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CONSERVATION PROCESSES DEVELOPED AND ADAPTED TO CLEAN, DISINFECT AND REINFORCE A COPTIC TEXTILE OBJECT IN EGYPT

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ABSTRACT

This study aims at establishing and designing effective conservation processes to conserve a Coptic textile object selected from museum of faculty of Applied Arts in Egypt. Various novel investigation methods were used to assess the statement of the selected textile object before establishing any conservation process. Investigations and analysis were carried out for identifying the fibers and the extent of deterioration by using non-invasive methods. Transmitted light microscope (TLM) and scanning Electron microscope (SEM) were used for identifying the fibers and the various deteriorated aspects. Also, the fungal microflora deteriorating the selected textile object was identified. Then different conservation processes were established and used to conserve the selected textile object according to its condition and statement. The results showed that the selected textile object was very dirty, with cavities and holes, wrinkles and creases, and also noticed fibers damage. These damages may be due to the improper displayed method in the museum, or due to the incompatible environmental conditions surrounding the artifacts during exhibition such as: light, temperature, relative humidity, pollutants and fungal attacks. The results show that the most dominant fungi isolated from the current textile object belong to *Alternaria, Aspergillus, Chaetomium, Penicillium and Trichoderma* species. In this study, various techniques were used for treatment and protection of textile object. For disinfection of fungal infestation on the Coptic textile object, a fungicide that is safe for both the textile object and the conservator has been used. Various methods were used for cleaning the textile object. The current textile object was consolidated and reinforced using modified nano polymer (microemulsion polymer prepared from Methyl methacrylate (MMA) and Hydroxy ethyl methacrylate (HEMA) monomers using Eco-friendly initiation system represented as ultrasonic mechanism). The selected nano polymer was applied on a silk screen that has been previously treated with Neo-Desogen fungicide. The treated new silk screen was used for reinforcement of the textile object. Treatment of this textile object by the suggested nano polymer and fungicide not only reinforces this textile, but also prevents fungal deterioration and increases the durability of this textile object. Finally the current study suggested recommendations for display of the current textile object in its showcase in the museum.

KEYWORDS: Egyptian Coptic textile, deterioration, fungal species, cleaning, suction table, fungicide, disinfection, nano polymer, reinforcement

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1. INTRODUCTION

There is no doubt that Coptic textile is one of the most important and widely present textile objects in museums in Egypt. Coptic textiles have been constructed using varied materials and techniques. Tapestry textile is the most common used in producing Coptic textiles and named (Capatii textiles) by Arab people. Tapestry textiles are valued for their historic interest, their aesthetic appeal and their culture significance through all types of the Coptic textiles in Egypt. They have been commonly made from natural fibres and natural dyes (Landi, 1998; Abdel-Kareem, 2002; Timar-Balazsy and Eastop, 2002).

Coptic textiles such as other museum textiles are considered sensitive materials for deterioration by various deterioration factors such as light, heat, pollutions and microorganisms (Landi, 1998; Timar-Balazsy and Eastop, 2002; NPS, 1999; Abdel-Kareem, 2002; Garside, Wyeth, 2002). Therefore, they are extremely vulnerable to damage when they are stored or displayed in inappropriate environmental conditions (Abdel-Kareem, 2002; Fahey, 2007). There is no doubt that the most serious damages in museum textiles are caused by microorganisms such as bacteria, actinomycetes and fungi (Abdel-Kareem, 2009). Fungal degradation is one of the highest risk factors for deterioration of historic textiles (Abdel-Kareem, et al, 1997). Fungi can cause staining, weakening, or complete destruction of fibers. Fungi feed by digesting the substrate on which they grow. Cellulosic fibers such as cotton and linen are particularly vulnerable, but proteins such as wool and silk can also be affected (CCI Notes 13/15). Fungal deterioration causes changes in the properties of textiles such as losses in the strength, general durability, discoloration, and appearance. In addition, many fungi contain coloured substances that can cause stains and spots on textile objects. Fungal deterioration causes various colored stains on the surface of a textile object (Szostak-Kot, 2004; Abdel-Kareem and Szostak-Kot, 2005; Abdel-Kareem, 2007; Gutarowska, et al, 2017; Matusiak, et al, 2018). For all previous causes many efforts should be done to conserve of biodeteriorated textiles in Egypt.

