



School of Applied Arts and Sustainable Design

MSc Protection of Cultural Heritage and Monuments of
Nature from the Effects of Climate Change

Postgraduate Dissertation

“Sustainable Management of Museum Collections in the
Mediterranean and in Western Greece in cities under 200,000
inhabitants: Guidelines for Internal Environmental Conditions in
the Context of Climate Change”

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Patras, Greece, June 2026

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Abstract

Museums play a vital role in the preservation and transmission of cultural heritage, preserving objects of historical, artistic and scientific importance for present and future generations. However, the long-term conservation of museum collections is increasingly challenged by environmental factors exacerbated by climate change. Rising temperatures, more frequent extreme weather events and fluctuations in relative humidity pose significant risks to museum collections, especially in Mediterranean regions where climatic conditions are already demanding.

Preventive conservation has become a fundamental approach to the care of museum collections, focusing on the management of environmental conditions to minimize degradation. Temperature, relative humidity, light exposure and air quality are among the most important factors affecting the physical and chemical stability of museum objects. Although international organizations such as ICOM, ICCROM, ASHRAE and the European Standardization Bodies (EN) provide widely accepted recommendations for the environmental control of museums, their implementation is often difficult in small museums operating under Mediterranean climatic conditions. High summer temperatures, seasonal humidity fluctuations, strong solar radiation and limited financial and technical resources make sustainable environmental management particularly difficult.

This thesis focuses on the sustainable management of indoor environmental conditions in small museums located in Western Greece, using the wider Mediterranean region as a comparative framework. The research aims to examine how these museums manage their indoor environmental conditions, identify the main risks affecting their collections, evaluate current practices in relation to international recommendations and propose practical, sustainable and cost-effective strategies suitable for institutions with limited resources.

The specific objectives of the study are to examine the principles of preventive maintenance and their application in museums, to investigate the effects of temperature, relative humidity, light and air quality on different categories of museum collections, to evaluate the application of international environmental standards under Mediterranean conditions, to identify the challenges faced by small museums in Western Greece, to analyze existing environmental management practices through selected case studies and to propose realistic proposals for improving indoor environmental management.

The research adopts a qualitative methodology based on a comprehensive literature review and comparative analysis of case studies. The literature review examines scientific publications, technical reports and international guidelines related to preventive conservation, museum environmental management, sustainability and adaptation to climate change. The practical part of the research includes four museums in Western Greece representing both archaeological and folklore collections. These case studies were selected according to criteria such as the size of the institution, the diversity of the collections, the available resources and the representativeness of Mediterranean conditions. The museums include a wide range of organic materials, such as wood, paper and textiles, inorganic materials such as stone, ceramics and metals, as well as complex objects with different environmental sensitivities. This diversity allowed the study to examine environmental management practices under different collection requirements and museum conditions. Data were collected primarily from institutional documentation, environmental monitoring records, published reports and available technical information. Additional information was obtained through contact with museum professionals, including brief interviews and structured questionnaires, where available. The information collected was analyzed using a comparative and thematic approach to identify common environmental challenges, current management practices and practical solutions. The findings were then compared with international standards and professional recommendations on preventive maintenance to assess their applicability to the selected museums.

Keywords

Preventive Conservation, Museum Environmental Management, Climate Change, Small Museums, Mediterranean Climate, Western Greece

«Βιώσιμη Διαχείριση Μουσειακών Συλλογών στη Μεσόγειο και στη Δυτική Ελλάδα: Κατευθυντήριες Οδηγίες για τη Διαχείριση των Εσωτερικών Περιβαλλοντικών Συνθηκών σε Μικρά Μουσεία στο Πλαίσιο της Κλιματικής Αλλαγής»

Όλγα Κατσαρού

Περίληψη

Η παρούσα διπλωματική εργασία εξετάζει τη βιώσιμη διαχείριση των εσωτερικών περιβαλλοντικών συνθηκών σε μικρά μουσεία της Δυτικής Ελλάδας, στο ευρύτερο πλαίσιο των προκλήσεων που θέτει η κλιματική αλλαγή για τη διατήρηση της πολιτιστικής κληρονομιάς. Η αύξηση της θερμοκρασίας, οι μεταβολές της σχετικής υγρασίας και η συχνότερη εμφάνιση ακραίων καιρικών φαινομένων επηρεάζουν σημαντικά τη μακροπρόθεσμη διατήρηση των μουσειακών συλλογών, ιδίως στις μεσογειακές περιοχές.

Η εργασία βασίζεται στις αρχές της προληπτικής συντήρησης, δίνοντας έμφαση στον έλεγχο της θερμοκρασίας, της σχετικής υγρασίας, του φωτισμού και της ποιότητας του αέρα ως βασικές παραμέτρους για την προστασία των συλλογών. Παράλληλα, εξετάζεται η εφαρμογή διεθνών προτύπων και κατευθυντήριων γραμμών σε συνθήκες που χαρακτηρίζονται από περιορισμένους οικονομικούς και τεχνικούς πόρους, όπως συμβαίνει σε πολλά μικρά μουσεία της Δυτικής Ελλάδας.

Η έρευνα ακολουθεί ποιοτική μεθοδολογία και συνδυάζει την ανασκόπηση της βιβλιογραφίας με τη συγκριτική ανάλυση τεσσάρων μελετών περίπτωσης μουσείων στη Δυτική Ελλάδα, οι οποίες περιλαμβάνουν αρχαιολογικές και λαογραφικές συλλογές. Η συλλογή δεδομένων βασίστηκε σε διαθέσιμη τεκμηρίωση, περιβαλλοντικά αρχεία, δημοσιευμένες πηγές και επικοινωνία με επαγγελματίες των μουσείων. Τα ευρήματα αναλύθηκαν συγκριτικά και αξιολογήθηκαν σε σχέση με τις διεθνείς συστάσεις για προληπτική συντήρηση.

Η εργασία καταλήγει σε πρακτικές, βιώσιμες και οικονομικά εφικτές προτάσεις για τη βελτίωση της διαχείρισης των εσωτερικών περιβαλλοντικών συνθηκών σε μικρά μουσεία. Με αυτόν τον τρόπο, συμβάλλει στην προσαρμογή των μουσείων στις επιπτώσεις της κλιματικής αλλαγής, ενισχύοντας τη μακροπρόθεσμη προστασία των συλλογών και προωθώντας πιο ανθεκτικές και περιβαλλοντικά υπεύθυνες πρακτικές διαχείρισης της πολιτιστικής κληρονομιάς.

Λέξεις – Κλειδιά

Προληπτική Συντήρηση, Περιβαλλοντική Διαχείριση Μουσείων, Κλιματική Αλλαγή, Μικρά Μουσεία, Μεσογειακό Κλίμα, Δυτική Ελλάδα

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List of Abbreviations & Acronyms

Abbreviation	Meaning
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CEN	European Committee for Standardization
EN	European Standard
HVAC	Heating, Ventilation, and Air Conditioning
ICCROM	International Centre for the Study of the Preservation and Restoration of Cultural Property
ICOM	International Council of Museums
RH	Relative Humidity
UV	Ultraviolet
VOC(s)	Volatile Organic Compound(s)

1. Preventive Conservation and Environmental Management of Museums

1.1 Principles of Preventive Conservation

Preventive conservation is a fundamental approach to the conservation of cultural heritage, focusing on minimizing the processes of degradation through the control of environmental and external risk factors. In contrast to interventional conservation, which involves the immediate treatment of objects, preventive conservation aims to create stable conditions that reduce the likelihood of damage over time, ensuring the long-term preservation and prolonged lifespan of cultural heritage collections. This approach is particularly important in small and low-budget museums, where extensive conservation interventions are often not feasible due to financial and technical constraints (International Council of Museums Committee for Conservation [ICOM-CC], 2008; ICCROM, n.d.; Staniforth, 2013).

Degradation processes are usually the result of the combined and cumulative effects of multiple environmental factors, such as temperature, relative humidity, light exposure, pollutants, and biological agents. These factors interact in complex ways and can lead to chemical, physical, and biological degradation. In many cases, damage occurs gradually and is not immediately visible, making preventive strategies essential for long-term conservation (Canadian Conservation Institute, 2020; Michalski, 2004).

Modern conservation practice increasingly adopts a risk-based approach, as promoted by organizations such as ICOM and ICCROM. Rather than aiming to achieve ideal environmental conditions, this approach focuses on identifying and reducing the most significant risks affecting collections. This is particularly important in small museums in regions such as Western Greece, where limited resources require prioritization and adaptive decision-making (Ashley-Smith, 1999; ICCROM, n.d.).

A significant shift in preventive conservation is the move from strict environmental objectives to an emphasis on the stability of conditions. Research has shown that rapid or frequent fluctuations in environmental parameters - particularly relative humidity - can be more damaging than stable conditions that deviate slightly from recommended values. This is particularly evident in Mediterranean climates, where seasonal variability can lead to repeated cycles of expansion and contraction in hygroscopic materials (Camuffo, 2014; European Committee for Standardization, 2010).

In addition, preventive conservation requires a materials-based approach, recognizing that different materials react differently to environmental changes. For example, wood and textiles are particularly sensitive to humidity fluctuations, while composite objects may experience internal stress due to differential responses of their components. This complexity is often seen in small museums, where mixed collections are displayed under uniform conditions that may not be appropriate for all materials. Overall, this section highlights the importance of adopting a risk-based and material-sensitive approach to preventive conservation, especially in small museums operating under resource constraints (Michalski, 2004; Thomson, 1986).

