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The Impact of Preservative Storage Environment Adjustment on the Sustainability of Archival Materials: A Case Study on Microbiological Pollution in Library Collections

Hebatallah S. El-Menshawy, [1, *] Mohamed Ahmed Helal [2]

[1] Conservation and Restoration Department, Bibliotheca Alexandria, Alexandria, Egypt

[2] Faculty of Fine Arts, Alexandria University, Alexandria, Egypt

Abstract

This research aims to study the impact of temperature and relative humidity variations, along with microbiological contamination, on archival materials, particularly photographic images, focusing on fungal and bacterial species. The study involves assessing microbiological pollution levels by collecting samples from various locations within the storage areas of museum collections at the University of Alexandria and Bibliotheca Alexandria. Suitable nutrient media are used for the growth of fungi and bacteria, and temperature and relative humidity are measured over a period using a Data Logger device. The research also includes measuring air pollution levels. The results indicate the influence of certain fungi and bacteria present in the air on museum collections.

Keywords

Archival Materials; Preservation Status; Microbiological Deterioration; Nutrient Media; Library of Alexandria.

Article History

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* Correspondence Author: heba.elmenshawy@bibalex.org; heba.elmenshawy79@gmail.com

تأثير ضبط بيئة الحفظ الوقائي على استدامة المواد الأرشيفية: دراسة حالة للتلوث الميكروبيولوجي في مقتنيات المكتبات

هبة الله صلاح المنشاوي، [1] محمد أحمد هلال [2]

[1] قسم الترميم والصيانة، مكتبة الإسكندرية، الإسكندرية، جمهورية مصر العربية

[2] كلية الفنون الجميلة، جامعة الإسكندرية، الإسكندرية، جمهورية مصر العربية

الملخص

يهدف البحث إلى دراسة تأثير التغير في درجات الحرارة والرطوبة النسبية، بالإضافة إلى التلوث الميكروبيولوجي، على المواد الأرشيفية، خاصة الصور الفوتوغرافية، مع التركيز على الأنواع الفطرية والبكتيرية. يتضمن البحث تقييم مستويات التلوث الميكروبيولوجي من خلال جمع عينات من مواقع متعددة داخل مناطق تخزين المقتنيات المتحفية في جامعة الإسكندرية ومكتبة الإسكندرية. يتم استخدام أوساط غذائية مناسبة لنمو الفطريات والبكتيريا، مع قياس لدرجات الحرارة والرطوبة النسبية لفترة زمنية باستخدام جهاز Data Logger كما يتضمن البحث قياس نسبة التلوث الجوي. تشير النتائج إلى تأثير بعض الفطريات والبكتيريا الموجودة في الهواء على المقتنيات المتحفية.

الكلمات الدالة

المواد الأرشيفية؛ حالة الحفظ؛ التلف الميكروبيولوجي؛ الأوساط الغذائية؛ مكتبة الإسكندرية.

Introduction:

Museum collections, especially photographic images, have become repositories of invaluable historical and cultural significance, reflecting the evolution of society and the human historical memory. With the increasing necessity to preserve these precious materials, it becomes crucial to understand the impact of environmental factors on them, especially fluctuations in temperature and relative humidity, and microbial pollution they might be exposed to. It appears that the challenges facing this cultural heritage extend beyond traditional environmental factors. Microbial pollution causes continuous deterioration of archival materials, as fungal and bacterial growth contributes to the degradation of gelatin and reacts with the chemical components of photographic images (Lavedrine, 2011). This reaction can lead to the breakdown of gelatinous materials and the gradual fading of images.

To address these challenges, the methods used in storing and preserving artifacts play a vital role. Lourenço (2009) emphasizes the importance of dividing storage areas into small imaging zones to analyze microbial pollution. Additionally, continuous monitoring of temperature and humidity is necessary to ensure a stable storage environment, as reflected by Patel (2012) in the importance of air analysis and climate conditions monitoring to determine the artifacts' need for environmental control and treatment. The importance of monitoring temperature and relative humidity in preserving artifacts is evident, as indicated by Reilly (2009), who suggests that maintaining a certain temperature between 18-21 degrees Celsius can contribute to preserving photographic images. Furthermore, humidity control is necessary to avoid cracking and loss of the gelatin-binding layer.

Therefore, this research aims to explore the impact of these factors on archival materials, focusing on photographic images as representative artifacts, and to provide a comprehensive assessment of microbial pollution levels in cultural institutions and museums. By studying samples taken from multiple sites within museum storage areas at the University of Alexandria and Bibliotheca Alexandria, we will analyze the fungal and bacterial species present and evaluate their impact on archival content. Changes in temperature and relative humidity will be monitored using advanced techniques for measuring the surrounding environment, and we will present the results of air pollution measurements to identify potential external factors that may affect archival materials. Through this research, we seek a deeper understanding of how to preserve this important cultural heritage amidst increasing environmental challenges.