The main aim of the conservation of a textile object is to improve the long-term preservation of this object by making it safe and pleasing for display (Abdel-Kareem, 2005; Abdel-Kareem and Alfaisal, 2010). The most common conservation processes of a textile object include disinfection, cleaning, stabilization, consolidation, restoration, exhibition and storage. Any conservation process should be started with a complete examination and documentation of the object. (Eastop and Brooks, 1996; Shashoua, 1996; Abdel-Kareem, 2002; Timar-Balazsy and Eastop, 2002; Abdel-Kareem, 2010 a; Matusiak, et al, 2018). Fungicides are the most common method used in protection of fungal deterioration on museum textiles in Egypt (Abdel-Kareem, 2000, Abdel-Kareem, 2010 b).

The fragility of certain biodeteriorated textiles has caused particular conservation problems, and a wide variety of polymers have been used in an attempt to enhance their long-term preservation. Polymers can be used as consolidating materials or adhesives in conservation of deteriorated textiles (Takami, 2002; Timar-Balazsy, Eastop 2002; Abdel-Kareem, 2005; Coccaa, et al, 2006; Abdel-Kareem, et al, 2008, Abdel-Kareem, et al, 2015; Amin, 2018; Al-Gaoudi, 2020). Newly nano polymers produced from methylmethacrylate was suggested to be used in textile conservation. These nano polymers are Microemulsion copolymers prepared from MMA and MMA/HEMA (having different monomers composition ratios) using Eco-friendly initiation system represented as ultrasonic mechanism (Abdel-Kareem and Nasr, 2010; Nasr et al, 2010).

This paper aims to describe a practical case study in conservation of a biodeteriorated Coptic textile object in Egypt. In this study innovative nano polymer (MMA-HEMA) was applied to reinforce the biodeteriorated textiles. In this study some textile conservation processes were developed and adapted to be able to apply in conservation of the current textile object. This study will help the conservators in developing and establishing methods for conservation of biodeteriorated Coptic textile objects simulated to these objects in Egypt.

2. EXPERIMENTAL DETAILS

2.1. Object description

Selected biodeteriorated Coptic textile object obtained from the Museum of Faculty of Applied Arts, Helwan University, Egypt, was used in this study. The pattern weave of the object is a tapestry textile fabric with extra wefts. The warp is linen and the weft is wool. The characterization of decoration type and the results of the investigation of the materials and technical used in manufacture of the textile object show that it dates back to the (4th – 6th c AD) (see Table 1, Figure 1) (Maher, 1977).

2.2. Assessment of the condition of the selected object

The selected object was investigated by various methods (such as digital optical microscope, Transmitted Optical Light Microscope (TLM) and Scanning Electron Microscope SEM). This investigation was done to assess the statement of the object. The conservation processes suggested to conserve the selected object was chosen according to its statement. Also, the

environmental condition in storage area in the museum was investigated to understand the problems responsible for the deterioration of the selected object. The visual observation showed that the fungal deterioration may be the most deteriorating factor affecting the selected object. Therefore, laboratory study was done to isolate and identify the fungi occurred on the selected object.

Transmitted Optical Light Microscope (TLM): Textile fibers were identified microscopically under Transmitted optical light microscope and viewed through a video microscope system (Nikon H- III). Very small fragment of fibers from both warp and weft of each object were transferred to slides and examined in longitudinal views. The type of fibers was investigated under TLM, at magnifications 400 X.

Scanning Electron Microscope (SEM): FEI Quanta 200 Netherlands Scanning Electron Microscope was used to study the surface morphology of the textile fibers samples. Samples were mounted on aluminum stubs by double-sided sticky tabs, then gold coated of about 20 nm thick by sputtering method using vacuum coater (Polaron E6100. UK). Coated samples were examined to detect possible morphological indication of degradation, splitting and dirt (Abdel-Kareem and Alfaisal, 2010).

2.3. Isolation and identification of fungi from the selected historical biodeteriorated textile objects

Very small bio-deteriorated textile parts separated from the original ancient object were washed with sterilized distilled water and were transferred by using sterilized tweezers and were put on 2 modified media in Petri dishes (Abdel-Kareem, et al, 1997). The used media are 1- Medium of Greathous, Klemme and Barker with disk of pure 100% linen fabric with linen textile samples or with disk of pure 100% wool fabric with wool textile samples. 2- Czapek-Dox agar modified without sugar. In some areas of the object where there are no separated textile parts, the cotton swab technique was used. This method has scores highly in most of the criteria required for isolating fungi from ancient objects (Chaisrisook, et al, 1995). In case of using the cotton swab technique the fungal species were isolated by using sterile moist cotton buds swabbed onto the surface of the textile object where fungal growth or fungal structures were observed. Cotton swabs were then used to distribute fungi on used media in Petri dishes. These prepared cultures were incubated at 28 °C for three to four weeks {until growth of colonies was observed}. For purification and identification, the developed fungi were isolated in pure culture on slants of the appropriate media (Czapek dox agar and malt extract agar) (Booth, 1971). The identification of fungal species was performed according to standardized methods by consulting the appropriate manuals **(**Raper and Thom, 1949; Raper, and Fennell, 1965; Gilman, 1975; Domsch, et al, 1980).