In particular, materials such as wood, textiles, wax and paper are particularly sensitive to fluctuations in relative humidity and temperature, while metals are vulnerable to corrosion under high humidity conditions (Michalski, 2004; Thomson, 1986).

1.2 Indoor Environmental Conditions in Museums

The internal environment of a museum plays a critical role in determining the rate and extent of deterioration of materials. Environmental parameters such as temperature, relative humidity, light, and air quality directly affect the physical and chemical stability of collections. These factors do not act independently. Instead, their combined effects often intensify deterioration processes (Camuffo, 2014; Thomson, 1986).

Temperature affects the rate of chemical reactions, including oxidation and hydrolysis, as well as biological activity. Elevated temperatures accelerate degradation processes, particularly in organic materials such as paper, textiles, and adhesives. In Mediterranean environments, high summer temperatures can significantly increase these risks, especially in buildings without adequate insulation or cooling systems (Camuffo, 2014; Thomson, 1986).

Relative humidity is widely considered one of the most critical environmental parameters in museum environments. Hygroscopic materials absorb and release moisture in response to changes in relative humidity, resulting in dimensional changes that can cause cracking, warping or delamination. High humidity levels can also promote mold growth and biological contamination, while low humidity can lead to drying and brittleness. In areas such as Western Greece, where humidity levels vary significantly between seasons, maintaining stable relative humidity conditions is particularly difficult (Camuffo, 2014; Postgraduate Dissertation

Exposure to light represents a cumulative and irreversible form of damage. Ultraviolet and visible radiation can cause photochemical reactions, leading to fading, discoloration, and loss of structural integrity. This issue is particularly important in small museums that rely on natural lighting, where inadequate control measures can lead to prolonged exposure to sensitive materials (Michalski, 2004; Thomson, 1986).

Air quality is another important factor, as pollutants such as sulfur dioxide, nitrogen oxides, ozone, and particulate matter can contribute to chemical degradation. In smaller institutions, where advanced filtration systems are often not available, indoor air quality is strongly influenced by outdoor conditions and building characteristics (Brimblecombe, 2013; Tétreault, 2003).

These environmental challenges are particularly significant in small museums, where limited infrastructure and financial constraints limit the ability to maintain stable and controlled internal environments.

These observations demonstrate that indoor environmental conditions must be managed in a comprehensive manner, especially in small museums where environmental control is limited.

1.2.1 Temperature and relative humidity requirements

Temperature and relative humidity are central to environmental management in museums because of their direct impact on both chemical and mechanical deterioration processes. Traditional conservation guidelines recommend maintaining relatively narrow ranges of temperature (approximately 18–22°C) and relative humidity (45–55%). However, these values are increasingly understood as ideal targets rather than universally achievable conditions (ASHRAE, 2023; Thomson, 1986).

Recent approaches emphasize the importance of acceptable ranges and gradual change, rather than strict adherence to fixed values. Fluctuations in relative humidity (RH), particularly when frequent or abrupt, can lead to mechanical stress in hygroscopic materials, resulting in long-term structural damage. This issue is particularly important in Mediterranean climates, where seasonal variations can cause significant changes in environmental conditions (Camuffo, 2014; European Committee for Standardization, 2010).

The European standard EN 15757 proposes a more flexible approach, indicating that acceptable humidity ranges should be based on the historical climatic conditions to which

the objects have already adapted. This method allows for environmentally sensitive environmental management and is particularly suitable for historic buildings and small museums where strict environmental control is not feasible (European Committee for Standardization, 2010).

In practice, maintaining stable environmental conditions is often more important than achieving precise target values. In small museums, where HVAC systems may be absent or used intermittently, priority should be given to minimizing fluctuations and avoiding extreme conditions. This approach reflects a shift towards realistic and sustainable preventive conservation strategies (ASHRAE, 2023; European Committee for Standardization, 2010).

This confirms that achieving stability, rather than strict fixed values, is a more realistic and effective strategy for environmental management in Mediterranean museum environments.

1.2.2 Light, Air Quality, and Pollution Risks

Exposure to light and air quality are critical factors in the conservation of museum collections, particularly due to the irreversible nature of their effects. Damage caused by light occurs through photochemical reactions that alter the structure of materials. This damage is cumulative and depends on both the intensity and duration of exposure (Thomson, 1986).

In many small museums, natural lighting is used to enhance the visitor experience, but without adequate control measures, such as UV filters or shading systems, it can lead to long-term deterioration of sensitive materials. The concept of cumulative light exposure is therefore essential, highlighting the need to manage both light intensity and exposure duration (Heritage Collections Council, 1998; Thomson, 1986).

Air quality is closely linked to the presence of gaseous pollutants and particulates. Pollutants such as ozone, nitrogen oxides, sulphur compounds, and carbon-based pollutants can react with sensitive materials, accelerating processes of corrosion, discoloration, and surface deterioration. In coastal environments, salts and chlorine compounds are also significant factors, particularly for stone collections close to the sea, as salt crystallization processes may lead to cracking, flaking, and gradual deterioration of porous stone materials. In small

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museums, where advanced filtration systems are often not available, air quality management relies on basic ventilation practices and the reduction of indoor sources of pollutants (Brimblecombe, 2013; Tétreault, 2003).

These risks are particularly significant in Mediterranean environments, where high levels of solar radiation and airborne particles can further intensify deterioration processes.

Therefore, light and air quality management should be considered an essential element of preventive maintenance, especially in museums with limited control systems.

Air pollutants, including gaseous compounds such as sulfur dioxide and nitrogen oxides, as well as particulate matter such as dust, contribute significantly to the degradation of museum collections. These pollutants can originate from both external sources and materials within the museum environment, leading to chemical and physical damage such as corrosion, fading, and weakening of organic materials (Brimblecombe, 2013; Tétreault, 2003).

1.3 International Standards and Guidelines

Environmental management in museums is guided by international standards developed by organizations such as ICOM, ICCROM, ASHRAE and the European Committee for Standardization (CEN). These frameworks provide essential guidance for creating appropriate environmental conditions and implementing proactive conservation strategies (ASHRAE, 2023; European Committee for Standardization, 2010; ICCROM, n.d.).

ASHRAE guidelines define different categories of environmental control, allowing institutions to choose appropriate levels of precision based on risk and resource availability. Similarly, ICOM and ICCROM promote flexible risk-based approaches that emphasize sustainability and practical application (ASHRAE, 2023; ICCROM, n.d.).

European standards, including EN 15757, introduce adaptive methodologies based on acceptable variations rather than fixed environmental targets. This reflects a broader shift in conservation practice towards environmentally sensitive and realistic approaches (European Committee for Standardization, 2010).

However, these standards are often developed on the basis of assumptions that do not fully reflect the conditions prevailing in small museums, especially in Mediterranean regions. As a result, their direct application may be difficult or impractical.

While international standards provide valuable guidance, their application must be adapted

to the specific circumstances of each museum.

1.3.1 Limitations of Existing Standards in Mediterranean Contexts

The application of international environmental standards in Mediterranean environments presents significant challenges. The Mediterranean climate is characterized by high temperatures, strong solar radiation and seasonal humidity fluctuations, which complicate the maintenance of stable indoor conditions (Lionello, 2012).

Furthermore, many museums in Western Greece are housed in historic or adapted buildings that lack insulation, climate control systems and airtight construction. These factors increase the impact of external climatic conditions on the indoor environment (ASHRAE, 2023; Camuffo, 2014).

Financial constraints further limit the ability of small museums to implement advanced technological solutions. Continuous operation of HVAC systems may not be economically viable, leading to intermittent use and increased environmental variability (ASHRAE, 2023; International Energy Agency, 2020).

These constraints highlight the need for adaptive and environmentally sensitive approaches that prioritize stability, risk reduction and sustainability. Such approaches are particularly important for small museums, where environmental management must be effective and feasible (Council of Europe, 2017; ICCROM, n.d.).

This highlights the need for flexible and context-sensitive approaches to environmental management in Mediterranean museums.

2. Mediterranean Climate and Challenges for Small Museums

2.1 Characteristics of the Mediterranean Climate

The Mediterranean climate is characterized by distinct seasonal patterns, such as hot, dry summers and mild to wet winters. These conditions are influenced by geographical factors such as proximity to the sea, regional topography and local microclimates, resulting in variability between different regions of the Mediterranean (Lionello, 2012).

In Western Greece, climatic conditions often include high summer temperatures exceeding 30°C, combined with increased solar radiation and dry atmospheric conditions. During winter, relative humidity levels often increase above 70-80%, accompanied by lower

temperatures and increased rainfall. This seasonal contrast creates significant environmental variability, which directly affects the indoor conditions in museum environments (Lionello, 2012).

A key feature of the Mediterranean climate is the intensity of solar radiation, especially during the summer months. This contributes to increased indoor temperatures, especially in buildings with limited insulation or shading systems. In many small museums, where building envelopes are not optimized for environmental control, solar gain becomes a significant factor affecting indoor microclimates (Lionello, 2012).

Furthermore, seasonal transitions often involve relatively rapid changes in temperature and humidity. These fluctuations are particularly problematic for hygroscopic materials, as they can lead to repeated cycles of expansion and contraction. Such conditions are commonly observed in small museums in Western Greece, where internal environments are strongly influenced by external climatic fluctuations (Camuffo, 2014; Lionello, 2012).

These climatic characteristics create complex environmental conditions that directly affect the internal environments of museums in the Mediterranean regions.

