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MONITORING THE ENVIRONMENTAL CONDITIONS AND THEIR ROLE IN DETERIORATION OF TEXTILES COLLECTION IN MUSEUM OF FACULTY OF ARCHEOLOGY, CAIRO UNIVERSITY, EGYPT

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ABSTRACT

Textiles objects as organic materials are considered one of the most sensitive at-risk materials. Consequently, they are extremely vulnerable to damage when stored or displayed in inappropriate environmental conditions. This study was carried out to monitor the factors that can enhance deteriorating the historical textile objects in Museum of Faculty of Archaeology as an example of historical museums in Egypt. The existing problems in the environmental variables including temperature, relative humidity, light and air particulates pollutants have been monitored in the selected museum. The concentration of the gaseous air pollutants such as sulfur dioxide, nitrogen dioxide, and ammonia were measured. The results show that air pollution is one of the most serious deteriorating factors that jeopardize the long survival of museum textiles in Egypt. Some examples of characterizing features of the deterioration of museum textile objects by environmental factors were also recorded in this work. Textiles are subjected to physical abrasion and damage by dust and gritty particles. These particles in combination with air pollutants may accelerate the rate of chemical reactions in the textiles, subsequently accelerating their deterioration. Finally, this study concludes that the environmental condition in this museum out of standards. A strategy must be established for controlling and preventing the deterioration problems on museum textile objects in Egypt.

KEYWORDS: Museum textiles, Improper Environmental condition, measurements, Light, Heat, Relative Humidity, air particulates, Pollutants, Prevention Methods

1. INTRODUCTION

Preventive conservation includes several topics, including heat and humidity measurements in the environment surrounding the objects within the display and storage show cases, controlling methods used in reducing the damage of museum collections, as well as measurements of light and means of light control. Moreover, the intensity of appropriate lighting and the safe limits during the display of various archaeological materials, as well as air pollution and its problems on the effects and control methods are considered as the heart of preventive conservation. Studies on biological damage, including insects, microorganisms and methods and methods of prevention without therapeutic impact interventions, are also within the framework of the subject (Abdel-Kareem, 2015).

Museum artifacts are extremely susceptible to damage from many factors such as improper humidity, dust, air pollution, light, heat, microorganisms, etc (Abdel-Kareem, 2005; Al-Gaoudi, 2020; National Park Service (NPS), 2006). Monitoring, and controlling the environmental conditions and deterioration factors in museums remain a crucial scope of research over time (Camuwo et al., 2001; Abdel-Kareem, 2010; Walid, 2012; Aiea et al., 2012).

Textiles objects are considered as one of the most sensitive artifact materials, so they are extremely vulnerable to damage when stored or displayed in inappropriate environmental conditions. Museum textiles were made of natural fibers such as linen, cotton, wool and silk. They often deteriorate naturally due to oxidation, heat, mechanical stress, radiation, moisture, and microbiological attack (Abdel-Kareem, 2015; El-Gaoudy, et al., 2011). The changes in temperature or in the air moisture content cause changes in relative humidity. It is known that if the relative humidity increases, hygroscopic materials such as textiles adsorb water vapor molecules increasing their equilibrium moisture content, augment their size with dimensional changes, and generate internal stress. On the other hand, if the relative humidity level drops, the equilibrium moisture content of the hygroscopic artefacts such as textiles also decreases causing shrinkage. Therefore, the fluctuation in relative humidity causes cycles in dimensional changes of the textiles which is dangerous in the long run due to their cumulative effect. (Camuwo, et al, 2001). The amount of consequent damage is directly related to the type of textile material, and the degree of environmental changes. Therefore, whenever ancient and delicate textiles are displayed, the microclimatic conditions should be controlled to prevent or reduce the deterioration of textiles (Camuwo., et al, 2001).