Table 1 Relevant information data about the object

Catalogue No	MS 510		
Place	Museum of Faculty of Applied Arts, Helwan University		
The origin	Egypt		
Historical Context	Coptic period (4^{th}-6^{th} c AD)		
Patterns	Tapestry textile fabric		
Technical analysis	Dimensions	62 × 78 cm	
	Weave structure	Tapestry weave	
	Warp density /cm	8/cm	
	Weft density/cm	20/cm	
	Ply yarn	Warp: 1	Weft: 1
	Yarn twist direction	Warp: right	Weft: right
Material	Warp: linen	Weft: linen and wool	
Colors	Beige, light brown and brown.		

Figure 1 Image of the object before any treatment.

3. RESULTS AND DISCUSSION

3.1 The statement of the selected objects

The results of the visual and optical investigation of the Coptic textile object showed that the object was too dirty and there were many stains on the textile object (see Fig. 2). There were many loose areas and broken fibers. Also, there were splits and very weak areas in the object. The object was so weak and was stored in too bad conditions having installations and holes in skeleton reaches to about 12cm Length and 3cm dense; various cuttings in terminals were observed. Moreover, the back of the object suffers from dyes incredibly and paling. There were many tears and weak areas. Most colors were exposed to fading and discoloration phenomena. There were many stains that may be from fungal.

Figure 2 Images show the statement of the object, the upper photo show stains on the surface. The lower photo shows the dirt on the pile surface.

The results of the optical microscopy and SEM investigations show that the textile object made from two types of fibres. The warp threads and the ground fabrics are made from linen fibers. The weft threads show that the wefts and decorations are made from wool fibers. It is noticed that the fibres are too degraded as the scales on the wool may disappeared. Also there is many splits in the surface morphology of the fibres. It is noticed that both of the weft fibre (wool), and the warp fibre (linen) suffered from the deterioration (see Fig. 3).

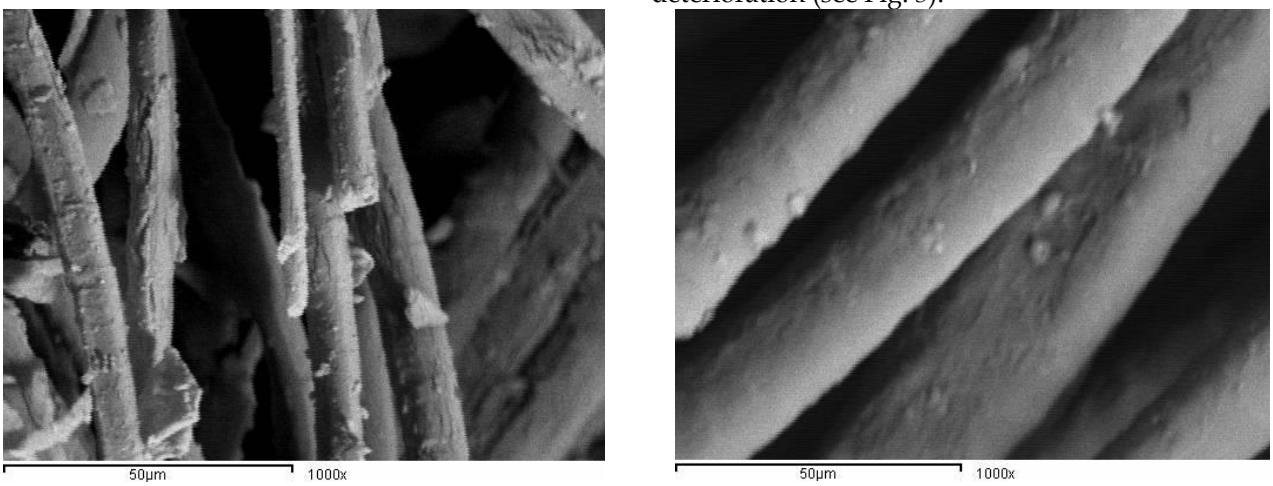

Figure 3 SEM Images of textile fibers obtained from object. The upper photo from the warp threads show that the warps and the ground fabrics are made from linen fibers. The lower photo from the weft threads show that the wefts and decorations are made from wool fibers.