Materials and Methods:

Microbiological examination:

Microbiological deterioration depends on the various species and strains of fungal and bacterial molds, as well as on different environmental factors. However, the single most significant factor conducive to the growth of these microorganisms is relative humidity. When it rises above 65%, metabolism is activated, and most types of mold proliferate at room temperature. Therefore, proper ventilation inhibits fungal growth. Mold is considered a serious cause of deterioration of museum collections, especially photographic images, as it feeds on gelatin, extracting carbon and nitrogen through enzymatic hydrolysis, weakening the image layer and potentially destroying it entirely (Lavedrine, 2011). To assess the degree of contamination and identify the different types of microbiological deterioration in the air and on surfaces, samples are taken from multiple sites. When the storage area is very large, it is divided into imaging zones of 20 square meters each, numbered, and a certain number of random locations are selected for biological pollution analysis (Lourenço, 2009).

Microbiological examination of storage areas:

A suitable nutrient medium for fungal growth, Sabouraud Dextrose Agar (SAD), was prepared. SABOURAUD DEXTROSE AGAR powder was added to distilled water at boiling temperature. After carefully mixing the components and ensuring there were no lumps, the temperature was reduced, and the mixture was allowed to boil for a short period. Sterilization was then performed using an autoclave, and the medium was poured into Petri dishes. After cooling, the medium was ready for fungal and bacterial sample inoculation. Petri dishes were placed in the storage locations of the studied artifacts, one in the Central Library Museum - University of Alexandria, and the other in the Museum Collection Store - Library of Alexandria. Petri dishes containing the nutrient medium were exposed to air for several hours, and then they were placed in an incubator at a temperature of 25 degrees Celsius for 7 days until fungal colonies appeared in both samples. Figs (1) and (2) illustrate the placement of Petri dishes in the storage areas, while Figs (3) and (4) show the appearance of fungal and bacterial colonies on the nutrient media.

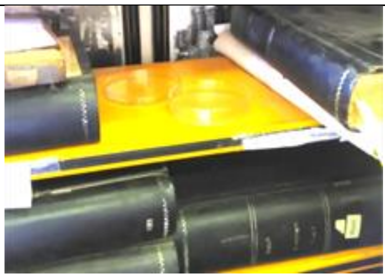


Fig. No. (1) illustrates the storage and preservation location of museum artifacts at the Central Library Museum at the University of Alexandria.

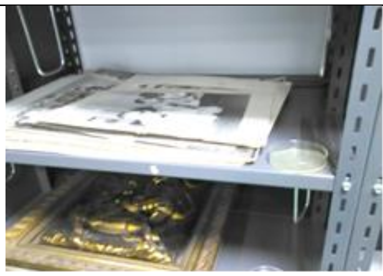


Fig. No. (2) illustrates the storage and preservation location of museum artifacts at Bibliotheca Alexandria.

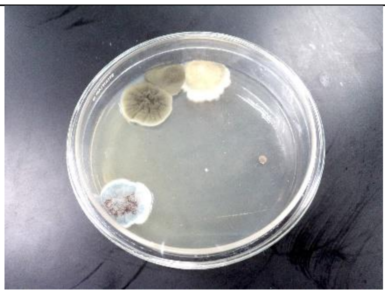


Fig. No. (3) Shows the growth of colonies on the nutrient medium exposed to air in the storage locations at the Central Library Museum - University of Alexandria.

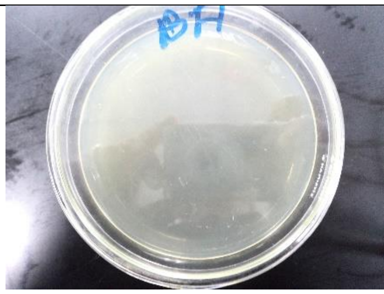


Fig. No. (4) Shows the growth of colonies on the nutrient medium exposed to air in the storage locations at Bibliotheca Alexandria.

Microbiological examination of the studied museum artifacts:

Several swabs sterilized with cotton swabs were taken from various locations on the museum artifacts under study to identify the types of fungi and bacteria affecting them. Sabouraud Dextrose Agar (SDA) was prepared as a specific nutrient medium for fungal growth, while Nutrient Agar (NA) was prepared as a specific nutrient medium for bacterial growth. The swabs were transferred into each of the fungal growth nutrient medium and bacterial growth nutrient medium inside a Laminar Flow hood. Subsequently, the samples were incubated in an incubator at a temperature of 25 degrees Celsius for 7 days until fungal and bacterial colonies appeared. Each type of bacteria was isolated separately in test tubes containing a nutrient environment suitable for bacterial growth, as shown in Fig. No. (5).