2.1.1 Climate-Related Risks to Museum Collections

The environmental characteristics of the Mediterranean climate pose certain risks to museum collections, especially when combined with limited environmental control. These risks vary depending on the type of material, the duration of exposure, and the degree of environmental fluctuations (Camuffo, 2014; Michalski, 2004).

High temperatures, especially during summer periods, accelerate chemical degradation processes such as oxidation and hydrolysis. Organic materials, including paper, textiles, and adhesives, are particularly vulnerable. In cases where internal temperatures are not controlled, these processes can lead to irreversible deterioration (Camuffo, 2014; Thomson, 1986).

Variability in relative humidity is one of the most critical risk factors. In Mediterranean environments, the transition between wet winters and dry summers creates conditions of repeated moisture exchange in hygroscopic materials. This results in dimensional instability, which leads to cracking, warping or delamination. In poorly ventilated areas, high humidity levels can also promote mold growth and biological activity (Camuffo, 2014; European Committee for Standardization, 2010).

Exposure to light, exacerbated by strong sunlight, contributes to cumulative photochemical damage. This is particularly important in small museums that rely on natural light, where inadequate control measures can lead to prolonged exposure to sensitive materials such as fabrics and pigments (Heritage Collections Council, 1998; Thomson, 1986).

Airborne pollutants and dust further contribute to the degradation of materials. In semi-urban or coastal areas, pollutants can enter museum spaces through natural ventilation, while internal sources may include building materials, display equipment, and the collection objects themselves, particularly organic materials that emit volatile organic compounds (VOCs) (Brimblecombe, 2013; Tétreault, 2003).

These risks are often interrelated. For example, high temperature combined with high humidity increases the likelihood of biological growth, while exposure to light can exacerbate the degradation of already weakened materials. This highlights the importance of integrated environmental management (Canadian Conservation Institute, 2020; Michalski, 2004).

This demonstrates that environmental risks in Mediterranean museums are interrelated and require integrated management strategies.

2.2 Museum Buildings in Mediterranean Regions

In addition to external environmental factors, building construction materials themselves may act as sources of dangerous airborne pollutants. Certain materials, paints, adhesives, coatings, and insulation products can release harmful compounds and volatile organic compounds (VOCs), negatively affect indoor air quality, and potentially accelerate the deterioration of museum collections (Tétreault, 2003, 2021).

The characteristics of museum buildings in Mediterranean regions play a crucial role in shaping indoor environmental conditions. Many museums, particularly in Western Greece, are housed in historic or adapted buildings that were not originally designed to meet modern conservation standards (ASHRAE, 2023; Camuffo, 2014).

Traditional building materials, such as stone and masonry, provide thermal mass, which can help mitigate temperature fluctuations. However, these materials are often combined with poor insulation and inadequate sealing, allowing significant heat gain during the summer and heat loss during the winter (ASHRAE, 2023; Camuffo, 2014).

Large openings, including windows and entrances, increase exposure to solar radiation and external environmental conditions. In small museums, where architectural modifications may be limited and buildings are frequently reused or adapted from their original function, many architectural characteristics may not fully support modern conservation requirements. As a result, these features contribute to uneven temperature distribution and local environmental fluctuations within exhibition spaces (ASHRAE, 2023).

Ventilation is another critical factor. In the absence of controlled ventilation systems, many museums rely on natural ventilation, which introduces outside air directly into indoor environments. While this can improve air circulation, it also leads to fluctuations in temperature, humidity, and pollutant levels (ASHRAE, 2023; Tétreault, 2003).

These building-related factors are particularly important in small museums, where limited resources limit the implementation of structural improvements or advanced climate control systems.

Building characteristics therefore play a crucial role in shaping indoor environmental conditions and conservation outcomes.

2.2.1 Small and Low-Budget Museums: Constraints and Realities

Small and low-budget museums represent a significant portion of cultural institutions in Western Greece and the wider Mediterranean region. These institutions often operate under constraints that directly affect their ability to effectively manage environmental conditions (Council of Europe, 2017; Michalski, 2004).

One of the main constraints is the absence or limited use of HVAC systems. Even when such systems are available, their continuous operation may not be economically viable due

to high energy costs. As a result, environmental control is often intermittent, leading to fluctuations rather than steady-state conditions (ASHRAE, 2023; International Energy Agency, 2020).

Limited staffing further limits the ability to systematically monitor and manage environmental conditions. Regular data collection, analysis, and response require time and expertise that may not be available. Consequently, environmental decisions are often based on observation and experience rather than continuous data analysis (Heritage Collections Council, 1998; Michalski, 2004).

Budgetary constraints also affect the availability of conservation-quality materials, storage systems, and monitoring equipment. This can result in collections being exposed to suboptimal conditions for extended periods of time.

Despite these challenges, small museums often develop adaptive strategies based on practical knowledge and local conditions. These strategies, while not always aligned with international standards, can provide effective solutions within existing constraints (Council of Europe, 2017; ICCROM, n.d.).

These constraints highlight the need for realistic and adaptable environmental management strategies in small museums.

2.2.2 Climate Change and Cultural Heritage in the Mediterranean

Climate change is expected to intensify existing environmental challenges in the Mediterranean region, increasing both the frequency and severity of extreme weather events. Rising temperatures, prolonged heat waves and changing humidity patterns will further complicate the management of indoor environments in museums (Lionello, 2012; UNESCO World Heritage Centre, 2007).

For small museums, these changes pose a significant challenge, as existing infrastructures are often not designed to cope with such variability. Increased thermal stress on buildings, combined with higher energy demands for cooling, puts additional pressure on already limited resources (ASHRAE, 2023; UNESCO World Heritage Centre, 2007).

At the same time, the need to reduce energy consumption and carbon emissions is becoming increasingly important. This creates a tension between maintaining optimal conservation conditions and achieving sustainability goals (International Council of Museums, 2019; International Energy Agency, 2020).

In this context, the concept of sustainable preventive conservation gains particular importance. This approach emphasizes the use of passive environmental control strategies, energy-efficient systems and adaptive management practices that respond to local climatic conditions (ASHRAE, 2023; International Council of Museums, 2019).

Small museums in Western Greece may address these challenges through a combination of passive environmental control methods, adaptive management practices, and selective use of energy-efficient systems. Depending on the characteristics, resources, and environmental

conditions of each institution, potential strategies may include:

- seasonal adaptation of environmental conditions
- improved use of building features (e.g. thermal mass)
- low-cost monitoring solutions
- flexible environmental targets that prioritize stability

These strategies aim to balance conservation needs with environmental and economic sustainability, reflecting a more realistic and environmentally sensitive approach to conservation (ASHRAE, 2023; Council of Europe, 2017).

This reinforces the importance of developing sustainable and climate-adaptive approaches to preventive conservation.

3. Methodology and Case Study Design

3.1 Research Design and Approach

This thesis adopts a qualitative research design, as it aims to investigate and understand the management of internal environmental conditions in small museums rather than to produce statistically generalizable results. The complexity of environmental factors, combined with institutional and financial constraints, requires an interpretive and context-based approach.

The qualitative approach is particularly well-suited to examining real-world practices in small and low-budget museums, where environmental management is often shaped by practical constraints rather than by strict adherence to standardized guidelines. This approach allows for the analysis of decision-making processes, adaptive strategies, and the interaction between environmental conditions and conservation practices.

The research follows a case study design, supported by an extensive literature review. This combination allows for the integration of theoretical knowledge with practical observations, providing a more comprehensive understanding of the subject.

The analysis is based on qualitative data derived from bibliographic sources, observational evaluation and previous academic work.

These case studies were selected as representative examples of small museums operating under Mediterranean climatic and institutional constraints

3.1.1 Research Objectives and Questions

The primary objective of this research is to investigate how to manage indoor environmental conditions in small museums located in Mediterranean regions, with an emphasis on Western Greece.

The study aims to:

- identify the main environmental factors that affect museum collections
- examine how to manage these factors in practice
- evaluate the effectiveness of existing environmental management strategies
- explore the constraints faced by small museums
- develop practical and sustainable guidelines for environmental management

Based on these objectives, the research is guided by the following questions:

- How do Mediterranean climatic conditions affect the indoor environments of museums?
- What are the main environmental risks for museum collections in small institutions?
- How do small museums manage environmental conditions in practice?
- What constraints affect environmental management strategies?
- What sustainable approaches can be implemented to improve preventive maintenance?

These questions structure both the data collection process and the analysis. These research questions provide a clear structure for both data collection and analysis

3.1.2 Case Study Selection Criteria

Case studies constituted a central element of the research, providing empirical insights into environmental management practices in small museums located in Western Greece. The selection of case studies was based on criteria intended to ensure relevance, feasibility, representativeness, and consistency with the research objectives.

The selected museums included:

Pavlos Vrellis Museum of Greek History (main case study)

Archaeological Museum of Nicopolis

Archaeological Museum of Arta

Folklore Museum of Preveza

The selection was based on the following criteria:

- Geographic relevance: all museums are located in Western Greece, ensuring relative consistency in climatic and environmental conditions.
- Institutional scale: focus on small and medium-sized museums operating under limited financial and technical resources.
- Building characteristics: inclusion of both traditional and modern museum structures, as well as buildings adapted for museum use.
- Collection diversity: representation of organic, inorganic, and composite materials with different conservation requirements, including archaeological, historical, and folklore collections.
- Information availability: accessibility of sufficient documentation and environmental data for analysis.