All previous bad features of the statement of the textile object may be due to both the fungal deterioration of the object and other deterioration factors in the environmental condition in the storage area surrounding the object (see Table 2).

Table 2 The environmental condition in storage area surrounding the textile object in the Museum

T°c	There are differences in temperature degrees between day and night due to using air condition for 8 hours in day only.
RH	There are differences in relative humidity degrees between day and night.
Pollution	Due to the museum is uncontrolled in surrounding environmental condition, most types air pollutants were found as an accumulated dust
Previous storage method	This object was storage between cartoon paper inside wooden cabinet
Previous restoration	There is no previous restoration

The results in Table 3 show that about 14 fungal species were isolated and identified on the textile object. The most dominant fungi on warp threads (linen fibers) were *Aspergillus* (7 species), *Penicillium* (4 species), *Chaetomium* (2 species), and *Alternaria* (1 specie). It is noticed that the order of occurrence of fungi on linen textile fabrics was as follows: *Aspergillus* > *Penicillium* > *Chaetomium* > *Alternaria*. The most dominant fungi on wool textile fabrics were *Aspergillus* (4 species), *Penicillium* (2 species). *Chaetomium* (1 species), and *Alternaria* (1 species). It was noticed that the order of occurrence of fungi on wool textile fabrics was as follows: *Aspergillus* > *Penicillium* > *Chaetomium* > *Alternaria*. The results showed that linen threads are more infested by fungi than wool piles as the number of identified fungi on linen were more than on wool.

Most of the identified fungi belong to the subdivision Deuteromycetys class or Fungi Imperfect. These fungi are called conidial fungi because their growth is initiated by conidia (Florian, 2004). These fungi are capable of rapid growth when the environmental conditions are favorable and are also able to survive under unfavorable conditions (Aranyanak, 1995). Most of identified fungal species were reported in previous studies as active fungi in deterioration of textiles. Many authors consider that most of these fungal species are the most active fungi among all fungal genera identified on textiles in the degradation of historical textiles (Abdel-Kareem, et al, 1997; Grag and Dhawan, 2005). The results showed that the most dominant fungi on the investigated textile object belong to *Aspergillus* and *Penicillium*. These two genera are very important, since they include species that can grow at relatively much lower conditions of moisture availability than other cellulolytic fungi. Under poor storage conditions, the water which is produced by demanding species as a result of their metabolism can accumulate, raising the moisture status of materials to levels at which more highly degradable species may flourish (Szostak-Kot, 2004). For all previous causes, there is a necessity to treat the textile object against fungal deterioration.

Table 3 Isolated fungi from various tested bio-deteriorated textile samples from the selected object

Fungi	Linen (warp)	Wool (weft)
Alternaria alternate (Fr.) Keissl	+	+
Aspergillus flavus Link	+	+
Aspergillus fumigatus Fresenius	+	+
Aspergillus nidulans Eidam	+	+
Aspergillus niger Tieghem	+	-
Aspergillus sp.	+	+
Aspergillus sp.	+	-
Aspergillus sp.	+	-
Penicillium asperum (Shear) n.comb.	+	-
Penicillium funiculosum Thom	+	-
Penicillium sp.	+	+
Penicillium sp.	+	+
Chaetomium globosum Kunze	+	-
Chaetomium sp.	+	+

3.2 Conservation processes used in conservation of the selected object

The results in the previous investigations of the statement of the textile object showed that that the current selected textile object suffered from the effect of fungal deterioration as there were many features of staining, weakening or complete destruction of fibers. There were many fungi (about fungal species) occurred on the textile object so that there is necessity for using fungicides to be used for disinfection of this textile object. The textile object was too dirty and there were many stains on the textile object so, there was a necessity to clean the textile object and to remove the stains using safe materials and methods. Various methods and techniques such as the suction table were used in cleaning the current textile object. Also the textile object was too damaged and too weak so, there was a necessity to use the polymers for reinforcing the weakness of the textile object. In previous study it is reported that some polymers combined with the fungicides prevent the fungal deterioration of textiles (Abdel-Kareem, 2010 a). Treatment of ancient textiles by suggested polymers combined with the suggested fungicides not only reinforces these textiles, but also prevents fungal deterioration and increases the durability of these textiles. Nasr, et al, 2010, produced a nano polymer (microemulsion polymer prepared from Methyl methacrylate (MMA) and Hydroxy ethyl methacrylate (HEMA) monomers using Eco-friendly initiation system represented as ultrasonic mechanism). It was evaluated for textile conservation and was confirmed that this nano polymer is very effective and suitable for consolidating and supporting wool textiles. It improves the long-term durability of treated wool textiles (Abdel-Kareem and Nasr, 2010). As there was a necessity to use both nano polymer and fungicide in conservation of the current fungal deteriorated textile object; the selected nano polymer was applied on a silk screen that has been previously treated with Neo-Desogen fungicide. The treated new silk screen was used for reinforcement of the textile object. Also other conservation processes required to complete the conservation of the textile object such as reinforcement of the consolidated textile object on a new board for display purposes have been done. The following conservation processes have been carried on the Coptic textile object.