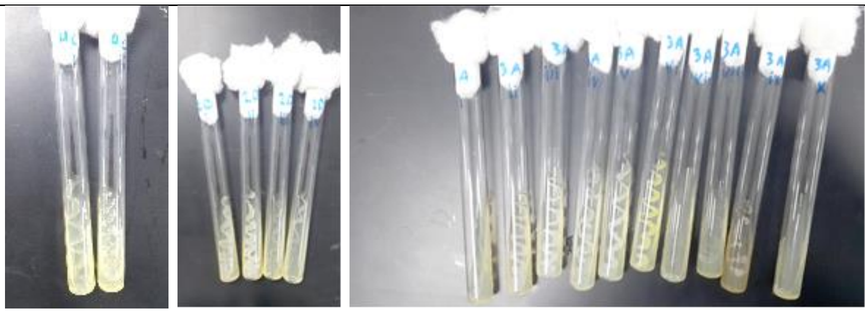


Fig. No. (5) Illustrates the isolation of different types of bacteria.

Environmental control (Storage and Preservation Environment Monitoring):

Storage areas with optimal climatic conditions are essential for preserving museum artifacts, especially photographic images. Temperature control systems, including cooling, heating, and humidity control through air conditioning units, are crucial for achieving stability in temperature and relative humidity (Norelle, 1996). Oliveira (2001) emphasized the importance of maintaining an ideal environment through climate control systems, as the climate of storage and preservation rooms affects the expected lifespan of museum collections. Patel (2012) also clarified that air analysis and continuous monitoring of temperature and relative humidity throughout the year can determine whether the storage environment requires treatment and adjustment. This is achieved by continuously recording and regulating temperature and relative humidity using thermo-hygrometers, thermostats, and humidistats placed in the environment closest to the presence of museum collections, especially photographic images. It is essential to calibrate these instruments periodically. Among the most significant factors influencing museum collections are:

- **Humidity:**

Relative humidity in the air is measured, and dry air - where the relative humidity is less than 30% - leads to the cracking of photographic images, causing the gelatin binding layer to detach from the paper support (Reilly, 2009). Stephanie (2004) pointed out that wrinkling and visible cracks occur in the three layers of the photographic image print, especially gelatin silver prints. An increase in relative humidity to 65% leads to chemical deterioration, resulting in hydrolysis and fading of silver. When examining photographic images, they may appear yellowed or faded, and silver-based images are susceptible to oxidation due to air pollutants, humidity, and temperature fluctuations. The phenomenon of silver mirroring is significantly evident on the surface of photographic image prints. Biological deterioration also contributes to the spread and growth of mold on the image surface, as gelatin provides an ideal medium for fungal and bacterial growth. Gelatin images can transform into a gelatinous state, making them prone to scratching and detachment from the paper support (Teper, 2009).

Table No. (1) Illustrates the different relative humidity levels, adapted from: (Lavedrine, 2011).

Very low relative humidity	Less than 20%	Very dry air
Low relative humidity	20 – 40%	Dry air
Moderate relative humidity	40 – 60%	Moderate humidity
High relative humidity	60 – 80%	Moist air
Very high relative humidity	Higher than 80%	Very humid air

- **Temperature:**

Temperature is the second primary factor causing deterioration in museum artifacts, especially photographic images, as it is closely related to relative humidity. Black and white photographic images with paper support can be preserved at temperatures between 18-21 degrees Celsius (Reilly, 2009). Stephanie (2004) added that air pollutants act as a contributing factor to visible damage on photographic images, causing color changes and yellowing, which initially appear in areas of medium tones.

- ***Monitoring Relative Humidity and Temperature:***

Temperature and relative humidity in the storage and preservation environment of the studied artifacts were monitored and recorded at both the Central Library of Alexandria University (C.L.) and Bibliotheca Alexandria (B.A.). A location inside Bibliotheca Alexandria was selected, where collections of photographic images are available in storage room B4, located on the fourth level below ground level. Additionally, places for manuscript preservation within Bibliotheca Alexandria were monitored, including the air purification device in the Archives Indexing section in B1, located on the first floor below ground level (M.R.H. - Manuscript Reading Hall). A recently calibrated Testo 175 Data Logger device was used to measure and monitor temperature and relative humidity within Bibliotheca Alexandria. This device is capable of monitoring and controlling temperature and relative humidity inside buildings and museums. It also includes an external humidity sensor for monitoring and recording data on a large memory, capable of providing up to one million readings. These aids in obtaining data readings over extended periods and the recorded data can be exported into various software programs (Excel, Pdf, etc.).