Particular importance was given to the inclusion of the Pavlos Vrellis Museum of Greek History, as its collections contain sensitive organic and mixed materials, including textiles, wood, paper-based elements, and wax components. These materials are especially vulnerable to fluctuations in temperature, relative humidity, pollutants, and volatile organic compounds (VOCs), providing a valuable case for examining preventive conservation challenges in Mediterranean museum environments.

The Archaeological Museum of Nicopolis and the Archaeological Museum of Arta were selected in order to represent archaeological collections primarily composed of inorganic materials, including stone, ceramics, mosaics, and metals. Their inclusion allowed the study to examine environmental management challenges associated with archaeological collections, such as corrosion, salt crystallization, moisture-related deterioration, and the influence of Mediterranean climatic conditions.

The Folklore Museum of Preveza was included in order to represent traditional folklore collections containing organic and composite materials, such as textiles, costumes, wood, paper, leather, and household objects. The museum provided an additional perspective on the environmental risks affecting hygroscopic and light-sensitive materials commonly encountered in regional museums.

The inclusion of a main case study supported a more in-depth analysis, while the

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comparative case studies facilitated the evaluation of similarities and differences in environmental management practices under varying institutional, environmental, and collection conditions.

The selected case studies, therefore ensured a balanced and context-based analysis of preventive conservation and environmental management practices in regional museums.

3.2 Data Collection Methods

The data collection process is based on multiple qualitative sources, selected in accordance with the scope and feasibility of the research.

3.2.1 Literature Review

The literature review forms the theoretical basis of the study and includes academic articles, books and institutional reports on:

- preventive maintenance
- indoor environmental conditions
- museum climate control
- sustainability and adaptation to climate change

This provides the conceptual framework necessary for the analysis of environmental management practices. This combination of data sources enhances the credibility and depth of the research

3.2.2 Case Study Data

Data for the case studies are collected through:

- existing documentation and reports
- observational analysis of building characteristics and environmental conditions
- previously conducted academic work (in the case of the primary case study)

In the case of the Museum of Pavlos Vrellis, data from prior academic work are incorporated, including observations related to environmental conditions, material sensitivity, and management practices.

3.2.3 Interviews and Questionnaires

Where possible, additional data can be collected through short interviews or questionnaires

addressed to museum professionals. These aim to provide information on:

- everyday environmental management practices
- perceived challenges
- decision-making processes

However, this element is considered complementary. The research does not depend on primary data collection, ensuring methodological flexibility in case of limited access.

This approach allows for a comprehensive understanding of environmental management practices in real institutional contexts.

Additional data summaries and supporting material on the case studies are presented in the Appendices.

A structured questionnaire (see Appendix B) was developed to support possible data collection from museum professionals. Due to time and access constraints, the questionnaire was not distributed, but it is included as a suggested tool for future research.

3.2.4 Data Analysis Methods

The analysis follows a qualitative and comparative approach, combining thematic and interpretive methods.

First, the data collected are organized into key thematic categories:

- building and climate context
- type of collections
- environmental challenges
- management practices
- constraints

This structured framework ensures consistency across case studies.

Second, a thematic analysis is conducted to identify recurring patterns and relationships between environmental factors and conservation practices. This allows for the identification of common challenges across different museums.

Third, a comparative analysis is applied to assess similarities and differences between the case studies. This comparison highlights how environmental management varies depending

on the scale of the institution, the characteristics of the building and the resources available.

Finally, the findings are interpreted in relation to the theoretical framework presented in Chapters 1 and 2, allowing for the development of practical and context-sensitive guidelines.

This analytical framework allows for a systematic comparison between theory and practice.

3.3 Ethical Considerations

The research is conducted in accordance with basic academic and ethical principles. Any information used from external sources is properly cited, and confidential or sensitive data is not included without permission.

In the case of observational data or institutional information, care is taken to present the findings in a general and analytical manner, avoiding misleading presentation

3.4 Methodological Limitations

This research is subject to several limitations, mainly related to the scope and availability of data.

One limitation is the small number of case studies, which limits the ability to generalize the findings to all museums. However, the aim of the study is analytical rather than statistical generalization.

Another limitation concerns the availability of detailed environmental data. In many small museums, systematic monitoring may be limited, requiring reliance on qualitative observations.

Access to museum professionals may also be limited, limiting the use of interviews and questionnaires. For this reason, these methods are considered optional.

Finally, time and resource constraints affect the depth of analysis. These limitations are addressed by maintaining a focused research scope and prioritizing realistic methodological choices.

The comparative analysis of the selected case studies was structured around common analytical categories in order to ensure consistency between the museums examined. The analysis focused on building and climate context, type of collections, environmental challenges, environmental management practices, and institutional limitations. Particular attention was given to environmental fluctuations, monitoring practices, technical infrastructure, resource limitations, and preventive conservation strategies under

Mediterranean climatic conditions.

A structured questionnaire (see Appendix B) was developed to support potential data collection from museum professionals.

4. Case Studies in Western Greece and the Mediterranean

4.1 Introduction to Case Studies

This chapter presents a structured and comparative analysis of selected museums in Western Greece, focusing on the management of internal environmental conditions under Mediterranean climatic constraints. While the previous chapters established the theoretical framework and environmental context, this chapter examines how these factors manifest themselves in actual museum settings.

The analysis is based on one primary case study and three comparative case studies selected to represent different museum types, collection categories, and environmental management challenges encountered in Western Greece:

- Pavlos Vrellis Museum of Greek History (primary case study)
- Archaeological Museum of Nicopolis
- Archaeological Museum of Arta
- Folklore Museum of Preveza

The use of a consistent analytical framework allows for the identification of common patterns, constraints, and adaptive strategies across different institutional contexts.

4.2 Primary Case Study: Museum of Greek History of Pavlos Vrellis



Figure 4.1. Exterior view of the Pavlos Vrellis Museum of Greek History.

The Pavlos Vrellis Museum presents particular preventive conservation challenges due to the presence of wax figures and mixed organic materials. Wax objects are especially sensitive to fluctuations in temperature and relative humidity, while excessive light exposure and airborne pollutants may accelerate discoloration, embrittlement, cracking, and surface deterioration. According to recommendations for the preservation of wax moulages, stable environmental conditions, controlled lighting levels, and careful monitoring of pollutants are considered essential for the long-term preservation of wax-based collections (Heritage Collections Council, 1998; Michalski, 2004; Thomson, 1986).

4.2.1 Building and Climate Context

The Pavlos Vrellis Museum of Greek History is located in a region characterized by a Mediterranean climate with continental influences. The area experiences high summer temperatures often exceeding 30°C, combined with dry conditions, and cold, humid winters with relative humidity frequently exceeding 70–80%. The museum is situated outside the urban center, in a predominantly rural and semi-natural environment with limited industrial activity and relatively low levels of atmospheric pollution. In addition, its inland location

and distance from the sea reduce the direct impact of marine salts and chlorine compounds,

which are commonly associated with coastal deterioration processes (Lionello, 2012).

The museum is housed in a traditional stone-built structure adapted for museum use and the exhibition of sensitive mixed-material collections, including wax figures, textiles, wood, and paper-based elements. The building provides a certain degree of thermal inertia; however, it lacks advanced insulation and airtight environmental control systems. As a result, indoor conditions are strongly influenced by external climatic variability, leading to seasonal fluctuations in both temperature and relative humidity. The display cases provide partial physical and environmental protection, although their sealing performance and long-term microclimatic stability remain limited (ASHRAE, 2023; Camuffo, 2014).



Figure 4.2. Exhibition space with wax figures and mixed-material displays at the Pavlos Vrellis Museum

This condition reflects a typical scenario described in Chapter 2, where building characteristics significantly determine indoor environmental performance. In this case, the absence of fully controlled systems contributes to the formation of a dynamic indoor

microclimate, requiring continuous monitoring and adaptive environmental management practices.

4.2.2 Type of Collections

The museum hosts a complex collection consisting of life-size wax figures combined with various materials, such as fabrics, wood, metals and painted surfaces. This composition creates an extremely sensitive and heterogeneous collection environment.

Wax is particularly vulnerable to high temperatures, as it can soften or deform, while organic materials such as fabrics and wood are particularly sensitive to fluctuations in relative humidity. Metal components are susceptible to corrosion under conditions of high humidity. The coexistence of these materials within complex objects introduces additional risks, as different responses to environmental changes can create internal stresses (Michalski, 2004; Thomson, 1986).

As discussed in Chapter 1, mixed-material collections require carefully balanced environmental conditions, which are often difficult to achieve in small museums operating under limited control systems.

4.2.3 Environmental Challenges

The environmental challenges observed in this case study include:

- significant seasonal and daily fluctuations in temperature and relative humidity
- high humidity levels during winter, increasing the risk of mold growth and metal corrosion
- elevated temperatures during summer, affecting the stability of wax materials
- cumulative light exposure contributing to pigment fading and material degradation
- dust accumulation and airborne pollutants
- microclimatic changes caused by visitors

Environmental conditions in the wider Ioannina region demonstrate considerable climatic variability throughout both the year and the day. Summer temperatures frequently exceed 30°C, while winter temperatures may fall below 10°C. Relative humidity levels commonly range between 40–60% during warmer periods and exceed 70–80% during colder and wetter months. Daily fluctuations in temperature and relative humidity are also significant, particularly in buildings lacking fully controlled environmental systems. These variations create unstable indoor conditions that may accelerate material deterioration (Camuffo, 2014; Lionello, 2012).

The table below presents indicative environmental conditions for the wider Ioannina region affecting the museum environment.