Light is a damaging factor that is difficult to prevent completely in museums because artifact objects cannot be displayed in the dark. All kinds of light have harmful effects on archaeological materials, particularly organic such as textiles. The most harmful effect of light on archaeological materials such as dyed textiles is the fading of colors and dyes from archaeological surfaces. Light also breaks down cellulose polymer bonds in textile fabrics and thus leads to weakening damaging, and fragmentation of these textiles. Light also yellows and damages polymers leading to the loss of their adhesive properties. Light can also cause occasional links to some of the polymers used for restoration and thus transfer them to insoluble matter in solvent. Therefore, it is recommended to display textiles in an area where lighting can be removed or turned off when the objects are not being viewed. Sunlight should be never used in display of museum textiles. Also, as fluorescent lights emit UV radiation, they shouldn't be used in museums or should be fitted with UV filters. In general, 50 lux is recommended for the display of textile objects as this ratio of light is considered to be safe for textile display (Abdel-Kareem, 2015; Elnagar, et al., 2013; Hustvedt and Crews, 2005).

Air pollution gases are one of the most common problems facing civilized societies. The progress and development of industry increases the amount of air pollution, and numerous studies has been carried out on air pollutants, their chemical nature, the conditions of their formation and the ways in which they are removed. Also, these studies have addressed the damage caused to archaeological materials in general.

Air pollutant in the museum is of great importance to maintain and serve the objects in the right conditions that prevent and resist deteriorations due to physical, mechanical, chemical stresses, and microbiological attacks. Airborne particulates should not be ignored within the museum's indoor air quality. They can negatively impact the textile artifacts. A side from dust and other suspended solid particulates, chemical/gaseous pollutants like Ozone, sulphur dioxide cause serious damages in the museum's indoor environment. They contribute in deoxidization, significant deterioration, as well as corrosion of metal threads. These pollutants should be blocked from entering the museums or removed from the environment. Indoor air quality of museum environments topic remains a crucial scope of research over time (Lee, et al., 2011; Vranikas, et al., 2011; Ferdyn-Grygierek, 2014; Baloccoa, et al., 2016; Litti, and Audenaert, 2018; Sharif-Askari and Abu-Hijleh, 2018; Silva, et al., 2016; Silva and Henriques, 2014; Proietti, et al., 2015; Zorpas and Skouroupatis, 2016; Chianese, et al., 2012; Hu, et al., 2015; Abdul-Wahab, et al., 2015). Atmospheric air pollutants were also covered in many publications (Krupińska et al., 2012; Krupińska et al., 2013; Wang, et al., 2015).

Textile objects are susceptible to destruction by microorganisms that come from soil, water and air. These microorganisms may lead to biodeterioration, which is a multistage and complex phenomenon that causes undesirable changes in the physical and chemical properties of textile materials. As a result of microbiological decomposition, stains, deposits, structural weakness, and color changes may appear in historical textile objects (Szostak-Kotowa, 2004; Abdel-Kareem, 2005; Gutarowska, et al., 2017; Wawrzyk, et al., 2018; Gutarowska, 2020; Elamin, et al., 2018).

Ancient Egyptian textiles have survived for thousands of years due to the fact that they have been preserved in very stable microclimatic conditions (in the buried tombs). From the moment of their excavation, these textiles start to deteriorate according to the changes in the environmental conditions surrounding them. There is no doubt that air pollution is one of the most serious deterioration factors that threaten the long survival of museum textiles in Cairo, Egypt. This is because Cairo is considered as one of the most polluted cities in all the world for about 64% of industries in Egypt are in Cairo (see Fig. 1).

It is noticed that the conditions in some museums in the universities in Egypt such as Museum of Faculty of archaeology, Cairo University; the Museum of applied Art, Helwan University, and others, don't meet the standard international regulations concerning the environment required in display showcases, windows and halls. Many deterioration factors such as improper humidity, dust, air pollution, light, heat, microorganisms, etc. are found in these museums. Moreover, materials and methods used in display of textiles accelerate damaging of these textiles. Preventive conservation is the most direct and uncomplicated way of caring for textile artifacts. Not only because conservation treatments are sometimes expensive, but also they do not always lead to the successful reversal of the cumulative effects of deterioration or damage. It is also clear that this damage can be the product of untrained or ill-advised attempts to conserve or restore works or objects.

Based on the previous points, the first step in the care of textile collections is to understand and minimize or eliminate factors that cause damage. Consequently, this study aims to monitor the factors that lead to the deterioration of textile objects in the Museum of Faculty of archaeology as an example for these museums. The dust concentration in the museum was monitored. Fungi that commonly occur on the textile collection in this museum was identified. The concentration of the air gases such as sulfur dioxide, nitrogen dioxide in the museum was also measured.