3.2.1 Temporary Support for Cleaning

As the textile object is particularly fragile so prior any cleaning action for the textile object, it was supported temporarily between two layers of a fine nylon tulle (sandwich method), to hold the object in its place and to protect the textile fabric from the risk of handling during the cleaning processes.

3.2.2. Disinfection

Disinfection refers to the destruction of microorganisms particularly fungi. Because the current object suffers from fungal deterioration, it was a necessity to disinfect the textile object before any conservation processes. To treat the textile object against the fungal deterioration the following processes have been used. Decontamination of the current textile object from conidia and mycelium to reduce the fungal growth on the textile object and prevention of contamination of other objects was done. The surface of the bio-deteriorated textile object has been vacuumed cleaning to remove mycelium and conidia. The vacuum cleaning method chosen is acceptable by conservation standards to protect the integrity of the textile object. The main goal of this process is to reduce the fungal load to the minimal level of the infestation and prevent recontamination (Florian, 2004). A vacuum cleaning method was applied at low suction power, and through a fine nylon tulle netting fabric placed over the textile object in order to not disturb loose fibers (Abdel-Kareem, 2009). After de-contaminating the bio-deteriorated textile object from conidia and mycelium, the textile object was treated with fungicide according to Abdel-Kareem and Alfaisal, (2010). Neo-Desogen was used for disinfection of the Coptic textile object, the new silk screen fabric, silk threads and lining fabric. This fungicide was confirmed in previous studies as safe and effective in protection of ancient textiles against fungal deterioration (Abdel-Kareem, 2000).

3.2.3 Cleaning

To remove mould spores and other loses dirt from the textile object, vacuum cleaner with a variable speed control that can modify the vacuum suction was used. When ready to vacuum, the hose nozzle was covered with fine screening to prevent loose portions of the textile object from being sucked into the machine. We did not allow the nozzle of the vacuum cleaner to touch the object. Rather, hold the vacuum nozzle very close to the textile object and allow the suction to pull the mould off.

Because the selected textile object suffers from too much stains and dirt distributed all over, it was required to clean this object and remove the dirt to ensure lengthen its survival. On the other hand, the object also suffered from damage and fiber collapses which could not tolerate any mechanical vibrations. For all previous reasons, wet cleaning particularly immersion was the best choice due to its ability for removing many types of dirt and stains, thus its potential to soften and relax the fibers which resulted in reduction of creases and also improve the chemical properties of the treated objects. The detergent which was used in cleaning the object is Synpronic N. It is recommended for cleaning ancient textiles for its good properties (Abdel-Kareem and Shofer, 2001; Timar-Balazsy and Eastop, 2002). The prepared washing solution composed synpronic N in concentration (0.1 g / L was dissolved in a 50:50 mixture of ethanol and deionizer water. Prior the cleaning process, it was imperative to experiment the effect of this washing solution on the studied object to ensure its effectiveness without any side effect.

The textile object was cleaned using a suction table locally and by taking care of the decoration. This technique is an effective, go-od and easy technique for cleaning ancient textiles (Abdel- Kareem 2002). The mixture of ethanol and water was used to relax the fibres sufficiently to soften the creases (Abdel-Kareem, et al, 2008). Most of the dirt was thus removed (Figure 5). This washing process was repeated with deionized distilled water for 3 to 4 times until the water seemed clear and all signs of detergent had disappeared. This is an important step to ensure that there is no presence of any residual detergent inside the fibers that may cause further harm. It is clear from washing solutions that too much dirt and soils were removed from the object.

Figure 5 Wet cleaning of the selected Coptic textile object using the suction table.