Table 4.1: Environmental conditions for the wider Ioannina region

Season	Average Temperature	Relative Humidity
Summer	28–35°C	40–60%
Winter	5–12°C	70–85%
Spring	15–22°C	55–70%
Autumn	12–20°C	60–80%

These factors interact to creating a complex degradation environment. High humidity combined with elevated temperatures increases the likelihood of biological activity, while repeated fluctuations in relative humidity contribute to mechanical stress on hygroscopic materials (Camuffo, 2014; Canadian Conservation Institute, 2020).

This observation confirms the importance of environmental stability, as discussed in Chapter 1. In this case, the lack of controlled conditions leads to a higher risk of long-term material degradation.

In addition to temperature and humidity fluctuations, atmospheric pollutants and dust accumulation contribute to material degradation, especially on sensitive surfaces such as wax and fabrics (Tétreault, 2003, 2021).

4.2.4 Environmental Management Practices

Environmental management at the museum relies primarily on adaptive and low-cost strategies, such as natural ventilation, the use of dehumidifiers, passive shading, and local microclimate solutions such as silica gel.

Rather than maintaining strict environmental standards, the museum adopts a flexible and seasonal approach, aiming to maintain environmental conditions within acceptable limits. This reflects a risk-based, preventive maintenance approach, prioritizing the reduction of extreme conditions and fluctuations (Ashley-Smith, 1999; European Committee for Standardization, 2010).

However, the effectiveness of these strategies is limited by the absence of continuous monitoring and automated control systems. Environmental management relies heavily on observation and practical experience rather than systematic data analysis

4.2.5 Limitations

The main constraints affecting environmental management include:

- lack of advanced HVAC systems
- strong dependence on external climatic conditions
- limited financial and technical resources
- constraints imposed by the building structure
- absence of systematic long-term monitoring

Despite these constraints, the museum demonstrates a pragmatic approach to environmental management. However, current strategies are not sufficient to ensure long-term environmental stability, which highlights the need for improved monitoring and more structured management practices.

This case clearly demonstrates the complexity of managing environmental conditions in small museums with sensitive and mixed collections

4.3 Comparative Case Study: Archaeological Museum of Nicopolis

4.3.1 Building and Climate Context

The Archaeological Museum of Nicopolis is located in a coastal Mediterranean environment, where high summer temperatures, strong solar radiation, and elevated humidity levels affect the internal conditions (Lionello, 2012).



Figure 4.3. Archaeological collections displayed at the Archaeological Museum of Nicopolis.

Although the building incorporates modern architectural elements, it is still influenced by

external climatic conditions, particularly through solar gain and air exchange. This results in seasonal variability in the parameters of the internal environment (ASHRAE, 2023; Camuffo, 2014).

4.3.2 Type of Collections

The museum houses mainly inorganic archaeological materials, such as stone, ceramics, mosaics and metals. While these materials are generally more stable than organic ones, metals and composite objects remain sensitive to humidity fluctuations and corrosion processes (Camuffo, 2014; Michalski, 2004).

Many of the objects are displayed within exhibition cases that provide partial environmental protection, although the degree of sealing may vary between cases. Larger objects and architectural elements may also be displayed openly within the exhibition spaces, increasing their exposure to fluctuations in temperature, relative humidity, dust accumulation and airborne pollutants (Tétreault, 2003; Thomson, 1986).

4.3.3 Environmental Challenges

The main environmental challenges include:

- seasonal temperature increases
- fluctuations in relative humidity
- influence of marine moisture and salt deposition

These factors contribute to gradual deterioration processes, particularly in porous archaeological materials. The presence of marine moisture and salts introduces additional risks related to salt crystallization, surface erosion, and corrosion processes, especially in stone, ceramics, and metallic objects (Brimblecombe, 2013; Camuffo, 2014).

Due to the predominantly inorganic nature of the collections, the impact of light exposure is considered relatively limited compared to collections containing highly sensitive organic materials and pigments (Heritage Collections Council, 1998; Thomson, 1986).

4.3.4 Environmental Management Practices

Environmental management combines mechanical systems and passive measures, including partial HVAC use, light regulation, and controlled display environments (ASHRAE, 2023; Heritage Collections Council, 1998).

However, these measures do not fully eliminate environmental variability. As a result, the

museum operates under semi-controlled conditions, where environmental stability is only partially achieved.

Environmental management relies partly on mechanical climate control systems and periodic environmental observations; however, continuous long-term monitoring and fully automated environmental regulation remain limited.

4.3.5 Limitations

Limitations identified in this case study include:

- incomplete environmental control
- dependence on mechanical climate control systems associated with increased energy consumption
- influence of external climatic conditions
- limited long-term environmental monitoring and data recording

This case highlights that even museums with comparatively improved infrastructure continue to face difficulties in maintaining stable environmental conditions under Mediterranean climatic conditions. Dependence on mechanical systems may increase energy demands, while the absence of continuous long-term monitoring limits the ability to evaluate environmental fluctuations and preventive conservation performance over extended periods (ASHRAE, 2023; International Energy Agency, 2020).

4.4 Comparative Case Study: Archaeological Museum of Arta

4.4.1 Building and Climate Context



Figure 4.4 The Archaeological Museum of Arta, Epirus, Greece, museum building

The Archaeological Museum of Arta operates under typical Mediterranean climatic conditions, characterized by high summer temperatures, seasonal humidity fluctuations, and considerable thermal variation throughout the year. The museum is located within an urban environment in the city of Arta, at a relatively low altitude and at a greater distance from the coastline compared to the Archaeological Museum of Nicopolis. Although the direct influence of marine salts and chlorine compounds is therefore less intense, the regional climate remains humid, particularly during the winter months, while atmospheric pollutants associated with urban activity and traffic may also affect the surrounding environment (Lionello, 2012).

The surrounding urban conditions influence the indoor museum environment through temperature fluctuations, air exchange, dust accumulation, and varying humidity levels. Unlike rural or semi-natural settings, the urban context may contribute to a more complex environmental profile due to the interaction between climatic and anthropogenic factors.

Nevertheless, the absence of heavy industrial activity in the area means that pollution levels are generally moderate (Brimblecombe, 2013; Tétreault, 2003).

The museum building was designed and constructed specifically for museum use and incorporates basic environmental management and exhibition infrastructure. However, the building lacks fully advanced climate control systems and airtight environmental regulation. As a result, indoor environmental conditions remain strongly influenced by external climatic variability, especially seasonal changes in temperature and relative humidity. Daily environmental fluctuations may also occur due to visitor activity, air exchange, and the thermal behavior of the building envelope (ASHRAE, 2023; Camuffo, 2014).

These conditions create challenges for the long-term preservation of archaeological collections, particularly for composite objects and metallic materials that remain sensitive to humidity fluctuations, corrosion processes, dust accumulation, and environmental instability. The case therefore reflects the broader conservation difficulties faced by regional museums operating under Mediterranean climatic conditions with limited environmental control infrastructure (Camuffo, 2014; Tétreault, 2003).

4.4.2 Type of Collections

The collection includes ceramics, stone artifacts, and metal objects. While relatively stable, these materials remain vulnerable to long-term exposure to fluctuating environmental conditions (Camuffo, 2014; Michalski, 2004).

4.4.3 Environmental Challenges

Challenges include:

- limited control over temperature and humidity
- environmental fluctuations in temperature and relative humidity
- lack of systematic monitoring
- dependence on external climate

These conditions increase the complexity of environmental management and may affect the long-term stability of certain sensitive materials, particularly metals and composite archaeological objects (Camuffo, 2014; Thomson, 1986).

4.4.4 Environmental Management Practices

Management strategies include basic air conditioning, natural ventilation, and minimal monitoring. These approaches are largely reactive and do not provide long-term environmental stability.

4.4.5 Limitations

Limitations include:

- restricted financial resources
- limited technical infrastructure
- absence of systematic environmental monitoring
- reliance on manual and reactive practices

This case reflects the reality of many small regional museums, where environmental management practices are constrained by financial, technical, and institutional limitations. These limitations affect the ability to maintain stable indoor conditions, collect long-term environmental data, and apply preventive conservation measures consistently.

4.5 Additional Comparative Case Study: Folklore Museum of Preveza

4.5.1 Building and Climatic Context

The Folklore Museum of Preveza is located in a coastal Mediterranean environment characterized by high summer temperatures, mild winters, increased relative humidity and seasonal climate variability. Due to the proximity to the sea, the environment is affected by marine humidity and suspended salts, which may affect both the building environment and the collections kept in the museum (Lionello, 2012).

The museum is located in an urban coastal environment that is affected by local traffic, seasonal tourism, dust accumulation, and natural marine conditions. Although the area is not characterized by intense industrial pollution, the interaction between humidity, suspended particles, and salts can contribute to environmental degradation processes (Brimblecombe, 2013; Tétreault, 2003).

The building operates as a small regional museum and includes basic exhibition infrastructure but limited environmental control systems. Indoor environmental conditions are therefore strongly influenced by outdoor climate variability, natural ventilation practices, visitor activity, and seasonal environmental changes. As in many small museums,

the absence of advanced climate control and airtight environmental regulation can lead to daily and seasonal fluctuations in temperature and relative humidity (ASHRAE, 2023; Camuffo, 2014).

These environmental conditions are particularly important in the case of folklore collections, which often contain sensitive organic and composite materials. Elevated humidity levels, environmental instability, and inadequate environmental regulation may affect the long-term preservation of textiles, wood, paper-based materials, leather objects, painted surfaces, and other hygroscopic collections commonly exhibited in regional folklore museums (Michalski, 2004; Thomson, 1986).