Figure 1. Some examples of air pollution sources in Cairo

2. EXPERIMENTAL

2.1 Equipment used

- Thermo –Anemometer ± 0.1m/s
- Dust Trak™ Aerosol Monitor-TSI capable to measure air particulate of size 10 microns, has traceability to NIST- USA.
- High purity medical membranes and calibrated balance of sensitivity 0.00001 g, they have direct traceability to the SI measurement system through the Egyptian Prototype kilogram No. 58 (for gravimetrical analysis).
- Triple plus instrument equipped with high sensitivity sensor for the following gasses, SO_2, H_2S, CO_2, NH_3, NO, NO_2, VO, CL_2 This instrument purchased from TSI-USA and traceable to NIST-USA.
- P-Track™ capable to sense air particulates in the air in the size range 0.2 um to 2 micron.
- Hot wire thermo anemometer for measuring air velocity (m/s) and temperature of the ambient.
- Testo 450 for measuring air pollutants (RH%, CO2, CO, Temperature and air velocity). It was supplied by TSI-USA.
- Noise tester manufacture
- Testo 350 supplied by TSI-USA. It was used for measuring (confirmatory tool) for CO and CO_2.

2.2 Traceability of measurements

These instruments have direct traceability to SI measurement system via calibration certificates from National Institute for standard and technology NIST –USA. Temperature sensor is calibrated and has direct traceability to the International temperature scale (ITS). All measurements were carried out by competent personnel with enough qualifications and using calibrated equipment and the measurement procedure was conducted in compliance with the requirements of ISO/IEC 17025:2005.

2.3 Selected position for the measurements

Textile collections in the museum of Faculty of archaeology are displayed in different methods. They are displayed in open air by hanging on stands and walls of the museum hall or are displayed in closed showcases (see Fig. 2-3). So, it is very important to monitor the environmental condition in all areas surrounding the textile objects. For measuring the environmental condition in the display hall of the museum surrounding the textiles, we selected 9 positions to cover the display. These locations were coded by numbers from 1 to 9 inside the display hall (see Fig.4). Three showcases (carried museum catalog no. 42, 41 and 40) were selected for measuring the environmental condition insides the showcases in the current museum. The upper part of the selected showcases is used to display textile objects and the lower part is used to store textile objects. The measurements were carried on three parts of each showcase, the first part (a) means the upper shelf, the second part (b) means the medium shelf, and the third part (c) means the lower part of the showcase that is used for storage of textile objects.

Figure 2. Showcases used in display of textile objects in the Museum of Faculty of Archaeology.

Figure 3. Three methods used to display of textile objects in the Museum of Faculty of Archaeology, A) by hanging on wood stand, B) by hanging on wall but inside 2 sheets of glass, C) by hanging directly on wall.

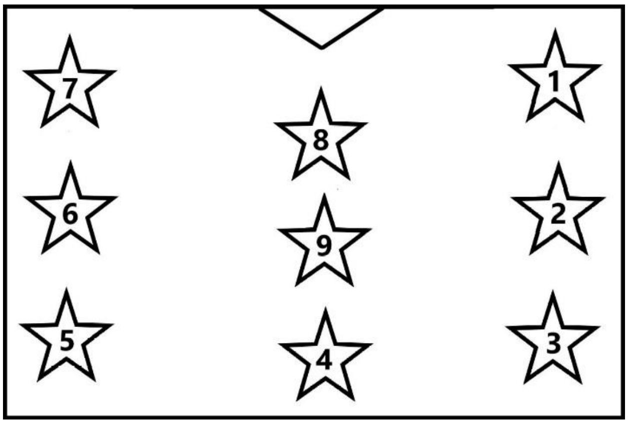

Figure 4. Map of tested locations in the Museum of the faculty of Archeology- Cairo University, Cairo Egypt.

2.4 Instrumentation and Measurements

Dust measurements: the dust concentration as particulate of 10 micrometer size was measured by the Dustrack device.

Air particulate (03 μm to 5 μm): For the air particulate (03 μm to 5 μm), P-Track™ capable to sense air particulates in the air in the size range 0.2 um to 2 micron was used.

