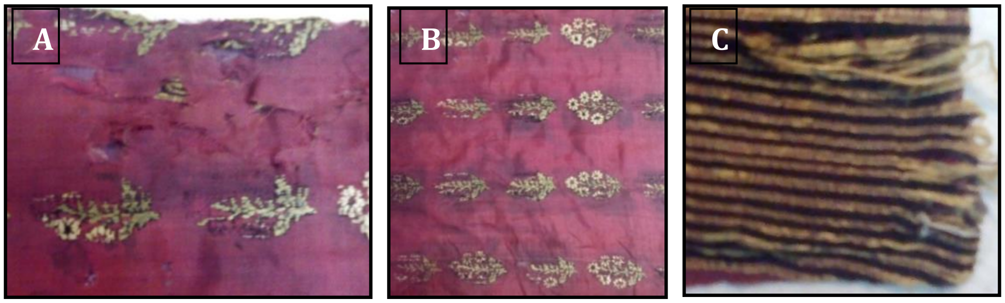


Figure 2.A.B.C. The types of damage in the first face.

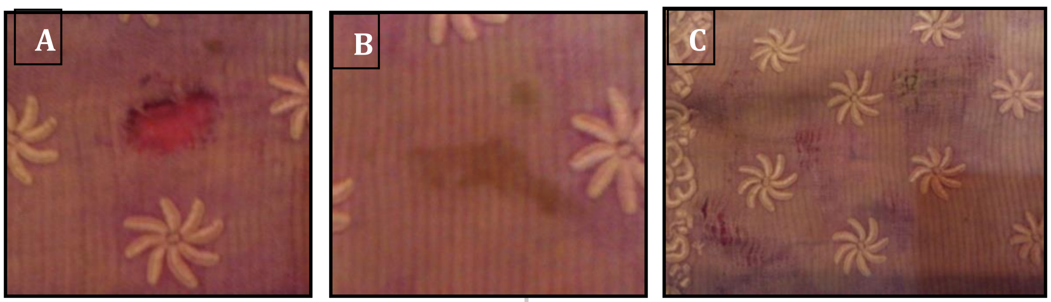


Figure 3. A. B. C. The types of damage in the second face.

3. Investigations

3.1. Stereo Microscopy:

Images(x40) (The investigation was carried in the Minia University, Faculty of Fine Arts, Conservation Dept. Center, Minia, Egypt), to investigate the weave structure of the object.

3.2. Scanning Electron Microscopy (SEM):

With energy-dispersive X-ray microanalysis (SEM/EDAX) is the most frequently used analytical technique to determine the chemical composition. The X-rays can be analyzed with an energy-dispersive system (EDAX), and they provide qualitative and quantitative information. The SEM images provide a characteristic surface morphology and are useful for judging the surface structure of the investigated sample, its fiber quality as well as its damage aspects. SEM was used to reveal diagnostic features of the fibers, necessary for their identification. The morphology of the surface of the fibres was investigated by using Scanning Electron Microscope (Ahmed, 2014). As well as the damage aspects of these fibers (The investigation was carried in the Egyptian Mineral Resources Authority, Central Laboratories Sector, the Scanning Electron Microscope for samples. Using SEM Model Quanta 250 FEG (Field Emission Gun) attached with EDAX Unit (Energy Dispersive X-ray Analyses, and K550X sputter coaterEngland), with accelerating voltage 30 K.V., magnification14x up to 1000000 and resolution for Gun.1n).