- ***Measurement of Air Pollutants:***

Air pollution elements in the environment surrounding the studied artifacts were measured, indicating the percentage of elements observed along with temperature, using an advanced sense (TG-501) Model device. This device measures the following elements in the air: sulfur dioxide (SO_2), nitric oxide (NO), nitrogen dioxide (NO_2), ozone (O_3), and hydrogen sulfide (H_2S)

Results and Discussion:

Microbiological Contamination in Storage Areas:

Microscopic examination of colonies grown on the nutrient agar exposed to the open storage environment in both the Alexandria Library and Alexandria University revealed the identification of fungal and bacterial infections, as shown in Table No. (2). The results indicate that the storage area for archaeological collections in the central library of Alexandria University contains biological contamination leading to deterioration and mold growth on the selected specimens for examination, as depicted in Figs (6, 7, 8). Gelatin layers in photographic images serve as an ideal medium for fungal growth. The spread of mold on the images is evident through the appearance of grayish blisters or small spots surrounded by filamentous networks, which may be discolored, resulting in the disappearance of the photographic image in the affected areas.

Table No. (2) Illustrates the result of incidental biological contamination in storage locations.

Storage locations at the Central Library - Alexandria University				Storage locations at Bibliotheca Alexandria	
Fungi	**No.**	**Bacteria**	**No.**	**Fungi**	**No.**
Aspergillus Sydowil	2	Unknown	2	---	---
Cladosporium sphaerospermum	1				
Penicillium Sp.	1				

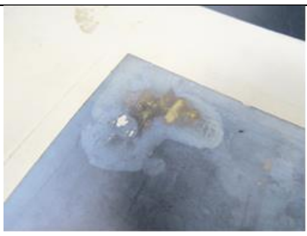


Fig. No. (6) Illustrates the spread of fungal mold on the surface of photographic images.

Fig. No. (7) Illustrates the spread of fungal mold on the surface of photographic images.

Fig. No. (8) Shows the spread of fungal mold on the surface of photographic images.

Microbiological Damage to Museum Collections:

Microscopic examination of colonies grown on the nutrient agar inoculated with swabs taken from the museum collections under study at the Central Library Museum of Alexandria University and the storage areas at the Alexandria Library revealed the contamination of these collections with various types of bacteria and fungi, as illustrated in Tables (3, 4, 5, 6).

Table No. (3) Illustrates the results of the microbiological examination of the swabs taken from the studied museum artifacts.

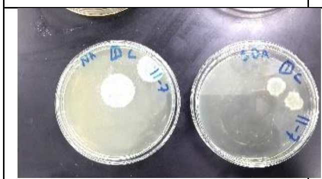
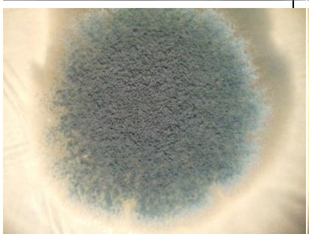
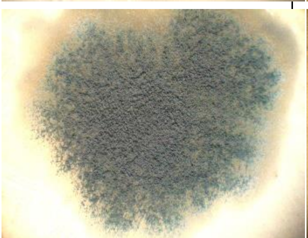
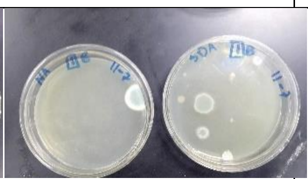
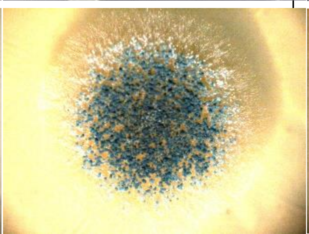
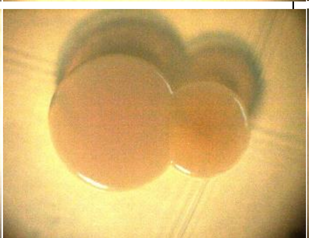
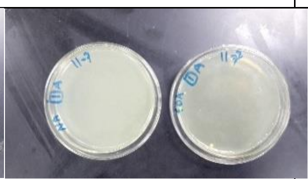
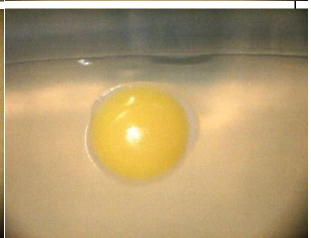
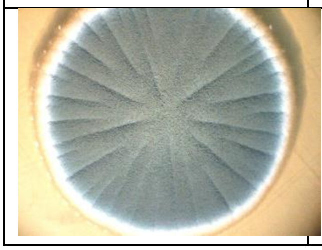
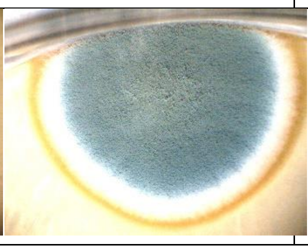
The locations of the swabs on the archaeological artifacts			A	
C	**B**	**A**		
			**The locations of the swabs for studying the growth of fungi and bacteria**	
Penicillium Sp.	Bacteria, Actinomycetes Aspergillusclaratus, Penicillium Sp.	Bacteria	Type	**(SDA) Sabouraud Dextrose Agar A special nutrient agar for fungal growth**
2	2 3	3	No.	
  	  	  	The morphology of the colony	
Penicillium Sp.	Penicillium Sp.	----	Type	**(NA) Nutrient Agar A special nutrient agar for bacterial growth**
2	1	----	No.	
		-----	The morphology of the colony	