Gasses content: The gasses namely CO_2, CO, VOC, H_2S, NO_3, SO_2 and CL_2 were measured using triple plus (USA) instrument with different gas sensors.

Air velocity measurements: The air velocity (m/s) was measured using Thermo-anemometer (ATI-USA).

Noise Measurements: The Noise (dB[A]) was measured using noise level meter (TSI-USA).

Intensity of the light measurements: The lighting distribution as lux measurement was measured using lux meter (TSI-USA).

Temperature and humidity%: The temperature and relative humidity % were measured using Thermo-hygrometer (Testo 450 -USA).

Note: For the statistical work, the following process was applied on all carried measurements; for each test, the measurements were taken seven times and statistical data were calculated.

3. RESULTS AND DISCUSSION

3.1. Dust measurements

The obtained data about the dust concentration as particulate of 10 micrometer in both of the hall of the museum and inside the showcases is presented in table 1. The results confirm that dust concentration is much higher in all selected locations of museum hall compared to that in selected showcases. This shows that showcases help in reducing dust accumulation on textiles. The obtained data of the average values of air particulate from 0.3 to 1 micrometer is presented in Table 2. By comparing the results in table 1 and table 2 it is clear that the percentage of fine particulates is higher than large ones. This indicates that fine dust can penetrate the fibers of textiles easier than larger ones. Table 3 shows the average values of air particulate from 2 to 5 micrometer. The results indicate that there is inversely proportional relationship between particulate size and amount of dust accumulated; as the particulate size decreases, the amount of dust accumulated increases. These results indicate that the dust can penetrate the textile fibers.

The obtained values of dust particulates showed that there are higher values of all types of dust particulates (p/m^3) report for both differential and cumulative techniques. According to these results, the stains on textile objects in this museum may be due to the deposition of airborne particulate matter on these textiles. These soiling may cause a hazard to textiles collections. In addition to soiling by airborne particles, the conservation literature suggests that deposited airborne material can attack textile collections chemically. Some objects such as old, fragile textiles and tapestries may be almost impossible to clean once they have become soiled. Textiles are subjected to physical abrasion and damage by dust and gritty particles. Also these particles in combination with air pollutants may accelerate the rate of chemical reactions in the textiles, subsequently accelerating their deterioration.

Table 1. The dust concentration as particulate of 10 micrometer size

The hall of the museum				**The Showcases**			
Position	Mean	S.D	S.E	**No.**	Mean	S.D	S.E
1	0.098	0.008	0.003	**42a**	0.029	0.011	0.004
2	0.085	0.014	0.005	**42b**	0.06	0.012	0.004
3	0.057	0.022	0.008	**42c**	0.017	0.007	0.003
4	0.07	0.02	0.008	**41a**	0.014	0.004	0.002
5	0.089	0.026	0.01	**42b**	0.011	0.005	0.002
6	0.065	0.009	0.004	**42c**	0.021	0.002	6E-04
7	0.052	0.014	0.005	**40a**	0.017	0.005	0.002
8	0.065	0.015	0.005	**40b**	0.012	0.006	0.002
9	0.161	0.192	0.072	**40c**	0.011	0.004	0.001

Table 2. The average values of the air particulate (0.3 μm to 1 μm) in the hall of the museum

Location	0.3		0.5		1	
	p/m³	Diff.	p/m³	Diff.	p/m³	Diff.
Location 1	1888590	1298994	589596	249110	340486	156964
Location 2	1869830	1210528	568291	257304	401998	180587
Location 3	1829375	1171772	611466	255532	373703	183690
Location 4	1923906	1335899	588007	262063	325943	162592
42a	1909198	1201922	443275	191940	209563	110706
42b	1747434	1312782	912613	228037	223283	118167
42c	1704392	1377900	326493	177292	149200	79953
41a	1748821	1264222	484599	230605	253994	132750
41b	1745733	1427582	318151	710000	141485	79951
41c	1712469	1422791	289678	179287	110391	63433

Table 3. The average values of the air particulate (2 μm to 5 μm) in the hall of the museum