3.3. Fourier Transform infrared spectral analysis (FTIR):

FTIR analysis of solid phase samples can be typically performed using two different methodologies. The first, more traditional and widely used approach, FTIR–KBr. FTIR analysis has been performed by transmission techniques, in which the infrared energy is passed directly through the compound being studied. The powder sample can be milled with potassium bromide (KBr) to form a very fine powder. This powder is then compressed into a thin pellet which can be analyzed. In this method the sample is diluted with KBr (IR grade) so that the concentration of the sample is 1%. Fabrics were measured by (Smart Performer ATR) unit accessory with Zinc Selenide crystal. ATR accessories require minimal setup and are easy to clean. Samples are placed directly onto the crystal surface itself. Single - bounce crystal modules tend to be the most versatile, since most are supplied with a pressure device and are appropriate for a variety of organic liquids and powders. Infrared Analysis was performed on a sample of the first face of object and compare the results with the results of infrared analysis of the natural dye known standard, which help knowing the dye used in fibre (Abo El enen, 2017; Ahmed et al., 2011; Kamal et al., 2013). (The analysis was conducted in the infrared laboratory in the sector of projects - Egypt. by using: Infrared spectrum origin JASCO, FT/ IR-6100Type, Light Source Standard Detector, TGS, Start 399cm-1, End 4000.6 cm-1).

3.4. Isolation and Identification of microorganisms:

3.4.1. Bacterial

Isolation procedures were carried out in Petri dishes containing NA (Nutrient Agar 5g/L Peptone, 5g/L beef extract, 5g/L sodium chloride (Domsch, 1980), after putting a sample of the object on the media at 30ºC, for 48 h.

The distinct obtained single colonies after growth it around the sample was sub-cultured onto NA for characterization.

3.4.2. Fungi

Fungal isolation of the colonies was performed in Petri dishes containing PDA (potato dextrose agar 15g/L Dextrose, 200g/L Potatoes extract, 15g/L Agar (Domsch, 1980), after putting a sample of the object on the medium. All cultures were grown for 7 days at 28ºC around the sample. Identification of fungi was based on the macroscopic features of colonies grown on agar plates, and the micro-morphology of the reproductive structures was identified by optical microscopy (OM). Fungal strains were identified following standard methods, based on their macro and micro-morphological characteristics (which have been investigated by the plant and microbiology laboratory, faculty of science, Minia University).

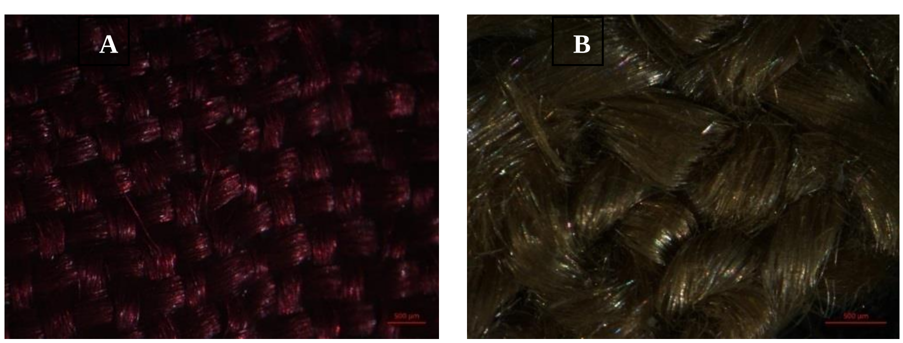
3.5. Testing the stability of dyes:

The object was to test the stability of the colored parts to wet cleaning by immersing a piece of cotton wrapped round a wooden stick into water and the cleaning solutions and placing it in contact with the colorful parts of the object, each part of the object was individually tested.