Table No. (4) Illustrates the results of the microbiological examination of the swabs taken from the studied museum artifacts.

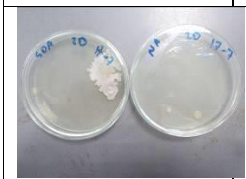
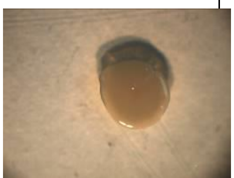
The locations of the swabs on the archaeological artifacts				B	
D	C	B	A		
				**The locations of the swabs for studying the growth of fungi and bacteria**	
Bacteria, Actinomycetes Aspergillusclaratus	-	-	-	Type	**(SDA) Sabouraud Dextrose Agar** **A special nutrient agar for fungal growth**
2 1	-	-	-	No.	
 	-	-	-	The morphology of the colony	
Bacteria	-	-	-	Type	**(NA) Nutrient Agar** **A special nutrient agar for bacterial growth**
2	-	-	-	No.	
 	-	-	-	The morphology of the colony	

Table No. (5) Illustrates the results of the microbiological examination of swabs taken from the studied museum artifacts.

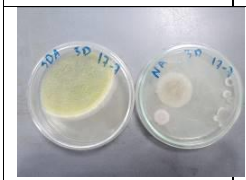
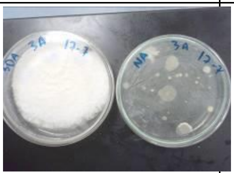
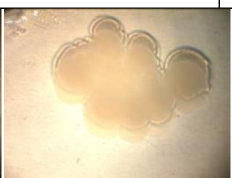
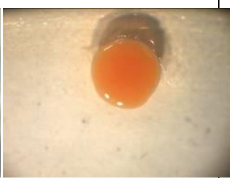
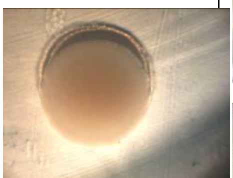
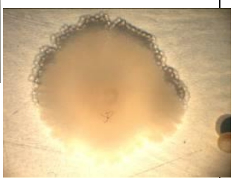
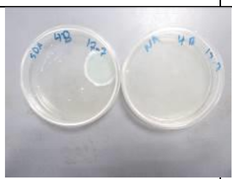
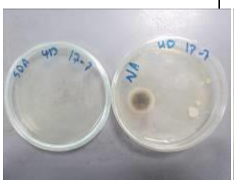
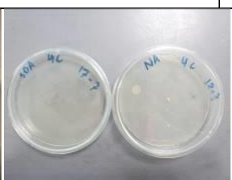
The locations of the swabs on the archaeological artifacts				C	
D	**C**	**B**	**A**		
				**The locations of the swabs for studying the growth of fungi and bacteria**	
Aspergillus Flavus	-	-	Unknown	Type	**(SDA) Sabouraud Dextrose Agar** **A special nutrient agar for fungal growth**
1	-	-	1	No.	
 	-	-	 	The morphology of the colony	
Penicillium Sp.	Bacteria	Bacteria	Bacteria, Actinomycetes Penicillium Sp.	Type	**(NA) Nutrient Agar** **A special nutrient agar for bacterial growth**
6	2	2	10 1	No.	
 	 		 	The morphology of the colony	

Table No. (6) Shows the results of the microbiological examination of the samples taken from the studied museum artifacts.