4.5.2 Collection Types

The collection of the Folklore Museum of Preveza consists mainly of organic and composite materials related to the local cultural heritage and traditional daily life. The collection of the Folklore Museum of Preveza consists mainly of organic and composite materials related to the local cultural heritage and traditional daily life. The museum preserves textiles, traditional costumes, embroidered fabrics, wooden objects, paper-based materials, photographs, household utensils, leather goods, painted objects, and composite artefacts combining materials such as wood, metal, textiles, leather, and paper. The presence of mixed-material objects is particularly important from a preventive conservation perspective, as different materials may respond differently to changes in temperature and relative humidity. Consequently, environmental management strategies must consider the varying conservation requirements of both organic and inorganic components (Michalski, 2004; Thomson, 1986).

In contrast to mainly archaeological collections, folklore collections are generally more sensitive to environmental instability, because many of their materials are hygroscopic and vulnerable to fluctuations in relative humidity and temperature. Organic materials such as fabrics, paper, wood and leather can absorb and release moisture depending on environmental conditions, leading to expansion, contraction, warping, brittleness and structural stress over time (Camuffo, 2014; European Committee for Standardization, 2010).

Elevated humidity levels may also increase the risk of mold growth, biological activity, staining and deterioration of sensitive organic surfaces. Painted and dyed materials are additionally vulnerable to cumulative light exposure and discoloration, while metal components incorporated into composite objects may develop corrosion under high humidity conditions (Canadian Conservation Institute, 2020; Thomson, 1986).

Many objects are displayed within display cases that provide a degree of physical and environmental protection, although the sealing performance of the cases may vary. Some larger objects and furniture items may also be displayed openly in exhibition spaces, increasing their exposure to dust accumulation, atmospheric pollutants, temperature and relative humidity fluctuations, and visitor-related environmental changes (Tétreault, 2003; Thomson, 1986).

The diversity and sensitivity of these collections make preventive maintenance particularly important, especially in small museums operating under limited environmental control and financial constraints (ICCROM, n.d.; Michalski, 2004).

4.5.3 Environmental Challenges

The environmental challenges observed in this case study include:

- seasonal and diurnal variations in temperature and relative humidity
- increased humidity levels during winter and transitional periods
- risk of mold growth and biological activity
- cumulative light exposure affecting sensitive organic and painted materials
- dust accumulation and airborne pollutants
- impact of marine humidity and airborne salts
- environmental changes related to visitor activity and natural ventilation

These factors create an unstable internal environment that can affect the conservation of sensitive organic and complex collections. Repeated fluctuations in relative humidity can contribute to dimensional changes, mechanical stress and gradual deterioration of hygroscopic materials such as fabrics, paper, wood and leather (Camuffo, 2014; European Committee for Standardization, 2010).

High humidity levels combined with inadequate ventilation can also create favorable conditions for mold growth, biological contamination, and staining of sensitive surfaces. In addition, airborne particles, urban dust and sea salts can contribute to surface contamination, chemical wear and corrosion processes in metal components and objects made of mixed materials (Canadian Conservation Institute, 2020; Tétreault, 2003).

Exposure to light is another important preventive conservation challenge, particularly for dyed fabrics, photographs, painted surfaces, and paper-based materials. Although light

damage is cumulative and irreversible, its effects can be reduced through controlled lighting strategies and limited exposure times (Heritage Collections Council, 1998; Thomson, 1986).

These conditions reflect broader preventive conservation challenges commonly encountered in small Mediterranean museums operating under limited environmental control systems and fluctuating climatic conditions.

4.5.4 Environmental Management Practices

Environmental management practices at the Folklore Museum of Preveza are based mainly on practical, low-cost and proactive approaches adapted to the operational constraints of a small regional museum. Environmental regulation is mainly based on natural ventilation, basic air conditioning systems, passive shading measures, controlled lighting practices and regular cleaning procedures aimed at reducing dust accumulation and exposure to pollutants (Heritage Collections Council, 1998; Tétreault, 2021).

Rather than maintaining strict environmental standards throughout the year, management practices focus on reducing extreme environmental conditions and limiting sudden fluctuations in temperature and relative humidity. Exhibit displays provide partial protection for sensitive collections, while light exposure is managed through selective lighting strategies and limiting unnecessary lighting where possible (European Committee for Standardization, 2010; Thomson, 1986).

Due to limited technical infrastructure, environmental management depends largely on observation, staff experience and local preventive interventions rather than fully automated climate control systems. Monitoring practices may include periodic temperature and relative humidity measurements, visual inspection of sensitive objects and observation of seasonal environmental changes (ASHRAE, 2023; Heritage Collections Council, 1998).

Preventive conservation practices also include regular cleaning, reducing dust accumulation, basic pollutant control measures, and efforts to improve the environmental awareness of museum staff. In small museums, even simple preventive strategies can contribute significantly to stabilizing internal conditions and reducing long-term environmental risks to sensitive collections (Canadian Conservation Institute, 2020; Tétreault, 2021).

This approach reflects a flexible and adaptive preventive conservation strategy that is consistent with the reality of many small Mediterranean museums operating under financial and technical constraints (Council of Europe, 2017; ICCROM, n.d.).

4.5.5 Limitations

The main constraints affecting environmental management at the Folklore Museum of Preveza include:

- limited financial resources
- absence of advanced climate control systems
- dependence on external climatic conditions and seasonal variability
- limited long-term environmental monitoring
- reliance on manual and reactive preventive practices
- increased sensitivity of organic and complex collections

As in many small regional museums, environmental management practices are constrained by financial, technical and institutional constraints. The absence of continuous environmental monitoring and fully automated environmental regulation makes it difficult to maintain stable internal conditions throughout the year.

These limitations are particularly important in the case of folklore collections, as organic and hygroscopic materials are more sensitive to fluctuations in temperature, relative humidity, biological activity, cumulative light exposure, and dust accumulation. Preventive maintenance therefore depends largely on practical low-cost measures, staff awareness and adaptive environmental management strategies rather than on technologically advanced infrastructure (Canadian Conservation Institute, 2020; Michalski, 2004).

The case study reflects broader preventive maintenance challenges commonly encountered in small Mediterranean museums, where environmental management must balance collection preservation, visitor comfort, building constraints, and limited institutional resources.

4.6 Cross-Case Analysis

The comparative analysis of the four selected museums revealed both common challenges and significant differences related to collection type, building characteristics, environmental

conditions, conservation risks, and environmental management practices. To facilitate comparison, the main findings are presented in the following tables.

Table 4.2: Comparison of Collection Types in the Selected Museums

Museum	Main Collection Types
<i>Pavlos Vrellis Museum</i>	Wax figures, textiles, wood, paper-based materials, painted surfaces, mixed-material objects
<i>Archaeological Museum of Nicopolis</i>	Stone artefacts, ceramics, mosaics, metal objects, inscriptions and archaeological finds
<i>Archaeological Museum of Arta</i>	Stone artefacts, ceramics, metal objects, inscriptions and archaeological finds
<i>Folklore Museum of Preveza</i>	Textiles, traditional costumes, wood, paper-based materials, leather objects, photographs, household utensils and composite artefacts

The selected museums contain a wide variety of collection materials, including both organic and inorganic artefacts. While the archaeological museums primarily preserve stone, ceramic and metal objects, the Pavlos Vrellis Museum and the Folklore Museum of Preveza contain a larger proportion of sensitive organic and mixed-material collections. This diversity significantly influences environmental management priorities, as different materials respond differently to fluctuations in temperature, relative humidity, light exposure and airborne pollutants (Michalski, 2004; Thomson, 1986).

Table 4.3: Comparison of Building Characteristics of the Selected Museums

Museum	Building Characteristics
<i>Pavlos Vrellis Museum</i>	Purpose-built museum Purpose-built museum
<i>Archaeological Museum of Nicopolis</i>	Modern museum building
<i>Archaeological Museum of Arta</i>	Modern museum building
<i>Folklore Museum of Preveza</i>	Adapted cultural building

The comparison demonstrates that museum buildings vary considerably in terms of architectural features and their original function. While some institutions operate in purpose-

built museum facilities, others occupy adapted buildings that were not originally designed with conservation requirements in mind. These differences affect environmental stability,

air exchange, thermal performance, and the effectiveness of environmental control measures (ASHRAE, 2023; Camuffo, 2014).

Table 4.4: Comparative Environmental Conditions across the Case Study Museums

Museum	Climate Context	Temperature Characteristics	Relative Humidity Characteristics	Light / Solar Exposure
<i>Pavlos Vrellis Museum</i>	In Land Mediterranean environment	High summer temperatures, cooler winters, seasonal fluctuations	RH varies significantly between seasons	Moderate daylight exposure
<i>Archaeological Museum of Nicopolis</i>	Coastal Mediterranean environment	High summer temperatures	Elevated humidity due to marine influence	High solar exposure
<i>Archaeological Museum of Arta</i>	Urban Mediterranean environment	Seasonal temperature variability	Moderate RH fluctuations	Moderate daylight exposure
<i>Folklore Museum of Preveza</i>	Coastal urban Mediterranean environment	Warm summers and mild winters	Elevated humidity and marine moisture influence	High sunlight exposure

Table 4.4 demonstrates that environmental conditions vary considerably among the selected museums according to their geographical location and building context. Coastal museums such as Nicopolis and Preveza are more strongly influenced by marine humidity, airborne salts, and increased solar exposure, while inland museums experience different seasonal patterns of temperature and relative humidity fluctuations. These environmental differences directly influence preventive conservation priorities and environmental management requirements (Camuffo, 2014; Lionello, 2012).