4. Results

4.1. Stereo Microscopy:

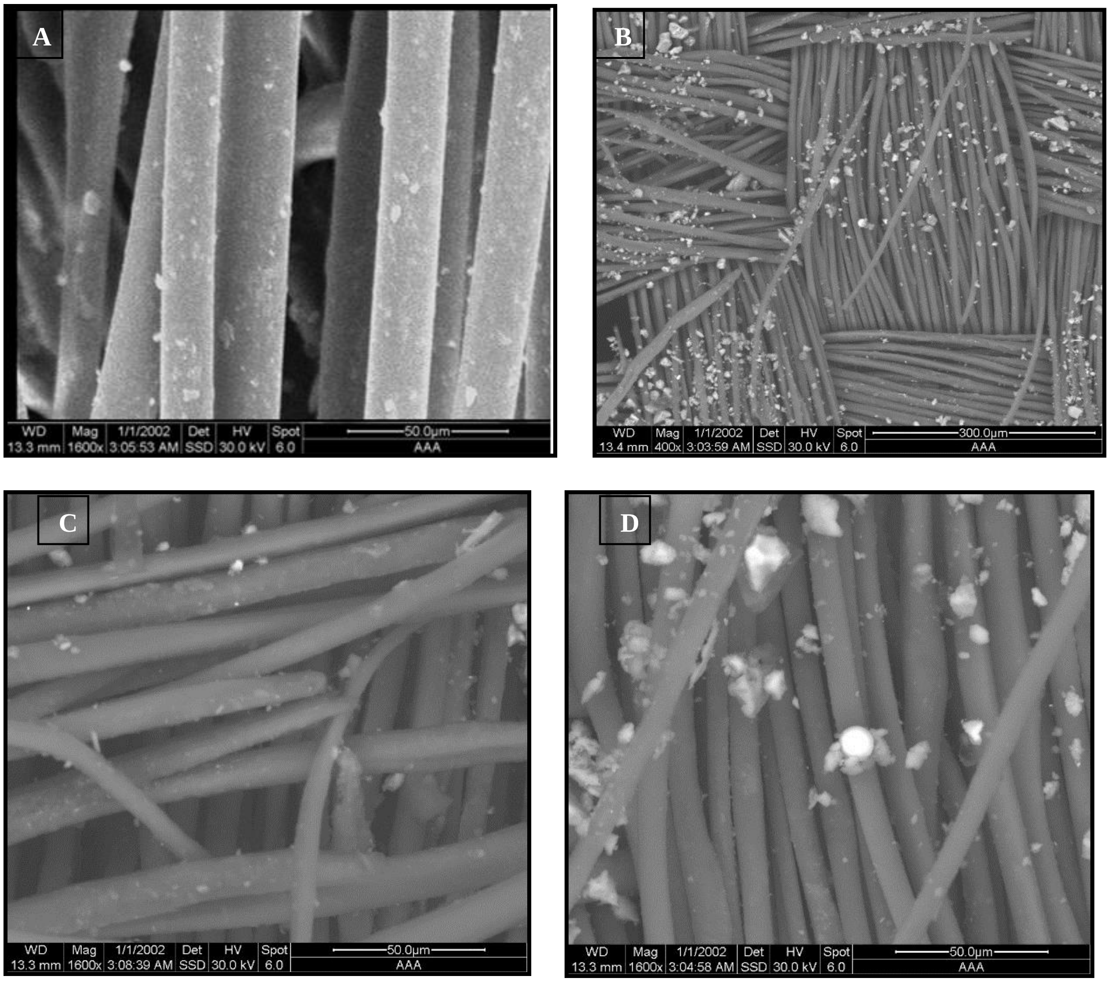
The microscopy photo of examining threads are illustrated that the weave structure of the object from the two faces was 1/1 plain weave technique (Figure 4. A. B.).



Figures 4. A. B. Stereo Image shows that the weave structure of the object was 1/1 plain weave technique.

4.2. *SEM Photos:*

When examining the threads, it is clear that the silk thread fibers (Figure 5. A. B.) are extremely damaged, broken and covered with dust and metal ions (Figure 5. C. D.).



Figures 5. A. B. SEM Image shows that all the threads are silk; C. Fibers are extremely damaged and broken; D. Threads covered with dust and metal ions.

4.2.1. The analysis by using (EDAX):

Provided that the salts and solid dirt consist of Na, Mg, Al, Si, Mo, Cl, K, Ca, Fe. (Figure 6), the effect of the metals nature of degradation of the dye, were presented that the metals, especially Al, Mg give a higher degradation rate of the dye. This can be attributed to the standard electrode potential of these elements, but the mechanism involves the diffusion of the dye to the iron metals where it is adsorbed. The degradation reaction of dyes occurs on the surface of metal iron, when an interaction between dye molecules and iron happens iron as an electron donor loses electrons, the dye molecule as an electron acceptor accepts electrons from iron and combined with H+ and turns into the transition product. This product gets electron from iron and combined with H+ again, then it turns into terminal products. So pH and iron amount would affect the degradation reaction (Mohammad, 2005). These reactions can cause dye bleeding and color changes. These elements also can attract and absorb acid or alkaline agents, and oxidizing or reducing agents from the atmosphere, such as Sulphur dioxide, nitrogen dioxide and hydrogen sulphide. Such absorption can result in the formation of acid solutions with moisture from the atmosphere or the materials themselves and promote hydrolysis, as well as resulting in oxidation or reduction reactions in fiber molecules (Marouf, 2009).