The locations of the swabs on the archaeological artifacts				D	
D	**C**	**B**	**A**		
				**The locations of the swabs for studying the growth of fungi and bacteria**	
-	-	Bacteria Penicillium Sp.	-	Type	**(SDA) Sabouraud Dextrose Agar** **A special nutrient agar for fungal growth**
-	-	13 1	-	No.	
-	-	 	-	The morphology of the colony	
Bacteria Ubocaldiumbotryis	Bacteria	Bacteria	Bacteria	Type	**(NA) Nutrient Agar** **A special nutrient agar for bacterial growth**
4 1	2	1	2	No.	
 	 		 	The morphology of the colony	

Based on the previous results, the museum collections at the Central Library Museum of Alexandria University and the Alexandria Library Museum were found to be affected by the following types and quantities of bacteria and fungi, as shown in Fig. No. (9).

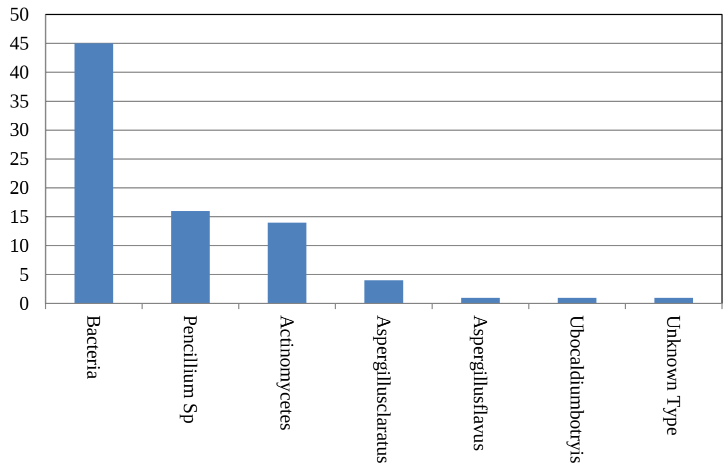


Fig. No. (9) Illustrates the types and quantities of bacteria and fungi that have affected the studied museum collections (by the researcher).

Monitoring changes in relative humidity and temperature:

Changes in temperature and relative humidity were monitored in the storage locations of the museum collections under study over six consecutive months. Months from both summer and winter seasons in Alexandria city were selected to determine the nature of the storage environment for the photographic collections and the variations in temperature and relative humidity during that period. Tables (7, 8, 9, 10, 11, 12) illustrate the monitoring of temperature and relative humidity in the storage locations of the studied collections, while Figs (10, 11, 12, 13, 14, 15) show the monitoring of temperature and relative humidity in those storage locations. Fig. No. (16) demonstrates the average temperature and relative humidity in the storage locations of the studied collections.

- ***Central Library (C.L.) Period from 14/7/2021 to 30/7/2021:***

Table No. (7) Shows the monitoring of temperature and relative humidity in the Central Library during July 2021 (by the researcher).

	Mean value	Maximum	Minimum
Relative Humidity [RH %]	65.542	73	54.6
Temperature [°C]	28.476	29.6	28

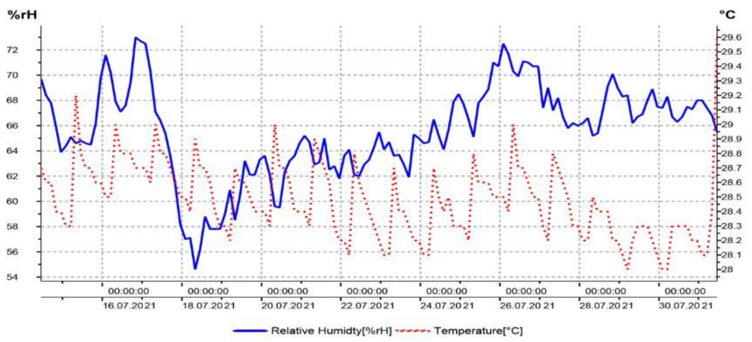


Fig. No. (10) Illustrates the monitoring of temperature and relative humidity at the Central Library during July 2021 (by the researcher).

- ***Bibliotheca Alexandrina (B.A.) Period from 1/8/2021 to 23/8/2021:***

Table No. (8) Illustrates the monitoring of temperature and relative humidity at the Bibliotheca Alexandrina during August 2021(by the researcher).

	Mean value	Maximum	Minimum
Relative Humidity [RH %]	75.336	81.3	69.4
Temperature [°C]	22.383	23.1	21.9

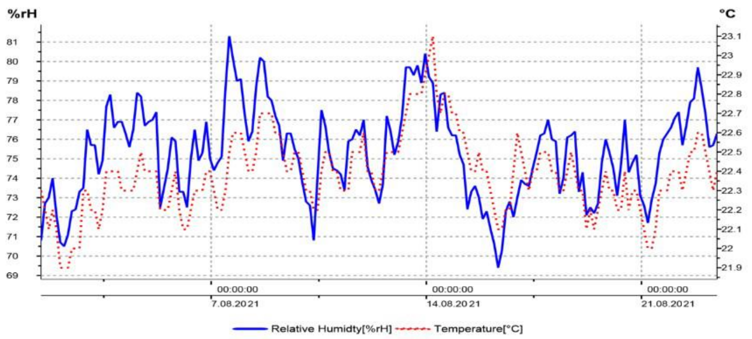


Fig. No. (11) Shows the monitoring of temperature and relative humidity at the Bibliotheca Alexandrina during August 2021 (by the researcher).