Table 4.5 Main Environmental Challenges in the Case Study Museums

Museum	Main Environmental Challenges
<i>Pavlos Vrellis Museum</i>	RH fluctuations, light exposure, biological activity, pollutants
<i>Archaeological Museum of Nicopolis</i>	RH fluctuations, marine salts, corrosion, pollutants
<i>Archaeological Museum of Arta</i>	Temperature fluctuations, RH fluctuations, corrosion risk, and limited monitoring
<i>Folklore Museum of Preveza</i>	RH fluctuations, biological activity, light sensitivity, and pollutants

Despite differences in collection type and location, all museums face challenges related to

environmental instability and preventive conservation. Temperature and relative humidity

fluctuations represent common risks across the case studies, while coastal museums experience additional pressures associated with marine salts and corrosion. The specific significance of each challenge depends on the material composition and environmental context of each collection (Camuffo, 2014; Tétreault, 2003).

Table 4.6 Environmental Management Practices in the Case Study Museums

Museum	Environmental Management Practices
<i>Pavlos Vrellis Museum</i>	Dehumidification, shading, monitoring
<i>Archaeological Museum of Nicopolis</i>	HVAC support, monitoring
<i>Archaeological Museum of Arta</i>	Ventilation, basic environmental control
<i>Folklore Museum of Preveza</i>	Passive ventilation, cleaning, preventive monitoring

The findings show that environmental management practices are strongly influenced by available resources and institutional capacity. Although the level of environmental control varies between museums, all case studies demonstrate the importance of combining preventive conservation principles with practical and sustainable management approaches. In many cases, low-cost interventions and passive environmental control measures play an important role in improving the conservation of collections (Council of Europe, 2017; Heritage Collections Council, 1998).

Table 4.7 Main Environmental Management Limitations of the Case Study Museums

Museum	Main Limitations
<i>Pavlos Vrellis Museum</i>	Limited monitoring, climatic dependence
<i>Archaeological Museum of Nicopolis</i>	Coastal environmental pressures
<i>Archaeological Museum of Arta</i>	Resource constraints
<i>Folklore Museum of Preveza</i>	Limited resources and environmental control

The comparison reveals that limited financial resources, building-related constraints and limited monitoring capacity remain significant obstacles to environmental management in

small museums. These constraints often prevent the implementation of ideal conservation conditions and reinforce the need for realistic, adaptive and risk-based approaches to

preventive conservation. The findings support the development of practical guidelines specifically tailored to the needs of small museums operating in Mediterranean environments (Ashley-Smith, 1999; ICCROM, n.d.).

Environmental instability, particularly seasonal and daily fluctuations in temperature and relative humidity, was identified as a common problem in all four museums examined.

Although the degree of environmental sensitivity varies depending on the type of collection and the characteristics of the building, all case studies demonstrated a strong dependence on external climatic conditions and limited environmental control capacity.

Building characteristics were found to play a decisive role in indoor environmental performance. Museums operating in traditional or adapted buildings showed increased vulnerability to uncontrolled air exchange, thermal variability, humidity fluctuations, and seasonal environmental changes. In coastal environments, the additional influence of marine moisture and airborne salts further exacerbated the risks of degradation, particularly for porous archaeological materials and metal objects (ASHRAE, 2023; Camuffo, 2014).

The type of collection also significantly influenced environmental management priorities. Archaeological collections composed primarily of inorganic materials were generally more resistant to certain environmental conditions, but remained vulnerable to erosion processes, salt crystallization, surface erosion, and pollutant-related degradation. In contrast, folklore and mixed-material collections containing textiles, paper, wood, leather, painted surfaces and composite objects were significantly more sensitive to fluctuations in relative humidity, biological activity, cumulative light exposure and environmental instability (Camuffo, 2014; Michalski, 2004; Tétreault, 2003).

The case studies also demonstrated that small museums rely heavily on adaptive, proactive and low-cost environmental management strategies. Common approaches included natural ventilation, passive shading, selective lighting practices, local humidity control, regular cleaning and hands-on observation by staff rather than advanced automated climate control systems.

At the same time, limited financial resources, limited technical infrastructure and the

absence of systematic long-term environmental monitoring were identified as significant constraints affecting all institutions. These constraints often reduce the ability of museums

to maintain stable environmental conditions or to fully implement proactive environmental management policies.

Despite these challenges, the comparative analysis demonstrates that effective preventive conservation in small Mediterranean museums does not necessarily depend exclusively on technologically advanced systems. Flexible, risk-based and environmentally sensitive management approaches can significantly contribute to the long-term conservation of collections when adapted to local climatic conditions, building characteristics, collection sensitivity and institutional capacities (Ashley-Smith, 1999; Council of Europe, 2017).

The findings of the case studies highlight the need for practical, adaptable and sustainable environmental management strategies, specifically designed for the realities of small museums operating in the Mediterranean regions.

Additional data and summaries of the case studies are presented in the Appendices.

5. Sustainable Guidelines for Internal Environmental Management in Small Museums

5.1 Introduction

The previous chapters have demonstrated that the management of indoor environmental conditions in small museums is shaped by a complex interplay of climatic, architectural, institutional and economic factors. In Mediterranean regions, and particularly in Western Greece, these challenges are exacerbated by high summer temperatures, seasonal variations in humidity, strong solar radiation and increasing pressures related to climate change. At the same time, small museums often operate in buildings that are not designed for modern conservation purposes and under conditions of limited financial and technical capacity (Lionello, 2012; UNESCO World Heritage Centre, 2007).

In this context, this chapter proposes a set of sustainable and realistic guidelines for the management of indoor environmental conditions in small and medium-sized museums. The aim is not to propose idealized or high-tech solutions that would be difficult to implement in low-budget institutions, but rather to develop an applied framework that balances the

demands of preventive conservation, operational feasibility and environmental sustainability.

The proposed guidelines are based on the theoretical discussion presented in Chapters 1 and 2, as well as on the observations arising from the case studies examined in Chapter 4. They therefore reflect both established conservation principles and the practical realities faced by museums in Mediterranean environments. The chapter is organized around the main dimensions of environmental management: general principles of sustainable preventive conservation, temperature and relative humidity control, light management, air quality and pollution control, environmental monitoring, building-related strategies, operational and institutional practices and broader sustainability parameters.

The following guidelines focus primarily on exhibition spaces in small museums, while also considering selected storage environments where applicable. In exhibition spaces, environmental management must balance preventive conservation requirements with visitor comfort, accessibility, and operational needs. Therefore, the proposed strategies aim to support both collection preservation and sustainable museum operation under Mediterranean climatic conditions (ASHRAE, 2023; Council of Europe, 2017).

5.2 Principles of Sustainable Preventive Conservation

Any environmental management strategy in a museum should begin with a clear understanding of preventive conservation as a risk reduction approach, rather than an attempt to impose ideal and constant conditions under all circumstances. For small museums, this principle is particularly important because limited resources require prioritization. Sustainable preventive conservation, therefore, depends on identifying the most significant threats to collections and addressing them in ways that are effective and feasible (Ashley-Smith, 1999; ICCROM, n.d.).

The first guiding principle is that consistency is often more important than perfection. In many museum environments, especially in areas with seasonal climate variability, it may not be possible to maintain precise temperature and relative humidity values throughout the year. However, even when ideal conditions cannot be achieved, it is possible to reduce risk by avoiding rapid fluctuations, extreme peaks, and prolonged exposure to harmful conditions. Stability should therefore be considered a central objective (ASHRAE, 2023; European Committee for Standardization, 2010).

A second principle concerns the need for a materials-sensitive approach. Environmental

management should not be based on the assumption that all objects require the same conditions. Mixed collections are common in regional museums, and different materials react differently to environmental stress. Wax, wood, textiles, paper, metals, and painted surfaces all present distinct vulnerabilities. As a result, environmental management should focus particularly on the most sensitive objects and spaces, rather than applying uniform strategies indiscriminately (Michalski, 2004; Thomson, 1986).

A third principle is proportionality. Small museums should avoid investing limited resources in highly complex systems that they cannot sustain over time. A sustainable solution is not simply one that protects collections in the short term, but one that can realistically be operated, monitored, and supported within the museum's institutional capacity. Long-term feasibility is therefore a key criterion (Council of Europe, 2017; International Energy Agency, 2020).

A fourth principle is integration. Environmental management should not be treated as a separate technical issue cut off from museum operations. It should be integrated into the museum's broader practice, including collections care, building management, visitor regulation, staff awareness, and energy use. This integrated approach improves both conservation outcomes and institutional resilience (ASHRAE, 2023; Council of Europe, 2017).

Finally, sustainable preventive conservation requires adaptation to the local context. Mediterranean museums cannot always apply international standards in a rigid manner, especially when these standards are based on temperate climates and technologically advanced buildings. Instead, environmentally sensitive interpretations of conservation principles are needed, based on local climate, building typology and functional realities (ASHRAE, 2023; European Committee for Standardization, 2010).

5.3 Guidelines for Temperature and Relative Humidity Management

Temperature and relative humidity are closely interconnected environmental parameters and should be managed together rather than independently. Their interaction directly affects the chemical, mechanical, and biological stability of museum collections. Rapid or repeated fluctuations may create greater risks than moderately stable but imperfect conditions, particularly in Mediterranean museum environments characterized by strong seasonal variability (Camuffo, 2014; European Committee for Standardization, 2010).