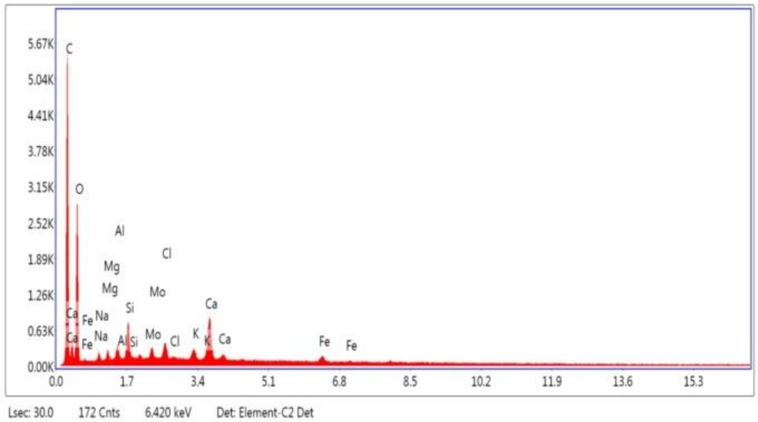
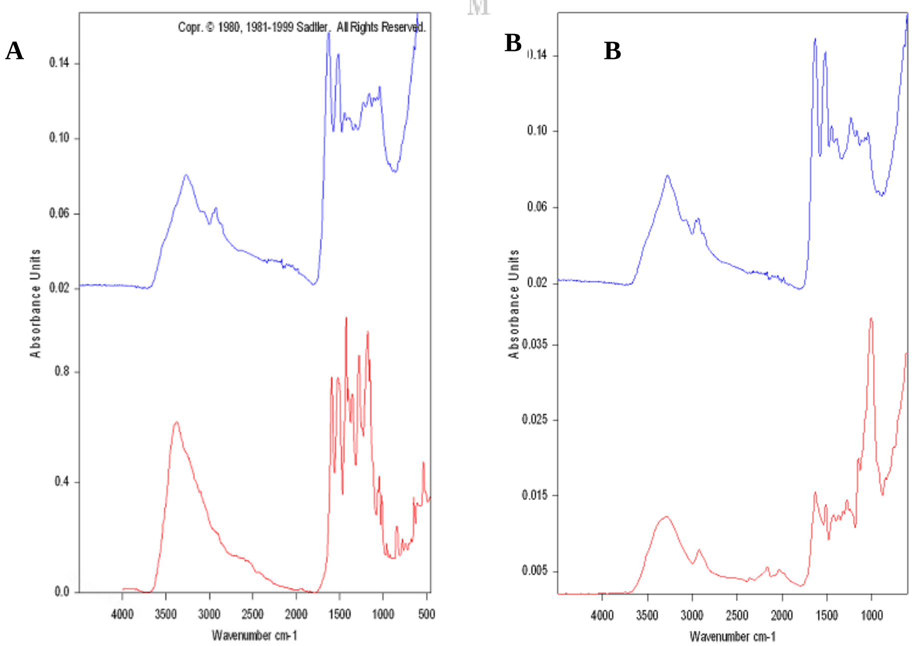


Figure 6. EDAX analysis of the chemical composition of the silk surface show that it is dirty and covered with metal ions.

4.3. FTIR analysis:

The results of the charts show that the source of the black decorated color is Haematein, which is an extract of Logwood (Figure 7. A.), and the yellow decorated color is Turmeric (Figure 7. B.). The source of the red colored object is Madder (Figure 7. C.). But, the second face results show that the source of the purple color is a mix of Madder and Indigo (Figure 7. D.).