Location	2		3		5	
	Cumul.	Diff.	Cumul.	Diff.	Cumul.	Diff.
Location 1	183522	99176	84346	64124	20223	20223
Location 2	221412	117483	103929	77641	26288	23155
Location 3	184180	112597	85983	67682	18301	18301
Location 4	163351	95002	68349	53901	14448	14448
42a	98857	58969	39888	32360	6128.2	7528
42b	105116	64367	40749	25356	7263.2	7245
42c	69248	41640	27607	21784	5823.7	5824
41a	121244	73167	44743	38913	9163.3	9163
41b	57830	28163	22420	18439	3981	3981
41c	52358	28951	18007	13972	4034.6	4035

3.2 Gasses content

The results of the environmental gasses content (ppm) in the hall of the museum in different locations are presented in Table 4, while the results of the environmental gasses content (ppm) in the museum showcases are presented in Table 5. The obtained results show that percent of carbon dioxide in both of the museum hall and the show cases is too high. By comparing the results in Table 4 and Table 5, it is clear that the percent of carbon dioxide in museum hall is more than in the showcases. This indicate that the show cases reduce the deterioration threats by carbon dioxide.

Table 4. Environmental gasses content (ppm) in the hall of the museum in different locations.

Position	CO_2	CO	VOC	H2S	NO_3	SO_2	Cl_2
1	910.28	0.20	2.00	0.0	0.0	0.0	0.0
2	907.50	0.58	2.00	0.0	0.0	0.0	0.0
3	935.70	0.30	2.00	0.0	0.0	0.0	0.0
4	868.00	0.20	1.86	0.0	0.0	0.0	0.0
5	882.43	0.13	2.54	0.0	0.0	0.0	0.0
6	874.00	0.30	2.00	0.0	0.0	0.0	0.0
7	809.00	0.30	2.14	0.0	0.0	0.0	0.0
8	924.00	0.37	2.00	0.0	0.0	0.0	0.0
9	922.30	0.37	1.71	0.0	0.0	0.0	0.0

Note: the values '0.00' indicates that the values below the detection lime of these gasses (LOD =0.01 ppm).

Table 5. Environmental gasses content (ppm) in the museum showcases.

Position	CO_2	CO	VOC	H2S	NO_3	SO_2	Cl_2
42a	757.3	0.4	0.0	0.0	0.0	0.0	0.0
42b	739.0	0.8	1.0	0.0	0.0	0.0	0.0
42c	674.3	0.3	1.0	0.0	0.0	0.0	0.0
41a	690.3	0.3	1.00	0.0	0.0	0.0	0.0
42b	683.0	0.0	1.0	0.0	0.0	0.0	0.0
42c	698.6	0.0	0.0	0.0	0.0	0.0	0.0
40a	808.0	0.0	0.0	0.0	0.0	0.0	0.0
40b	754.4	0.0	1.0	0.0	0.0	0.0	0.0
40c	655.7	0.0	1.0	0.0	0.0	0.0	0.0

3.3. The air velocity (m/s) measurements

The air velocity (m/s) measurements were done only in the museum hall as there is no necessity to measure them in the showcases. The results of the air velocity (m/s) measurements are presented in table 6. These results indicate that the windows in the museum are not closed well. The obtained results show that there is air flow in the museum hall that may cause movement of dust on the surface of textile objects causing abrasion of the fibers of textiles and damaging them.

Table 6. The air velocity (m/s) measurements with standard deviation and standard error

The hall of the museum			
Position	Mean	S.D	S.E
1	0.157	0.049	0.019
2	0.157	0.049	0.019
3	0.129	0.045	0.017
4	0.214	0.064	0.024
5	0.243	0.09	0.034
6	0.2	0.053	0.02
7	0.186	0.064	0.024
8	0.186	0.064	0.024
9	0.129	0.045	0.017

3.4. Noise Measurements

The results of the Noise (dB[A]) measurements from all sources (inside and outside the Museum) are presented in table 7. The obtained results indicate that the (4-7) windows in the museum are not closed well, and the museum walls are not treated and isolated against sound.

Table 7. The Noise (dB[A]) measurements

The hall of the museum			
Position	Mean	S.D	S.E
1	45.371	2.523	0.954
2	45.943	1.115	0.421
3	46.786	1.467	0.555
4	50.4	0.6	0.227
5	48.3	0.393	0.148
6	47	1.65	0.624
7	48.086	1.663	0.628
8	42.643	1.213	0.458
9	45.657	1.1	0.416

3.5. Intensity of the light measurements

The results of light intensity measurements are presented in table 8. The obtained results confirm that the intensity of light in the Hall (no 3) is about 500 lux which is much higher than the standard intensity for textiles display (50 lux). This causes fading of textiles displayed in the museum hall. However, the intensity of light in showcases is about 100 lux which is less harmful than that of museum hall.