- ***Manuscripts Reading Hall (M.R.H.) Period from 24/8/2021 to 7/9/2021:***

Table No. (9) Shows the monitoring of temperature and relative humidity in the Manuscripts Reading Hall during the months of August and September 2021 (by the researcher).

	Mean value	Maximum	Minimum
Relative Humidity [RH %]	71.914	82.20	56.80
Temperature [°C]	20.658	23.50	18.80

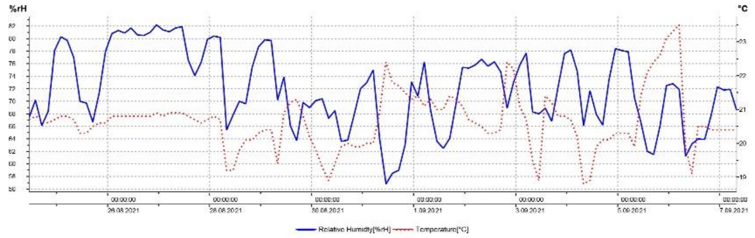


Fig. No. (12) Illustrates the monitoring of temperature and relative humidity in the Manuscripts Reading Hall during the months of August and September 2021 (by the researcher).

- ***Central Library (C.L.) Period from 12/12/2021 to 1/1/2022:***

Table No. (10) Shows the monitoring of temperature and relative humidity in the Central Library during the month of December 2021 (by the researcher).

	Mean value	Maximum	Minimum
Relative Humidity [RH %]	57.837	66.3	46.4
Temperature [°C]	16.4	21.5	14.4

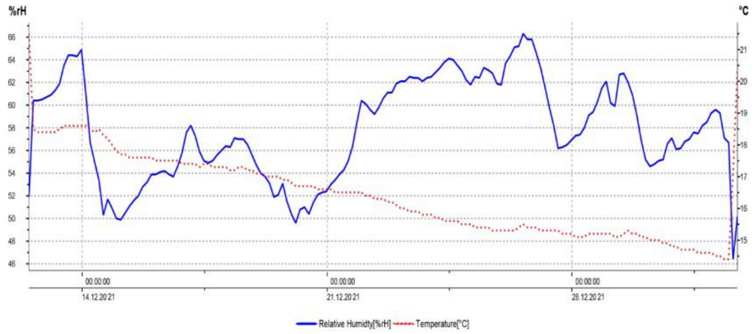


Fig. No. (13) Illustrates the monitoring of temperature and relative humidity in the Central Library during the month of December 2021 (by the researcher).

- ***Bibliotheca Alexandrina (B.A.) Period from 3/1/2022 to 31/1/2022:***

Table No. (11) Shows the monitoring of temperature and relative humidity in the Bibliotheca Alexandrina during the month of January 2022 (by the researcher).

	Mean value	Maximum	Minimum
Relative Humidity [RH %]	43.558	53.9	28.9
Temperature [°C]	20.915	21.4	20.5

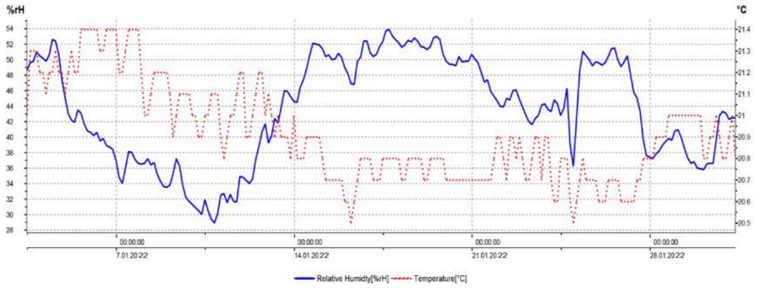


Fig. No. (14) Illustrates the monitoring of temperature and relative humidity in the Bibliotheca Alexandrina during the month of January 2022 (by the researcher).

- ***Manuscripts Reading Hall (M.R.H.) Period from 1/3/2022 to 21/3/2022:***

Table No. (12) Shows the monitoring of temperature and relative humidity in the Manuscripts Reading Hall during the month of March 2022 (by the researcher).