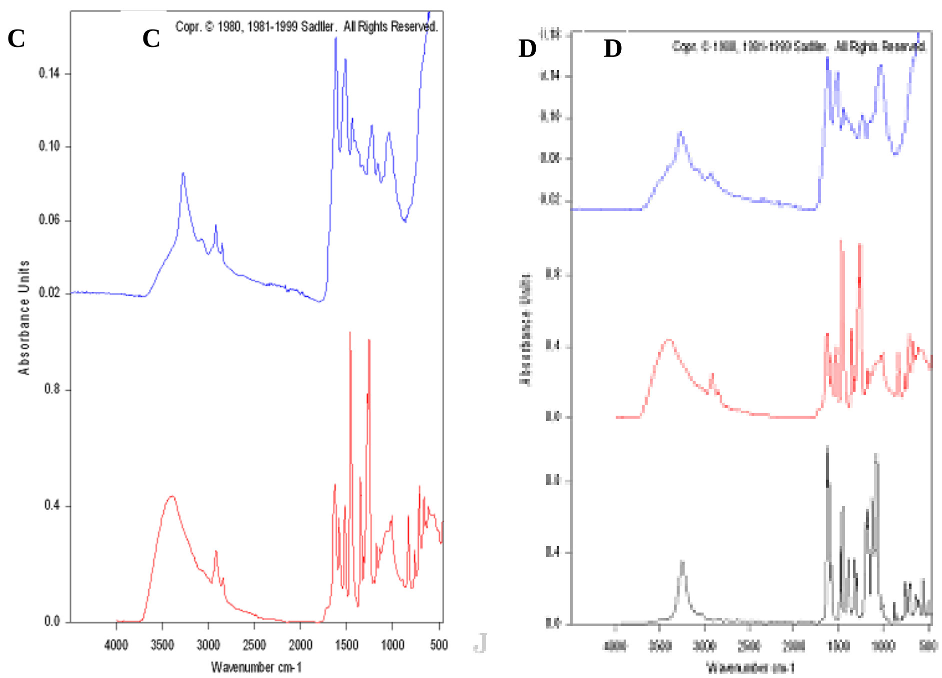


Figure 7. A. FTIR analysis of the dyes show that the black dye is Haematein; B. The yellow dye is Turmeric; C. The red dye is Madder; D. The purple dye is a mix of Madder and Indigo.