Table 8. The intensity of the light measurements as lux measurement

The hall of the museum				The Showcases			
Position	Mean	S.D	S.E	**No.**	Mean	S.D	S.E
1	508.714	7.126	2.693	**42a**	178.29	2.603	0.984
2	426.429	14.99	5.667	**42b**	70.429	1.591	0.601
3	500.714	3.369	1.273	**42c**	0	0	0
4	115.571	1.678	0.634	**41a**	215.71	3.534	1.336
5	338.571	3.156	1.193	**42b**	129.86	8.839	3.341
6	198.857	2.167	0.819	**42c**	0	0	0
7	150	2.33	0.881	**40a**	142.57	2.195	0.829
8	126.286	2.814	1.064	**40b**	84.286	6.562	2.48
9	127	1.414	0.535	**40c**	0	0	0

3.6. Temperature and humidity %

The data in Table 9 represents the results of temperature and relative humidity. The results confirm that the humidity in the museum hall is not harmful as it is about 50-55 in the museum hall which is suitable for textiles display. However, the results in showcases show that humidity is about 45 which causes textiles to be brittle and dry.

Table 9. Temperature (°C) and humidity (%) in the Museum

The hall of the museum					**The Showcases**				
Position	Temp. °C	**Humidity**			**No.**	Temp. °C	**Humidity**		
		Mean	S.D	S.E			Mean	S.D	S.E
1	20.8	53.957	0.256	0.097	**42a**	21.8	50.629	0.191	0.072
2	21.1	52.743	0.159	0.06	**42b**	21.7	48.357	0.168	0.063
3	21.1	52.871	0.148	0.056	**42c**	21.7	49.943	0.049	0.019
4	21.2	52.971	0.128	0.048	**41a**	21.9	48.6	0.076	0.029
5	21.1	52.143	0.266	0.101	**42b**	22	47.6	0.053	0.02
6	21.3	52.086	0.155	0.059	**42c**	21.7	47.486	0.125	0.047
7	21.2	51.457	0.219	0.083	**40a**	22.2	48.314	0.112	0.043
8	21.2	52.743	0.184	0.07	**40b**	22.1	47.314	0.173	0.065
9	21.1	53.786	0.931	0.352	**40c**	21.8	46.529	0.128	0.048

Features of deteriorations on textile objects

We have recorded the features of deterioration on textile objects in the collection of textiles in museum of faculty of archaeology. There are some signs regarding the effect of light intensity on textiles such as fading of dyes on the surface of textiles (see Fig.5). Also, there are signs of disintegrate of the fibers as this textile object is linen. It is known that light breaks down cellulose polymer bonds in textile fabrics (such as linin and cotton) and thus leads to weakening damaging, and fragmentation of these textiles.

Figure 5. An example of the effect of light intensity on fading of dyes on textile objects.

Many stains on the textile objects were recorded, and it was noticed that fibers are brittle (Fig. 6). These signs may be due to air pollutions or biological effect. Moreover, signs of abrasion in the fibers of textile objects were noticed (Fig.7). Air pollution comes from contaminants produced outside and inside museums. Common pollutants include: dirt, which includes sharp silica crystals; grease, ash, and soot from industrial smoke; sulfur dioxide, hydrogen sulfide, and nitrogen dioxide from industrial pollution; formaldehyde, and formic and acetic acid from a wide variety of construction materials; ozone from photocopy machines and printers; and a wide variety of other materials that can damage museum collections. Air pollutants are divided into two types: Particulate pollutants (for example, dirt, dust, soot, ash, molds, and fibers). Gaseous pollutants (for example, Sulphur dioxide, hydrogen sulphide, nitrogen dioxide, formaldehyde, ozone, formic and acetic acids).