	Mean value	Maximum	Minimum
Relative Humidity [RH %]	48.997	59.5	37.8
Temperature [°C]	19.988	23.9	17.1

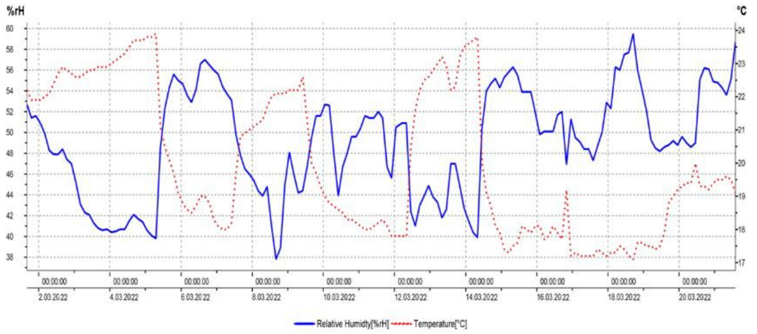


Fig. No. (15) Illustrates the monitoring of temperature and relative humidity in the Manuscripts Reading Hall during the month of March 2022 (by the researcher).

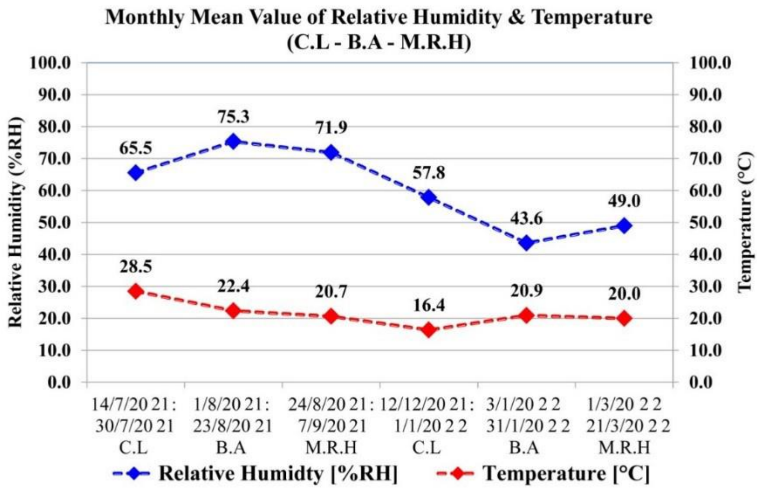


Fig. No. (16) Illustrates the average temperature and relative humidity in the storage locations of the studied artifacts (by the researcher).

Air Pollution Measurement:

The results of the measurements show the type and percentage of air pollutants in the storage areas of the studied artifacts. This is illustrated in Fig. No (17).

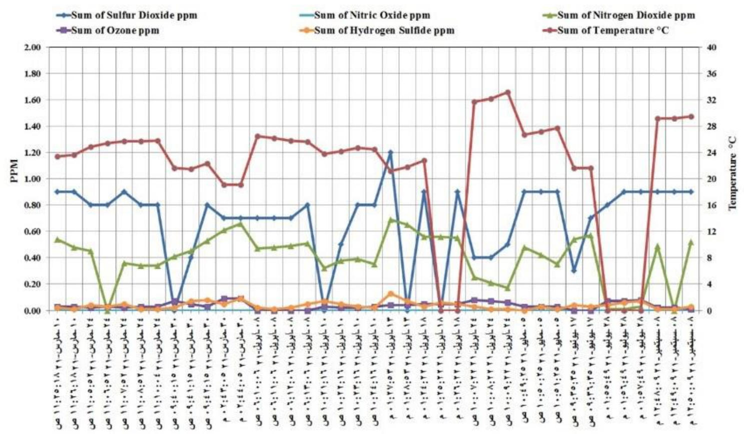


Fig. No. (17) Illustrates the percentage of air pollutants in the storage locations of the studied artifacts (by the researcher).

Conclusion:

In conclusion, this research on the impact of environmental control on preserving museum artifacts reveals that mold growth depends on various species and strains, alongside diverse environmental factors. However, the primary critical factor in the growth of these microorganisms appears to be relative humidity, as metabolism is activated when it rises above 65%. In this context, preventive conservation is deemed necessary to minimize rapid deterioration, and images should be stored in a controlled and consistently regulated environment. It is noted that images stored in unsuitable conditions lead to their deterioration and the growth of fungi and bacteria, especially in the presence of high temperatures, relative humidity, dust, and air pollutants. Therefore, it is recommended to provide a suitable storage environment and precise environmental control, along with regular monitoring of the condition of photographic images. Ultimately, this research underscores the importance of taking effective measures to preserve museum collections, focusing on improving storage and preservation environments.

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