4.4. *The Isolation and Identification of microorganisms:*

The results showed that there is one type of fungi and another of bacteria has been detected on silk fibers. The detected fungus are called Fusarium sp. (Figure 8). While the detected bacteria are called Bacillus sp. (Figure 9). Fungal deterioration of historical textiles in Egypt is due to improper environmental conditions in Egypt promote the fungal growth and the nature of the textiles too. Historical textiles in Egypt are more acidic according to the surrounding environments, which are considered to create favorable conditions for fungal growth (Abdel-Kareem, November 2010). The growth of microorganisms in organic materials is dependent on the presence of moisture, although, other factors such as temperature, pH value (Abdel-Maksoud et al., 2013); light, ventilation and material properties - the chemical constitution, structure and other compounds of the object, such as mordants, dyes, adhesives and finishes, which can slow down or accelerate the biodeterioration processes (Cybulska et al., 2008). Biodeterioration of textile materials in the wet archaeological environment is both physical and chemical in nature. On the microscopic level, physical biodeterioration is caused by microorganisms, in particular fungi and bacteria. These break down the textile fibers through the mechanical activity of their growth or movement. They envelop fibers with corrosive microbial films, or penetrate, branch out, and grow within fibers abrading and fracturing them. Microorganisms also bring about chemical biodeterioration by secreting extracellular enzymes onto the fibers (Ellen, 2003). Although fungi are the most active microorganisms in textile biodeterioration (Sterflinger et al., 2013); they are not frequently associated with the deterioration of silk fibers. This is due to a complex histological structure or strong inter-chain bonding and crystallinity (Garside et al., 2006). They can cause damage if the silk contains a high degree of sericin and are stored in warm and humid conditions (Ljaljević et al., 2014, Tiano). Some microorganisms do produce enzymes that break down these proteins (Abdel-Kareem, 2010). Extracellular proteinases (proteolytic enzymes) (Zaitseva, 2009, Shinde, 2010). Proteolytic enzymes of microbes hydrolyze disulphide and peptide bonds. Peptides in turn are hydrolyzed to amino acids by peptidases (Jain, 2008). This activity causes physical damage. In proteinaceous fibers this weakening of the structure has profound consequences for the long-term survival of the textile. Long polymer chains are chopped into shorter units, substantially reducing tensile strength. The increase in porosity arising from physical and chemical damage to the fibers permits easier access to agents of deterioration and readily allows degraded fragments to leach out into the surrounding environment (Ellen, 2003). The added auxiliaries in textile such as dust, dirt, stains, soilants etc. promote microbial growth. Due to hygroscopic nature of the above, they readily absorb moisture and help in adherence of air borne microbial spores on surface of textile material. In addition, they provide nutrients and moisture for their germination (Jain, 2008). If dissolved ionic salts are present, this swelling of the fiber structure is exacerbated (Ellen, 2003). Also, the Fungal hyphae penetrate into the fibers, and pierce it to find more easily digestible components. This can lead to the development of small cavities and shallow pits into the fiber originating at the surface or the extensive hollowing out of the fiber interior causing fiber collapse (Ellen, 2003) The first attack of fungi and bacteria occurs in the amorphous regions of the primary fiber wall, spreading out of the crystalline areas, following the direction of the secondary wall (Silveira, 2013). Textile objects which are a target of microbial attack and degradation, resulting as discoloration, staining, and loss of structural strength (Minocheherhomji, 2016). Causes changes in their oxidation stage, degrees of polymerisation, and breakdown of molecular structure. In turn, it results in loss of strength, extensibility, general durability, discoloration, and appearance (Guiamet et al., 2014).

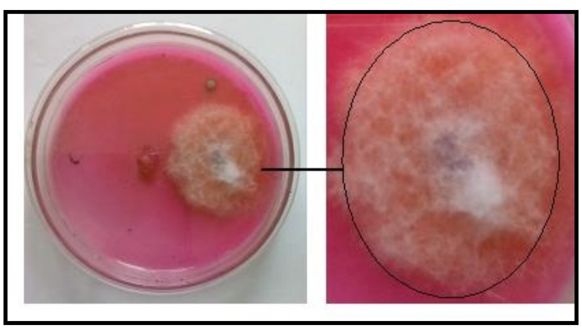


Figure 8. The Isolation and Identification of microorganisms show that the detected fungus is Fusarium sp.

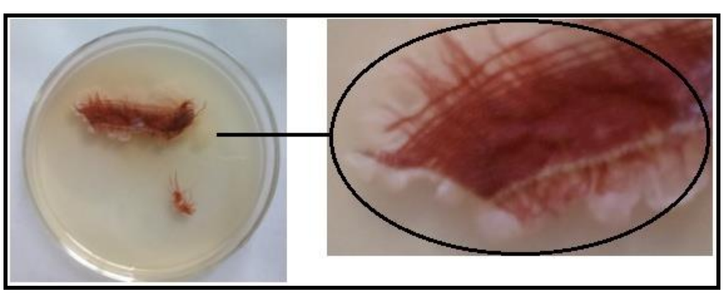


Figure 9. The Isolation and Identification of microorganisms show that the detected bacteria are Bacillus sp.

4.5. Testing the stability of dyes:

It was found that the (purple) dye of the second face was stable and did not fade with the wet cleaning solution. But the (red) dye of the first face was unstable and fades with the wet cleaning solution.

5. Conservation Processes

5.1. Cleaning procedure

5.1.1. Mechanical cleaning:

Various types of fine brushes are used for getting rid of dust and incompact stain on the textile.