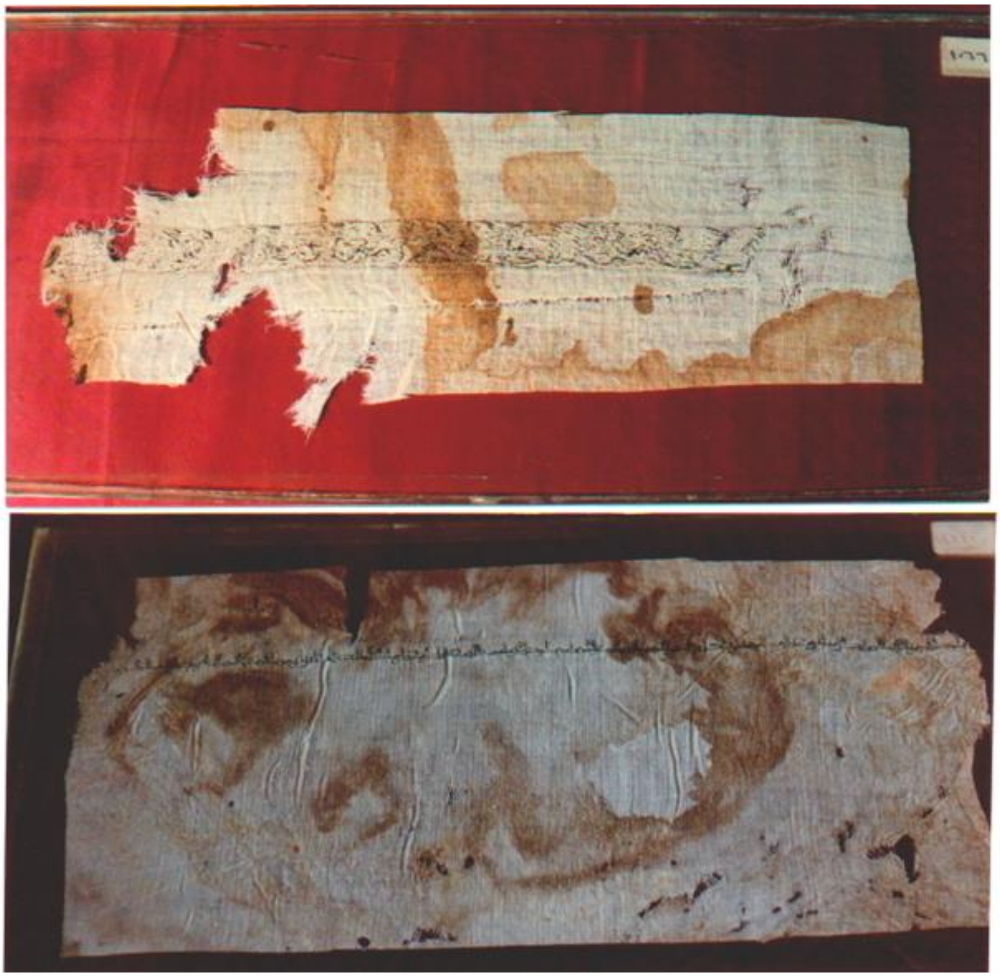

Figure 6. Examples of stains on dyed textile objects due to air pollutions or fungal deteriorations

Figure 7. An example of the effect of dust and air flow on abrasion of the piles on carpets.

Although the results of measuring the heat and relative humidity are not bad, some signs for the effect of condensation of water vapour on textile objects were noticed (Fig. 8). This may be due to the change between the night and day weather in Egypt which indicates that the condition system in the museum is closed after the day work time. It is therefore recommended that the condition system should not be closed all time in night and day while a repeat of measurements in the whole day and night for one year is necessary to get more information on the problems in the current museum.

Figure 8. An example of the effect of condensation of water vapour on textile objects.

4. CONCLUSION

The assessment of the environmental conditions in the Cairo University Museum has produced the following notion: that the environmental conditions used in display or storage of textile collection in the museum are extremely poor. There are obvious problems in the environmental conditions including temperature, relative humidity, light and air particulates in the museum space. There are many deterioration features on textile objects such as fading of dyes, discoloration and stains, brittleness, abrasion, etc. Our presented project emphasizes and indicates necessary measures to control the environmental conditions in this case study, the Cairo University Museum, recommending that the new museum must include the standards and suitable environment for display and storage of textiles.

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