After cleaning, the object was transferred into a flat horizontal, clean and smooth surface. Also, the stitching and protective tulle net were removed. Absorbent drying cotton fabric was used as a poultice and pressed lightly to the surface of the object to remove all excessive water. Moreover, slightly and carefully hand pressed on the surface of the object is an important step to check the lie of the weave correctly. After cleaning the object, it is treated again by Neo-Desogen to protect the textile object against fungal deterioration. Finally, the cleaned object was left to dry overnight as flat, right side uppermost.

3.2.4 Reinforcement and support

As the textile object is too damaged and too weak, there is a necessity to use the polymers to reinforce the weakness of the textile object. It was decided to support the textile object on a new silk screen by the selected nano polymer. The silk screen support was treated with the suggested nano polymer at a concentration of 10% according to the method No. 2 described by Landi, (1998). The aim of this technique is to create a film from the polymer in which the fabric is embedded (Abdel-Kareem, et al, 2008). The prepared support fabric was attached to the Coptic textile object according to the following procedure: The work surface (cleaned table) was covered with polyethylene and then coated with sheet of non-woven polyester as padding to absorb pressure during the work. The prepared surface was covered with a Teflon sheet to prevent sticking of the Coptic textile object to the surface. The Coptic textile object was placed face down. The previously treated silk screen support was laid over the back of the Coptic textile object, making sure that the warp is correctly aligned. It was fixed firmly in place by application of weight over it, smoothing it out as flat as possible but without putting it under tension. A Teflon sheet was laid over the back of the silk screen ensuring that the Another Teflon sheet was used to cover all area of work surface. Using a controlled electric Iron, the adhesive was reactivated and attached to the Coptic textile object. The iron was removed and the textile object was left for half an hour to cool to be sure that the Coptic textile object was attached to the silk screen (Abdel-Kareem, 2002).

To reinforce and support the Coptic textile object for display purposes, a new method was developed. The consolidated textile object has been supported on a Perspex sheet covered by layers of polyester sheet and a linen layer. Then the textile object was supported and fixed on the surface of the prepared lining layer by using sewing technique (see Fig. 6).

Figure 6 The final image of the textile object after applied all conservation processes.

This new method was developed from especial materials that can be more durable to biodeterioration problems and have very light weight in the display process. All used materials except linen fabric and sewing threads are safe against the biodeterioration. The linen fabric and sewing threads were treated with Neo-Desogen fungicide to be more durable and safer against fungal deterioration.

4. SUGGESTED RECOMMENDATIONS FOR DISPLAY OF THE CURRENT TEXTILE OBJECT IN ITS SHOWCASE

One of the best methods for protection of textile objects from fungal infestations in museums can be achieved by controlling the environmental conditions surrounding textile objects (Abdel-Kareem 2010 b). To display the current textile object, the following consideration should be undertaken.

4.1. Light, T°c and RH levels: Because the textiles are considered one of the sensitive organic materials, it is suggested that light, T°C and RH level are under-control and in moderate levels (e.g. light 50 Lux, temperature: 20°C, and relative humidity: 50-55%, In addition, the air pollutants must be not more than 50 microgram/m^3.

4.2. Regular examinations: It is suggested that there is a necessity to carry regular examinations to detect any changes in the condition surrounding of the object or deterioration signs on the textile object.

4.3. Display method: It is advised that the textile object can be displayed by using a Perspex sheet covered with nonwoven sheet of polyester and cover all of them with non-dyed linen textile fabric treated against biodeterioration infections.

5. CONCLUSION

There are obvious excessive fungal infestations in the tested Coptic textile object. The most dominant fungi isolated from tested samples belong to *Aspergillus, Penicillium, Chaetomium, Alternaria* and *Trichoderma* species. The order of occurrence of fungi on linen textile fabrics is as follows: *Aspergillus* > *Chaetomium* > *Penicillium* > *Alternaria* > *Trichoderma viride*. The order of occurrence of fungi on wool textile fabrics is as follows: *Aspergillus* > *Penicillium* > *Chaetomium* > *Alternaria*. There is necessity for using fungicides for disinfection of the biodeteriorated Coptic textile object. Also there is necessity for cleaning and consolidating the textile object. Both Neo-Desogen fungicide and the selected nano polymer (microemulsion polymer prepared from Methyl methacrylate (MMA) and Hydroxy ethyl methacrylate (HEMA) monomers gave satisfactory results in conservation of the current Coptic textile object. The developed conservation processes used in this study can be used as a guide for the conservators in conservation of biodeteriorated Coptic textile objects simulated to this object in Egypt.

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