5.1.2. Wet cleaning

This procedure takes many steps as follows:

- The first step the two faces of the object were separated from each other by unfastens the Casting over stitches preparing to wet cleaning the second face only.
- The second step prior to any cleaning action the textile was to apply a primary support to the object by placing it between two webbed support fabrics, and stabilizing it using appropriately thin needles and fine cotton thread with stitching using a running stitch. During stitching the needle was passed in between the yarns in the weave, not through them to avoid any damage to the weakened fibers. In order to protect the parts of the textile from disintegrating during the different cleaning processes.
- The third step fungicide (ethyl alcohol) was used for disinfecting the textile object (Abdel-Kareem et al., 2010). It is the best method to protect textile surfaces from any contamination and to prevent the future fungal and bacterial growth on historical textiles. It was put in the cleaning solution.
- The final step washing solution is prepared by mixing water with other detergent agents (Synperonic N), to increase the effectiveness of the cleaning process (Marian, 2014). It adheres to the surface of soiling and reduces the surface tension and penetrates into soiling on the fiber surface and removes it (Osman, 2011; Kim, 2011). The ratio was one part detergent Synperonic N to 100 parts of water. Other additive was also put like carboxymethyl cellulose (CMC) (concentration 0.1 g/L). It acts as a suspending agent preventing the redeposition of the dirt, by carrying it in the washing solution. It also increases the cleaning power and emulsifying power of the detergent (Weston, 1980). The water was agitated by brush to allow it to penetrate between the fibers to release the dirt particles for 15 mins. The bath temperature was 30 ˚C. Then a second cleaning bath with water only was applied for 10 mins again with water agitation, and then a third bath with water only, for 10 mins to remove any detergent remains. The wet cleaning reduced the soiling and relaxed the stain. As a result of cleaning treatments carried out in a humid environment, textiles regains elasticity allowing their handling for the purposes of subsequent interventions of restoration (Marian, 2014).

After cleaning the object was transferred onto clean and flat horizontal surface. The primary support was removed. The absorbent drying cotton fabric was used as a poultice and pressed lightly to the surface of the textile to remove all excessive water. By ensuring that the wet textile settled in a place. The object was left uncovered to complete drying at room temperature.

5.2. The final support process:

5.2.1. Preparing the support fabric:

Two supported linen fabric were used (1/1 Plain Weave). The linen fabrics are very strong. Its surface was cleaned using hot water with a few drops of detergent solution (Synperonic N), to remove chemical residues. This was to prevent possible shrinkage, due to humidity changes. Then, the textiles were rinsed with distilled water several times to ensure that it was free of detergent and prevent any future shrinkage. Then, the textiles were dried with an iron. The linen textile sizes are 75×60 cm. to support each part of the object on one linen fabric.

5.2.2. Dying procedure of the silk threads:

The threads were dyed with cochineal to give it a red color. It was divided into the following stages:

- The cochineal dye was ground to a fine powder and sieved to remove any large residues. The dry powder obtained was used for the process of extraction.
- Aqueous dye solutions were prepared, by adding the dye powder to water in large beakers. The extractions were obtained directly by boiling (50g) of dye in (1000ml) of water at 100C° for 1 hour; the extractions were filtered through a filter paper to remove any big residue and to obtain a clear filtrate. The filtrate was used for dyeing of silk fabric samples.
- Dying procedure was carried out by the exhaustion method with the natural dyes. The pH of the dye bath was adjusted at (2-3) by adding few drops of acetic acid. The dying was carried out in 80-90 C° for 45 minutes with continuous stirring and the liquor ratio was 1:30.
- Alum mordant was used by immersing the individual dyed silk threads in the mordant solution for one hour at a temperature of 80-90 C° using liquor ratio 1:100. The mordant solution was prepared by dissolving (alum, Tartaric acid). After dyeing, the unfixed dyestuff was removed by rinsing three times with cold water.

5.2.3. Temporarily fixing:

Every linen support fabric was stretched on the detached wooden frame which was prepared for temporary fixing with size (70×55 cm). Every part of the textile was pulled on a wooden frame by using pins with the province to keep its warps and wefts on a right direction.

Every face of the object was temporarily fixed on the textile support by using needle work, precisely using a thin needle with red cotton yarn. The piece was put on the textile support with taking into account putting the piece correctly in the middle. At the beginning, the piece was fixed by working longitudinal, straight and parallel lines and each line length 10 cm and far from the next line to it a distance of about 10 cm, first start the work on the lines of the first row and after completing it comes second row, so that mediates the distance between the first lines row, then comes the third row as the first alternately until fixed was completed, also the weak places were fixed.

5.2.4. Permanent supporting:

After temporary fixing the tacking stitches were used with a very fine needle and fine red dyed silk thread to fix every face. At the beginning of the final stage, the edges of the object all around were sewed with a small stitch technique (blanket stitch) and afterwards the edges of the missing and vulnerable parts were attached by the same stitches. Similarly, couching stitches were used to attach the face to the new linen fabric and fixed the separated threads in true place. The temporarily fixing was removed.

5.3. *Display:*

After completing the treatment process and fixing the object, it could be displayed in suitable manners which allow us to see the two faces of the object. It was divided into the following stages:

- Every supported fabric which curries, one face of the object was cut to become with size 67X52 cm.
- The two supporting fabrics were collected together, whereas every face of the object was put on the other and the back of the supporting fabric on the top. The two supporting fabrics were sewn together with Running Stitch whereas the sewing were taken at the beginning of the edge of the silk textile from the three sides.
- The Acrylic Sheets were prepared by porous it to allow with aerate the object during the museum display and with size 64.6X49.6 cm and 3mm thickness. The sheet was inserted onto the supporting textile from the fourth open side after turn it, whereas the two silk textile became on the top.
- The fourth side of the supporting textile was sewing with Over-Casting Stitch.
- The two faces of the silk textile were sewn together from the edges with Over-Casting Stitch with the red silk threads.

-The wood frame was prepared for the museum display. It is chosen with a good wood with size 66X51cm with two cross girders in the middle of the frame. There is one moving girder was fixed on the middle girder with hinge to allow the display object, in header position and diagonal with 45-degree angle (WAAC Newsletter, 2013). The frame was tightened with linen fabric from -the front and fixed on the girders from the back with pins. The frame was surrounded from the front with wood girders were tightened with linen fabric and were fixed on the frame girders with nails, to allow put the supporting object inside it on any face and we can pick it and display the other face when we want (Figure 10. A. B. C. D.).

Figures 10. A. B. show the final museum display for the object in frame; C. D. with˚45 angle.

6. Discussion and Conclusion

The decorated silk textile is in poor condition There are many signs of damage on this object are illustrated: missing area, many separated parts, dust, metal ions and stains, separated threads, bleeding the black color of the decoration plant in the first face and discoloration of the purple waved silk, which fades and became gray in many places in the second face, the fabric very brittle, and microorganism infestations which was Cleary appeared from the Isolation and Identification of microorganisms , there is one type of fungi is called Fusarium sp. and another of bacteria types are called Bacillus sp. The SEM of examining decorated textile threads are illustrated that all the threads made from silk threads. FTIR analysis show that The first face dyed with dark red color composed of Madder, the black decorated color is Haematein which extract of Logwood, and the yellow decorated color is Turmeric. The second face dyed with purple color composed of Madder and Indigo. The study confirms that it is necessary to conserve textile objects in the museum. Conservation processes improved the appearance of the silk textile due to improved physical and mechanical properties of the objects which will lengthen their survival and thus to insure that these collection are available for future generations. The conservation process includes various steps such as: cleaning textile objects by immersion in an aqueous solution (wet cleaning) was the most suitable for the silk textile in this study, the support process, display methods.

In conclusion, Textile finds are greatly damaged. They are very impermanent. For that, we must to intervene with the suitable treatment after using the new standards of documentation with the use of modern analytical methods, if we want to preserve them for the next generations to they explain many historical periods.

7. Acknowledgements

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