Temperature is one of the most important parameters affecting museum collections, as it directly affects the rate of chemical deterioration and can also contribute to the deformation of materials, especially in sensitive collections. High indoor temperatures accelerate oxidation, hydrolysis, and other forms of chemical degradation. They are particularly problematic for organic materials, adhesives, polymers, wax, and composite objects (Camuffo, 2014; Thomson, 1986).

For small museums in Mediterranean regions, temperature-related challenges are often more intense during the summer season due to high external temperatures, strong solar radiation, limited insulation, and increased indoor heat accumulation. These conditions may lead to increased indoor temperatures and thermal discomfort for visitors, particularly in buildings lacking advanced climate control systems. In museum environments, temperature management is often influenced not only by conservation requirements but also by visitor comfort and occupancy conditions. Environmental risks become more significant when elevated temperatures are combined with fluctuations in relative humidity and inadequate ventilation. Under these conditions, strict temperature control throughout the year may not be realistic. Instead, the following guidelines are more appropriate: (ASHRAE, 2023; Lionello, 2012).

5.3.1 Avoid temperature extremes rather than aiming for rigid uniformity

In small museums, temperature stability may also be supported indirectly through the management of relative humidity levels and moisture conditions within the building. Simple

measures such as controlled ventilation, reduction of excessive moisture, use of buffering materials, and localized humidity regulation can contribute to a more stable indoor environment without requiring energy-intensive mechanical systems (ASHRAE, 2023; Heritage Collections Council, 1998).

Small museums should prioritize the prevention of extreme temperatures, especially prolonged overheating above safe ranges for sensitive materials. Particular attention should also be given to daily temperature fluctuations, especially during spring and autumn, when Mediterranean climatic conditions may produce large temperature variations within short periods of time. In some cases, outdoor temperatures may vary from approximately 5°C to 25°C within the same day, creating unstable indoor environmental conditions that may affect sensitive and composite museum objects (ASHRAE, 2023; Camuffo, 2014).

If a perfectly stable temperature cannot be maintained, management should at least aim to reduce peaks and sudden changes. In preventive conservation practice, relatively stable temperature conditions are generally considered to involve limited daily fluctuations, often within approximately $\pm 3^{\circ}\text{C}$ to $\pm 5^{\circ}\text{C}$, depending on the type and sensitivity of the collections (ASHRAE, 2023).

5.3.2 Use seasonal temperature strategies

A seasonally adapted approach is often more realistic than fixed annual targets. For example, slightly higher summer temperatures may be acceptable if they remain within safe limits and daily fluctuations are relatively limited. In preventive conservation practice, temperature variations within approximately $\pm 3^{\circ}\text{C}$ to $\pm 5^{\circ}\text{C}$ per day are generally considered more stable than abrupt or repeated environmental shifts (ASHRAE, 2023; European Committee for Standardization, 2010).

5.3.3 Minimize solar heat gain

Simple passive measures such as external shading, curtains, blinds, UV-protective window films, planting trees around the museum perimeter, the use of awnings, and restricted opening times for sun-exposed rooms can significantly reduce overheating. In Mediterranean climates, solar control is often one of the most effective low-cost interventions (ASHRAE, 2023; International Energy Agency, 2020).

Improving the sealing performance of windows and doors may contribute significantly to the stabilization of indoor environmental conditions by reducing uncontrolled heat transfer, air exchange, humidity fluctuations, dust ingress, and pollutant penetration (ASHRAE, 2023; Tétreault, 2003).

The use of entrance barriers, transitional spaces, or vestibules may further reduce uncontrolled air exchange between indoor and outdoor environments, contributing to improved temperature and relative humidity stability within exhibition and storage spaces (ASHRAE, 2023).

5.3.4 Prioritize temperature-sensitive objects

Spaces housing wax objects, painted surfaces, photographs, adhesives, or composite

materials should receive priority in temperature management. If cooling resources are limited, they should be directed first toward the most vulnerable collections (Michalski, 2004; Thomson, 1986).

5.3.5 Avoid abrupt heating and cooling cycles

Intermittent heating or cooling can sometimes create more instability than moderate but steady conditions. Where mechanical systems are used, they should operate gradually and avoid sharp environmental shifts (ASHRAE, 2023; European Committee for Standardization, 2010).

Overall, temperature management in small museums should aim at moderation, seasonal adaptation, and the reduction of extremes rather than strict mechanical uniformity.

Temperature management should therefore focus on reducing extremes and ensuring gradual environmental variation.

5.4 Additional Considerations for Relative Humidity Control

Relative humidity is often the most critical environmental factor in museum conservation, especially for collections containing hygroscopic and composite materials. Changes in relative humidity cause expansion and contraction in wood, paper, textiles, leather and other moisture-sensitive materials, leading to warping, cracking, delamination and structural stress. Relative humidity is also a critical factor in the deterioration of inorganic materials, since the presence of moisture promotes chemical reactions involving oxygen, atmospheric pollutants, and salts. In stone materials, these reactions may contribute to the formation of surface crusts, black crusts, gypsum formation, salt crystallization, and progressive surface deterioration. High humidity also promotes the growth of mold and corrosion, while excessively low humidity may cause embrittlement, drying, and increased material fragility (Brimblecombe, 2013; Camuffo, 2014; Thomson, 1986).

In archaeological collections, relative humidity fluctuations may also affect inorganic and porous materials such as stone, ceramics, mosaics, and metals. High humidity levels can accelerate corrosion processes in metallic objects, while repeated moisture cycles may contribute to salt crystallization, surface erosion, cracking, and material instability in porous archaeological materials. These risks are particularly significant in Mediterranean and

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coastal environments, where humidity variations and marine salts interact continuously with collection materials (Brimblecombe, 2013; Camuffo, 2014).

In Western Greece and similar Mediterranean regions, humidity is particularly difficult to control due to strong seasonal fluctuations. Winter months can bring high humidity, while summer periods often lead to much drier indoor conditions. Under these conditions, the most important guideline is not strict control but fluctuation management (European Committee for Standardization, 2010; Lionello, 2012).

5.4.1 Prioritize RH stability over narrow fixed targets

Environmental policies should aim to minimize frequent and intense daily RH fluctuations. Small deviations from ideal values may be less harmful than repeated daily oscillations and abrupt environmental changes (European Committee for Standardization, 2010).

5.4.2 Identify high-risk seasons and spaces

Museums should determine which rooms are most affected by winter humidity, condensation, or summer dryness. Storage rooms, poorly ventilated spaces, and exhibition areas containing organic materials should be monitored more closely (ASHRAE, 2023; Heritage Collections Council, 1998).

5.4.3 Use localized humidity control when whole-building control is not possible

In small museums, it is often unrealistic to control RH throughout the entire building. In such cases, more feasible strategies include: (ASHRAE, 2023; Heritage Collections Council, 1998).

- microclimate vitrines
- silica gel or conditioned buffering materials
- localized dehumidifiers in critical rooms
- protective enclosures for highly sensitive objects

5.4.4 Prevent prolonged high RH conditions

Whenever relative humidity exceeds acceptable levels for extended periods, the risks of

mold growth, material deterioration, and corrosion processes in metallic objects increase considerably. Since acceptable RH ranges may vary depending on collection type, building conditions, and material sensitivity, each museum should monitor its collections and define appropriate environmental thresholds according to its specific conservation needs. Even simple and localized interventions may help reduce environmental risks under such conditions (Canadian Conservation Institute, 2020; Camuffo, 2014).

5.4.5 Avoid over-drying

While high humidity is often the primary concern in museum environments, excessively low RH may also damage hygroscopic and organic materials such as wood, paper, textiles, leather, and composite collections by causing shrinkage, embrittlement, cracking, and structural stress. Seasonal adaptation strategies should therefore avoid overly aggressive drying in collections containing moisture-sensitive materials (Camuffo, 2014; Thomson, 1986).

In contrast, many inorganic materials, particularly metals, are generally less affected by low-humidity conditions. For metallic collections, lower RH levels may even contribute positively to preventive conservation by reducing the risk of corrosion processes. As a result, environmental management strategies should be adapted according to the specific material composition and conservation requirements of each collection (Camuffo, 2014; Michalski, 2004).

5.4.6 Relate RH policy to collection type

Collections containing wax figures, textiles, wood, paper, and mixed materials require greater RH attention than collections composed mainly of stable stone or ceramic objects. This means that environmental priorities should vary across museum spaces (Michalski, 2004; Thomson, 1986).

In practice, RH management should be based on gradual adaptation, buffering, and targeted intervention rather than on unrealistic expectations of perfect uniformity (ASHRAE, 2023; European Committee for Standardization, 2010).

5.5 Guidelines for Light Management

Light is a unique conservation risk because its effects are cumulative and irreversible. Once fading or photochemical alteration occurs, the original state of the object cannot be recovered. This makes light management one of the most important aspects of preventive conservation, especially in museums displaying textiles, paper, photographs, dyes, painted surfaces, and wax objects (Heritage Collections Council, 1998; Thomson, 1986).

The museums examined in this dissertation illustrate that light control is often uneven. In some cases, natural light enhances the visitor's experience but increases risk for collections. The following guidelines are therefore recommended:

5.5.1 Apply object-sensitive lighting policies

Lighting levels do not need to be uniform throughout the museum, since different materials present different levels of sensitivity to light exposure. Highly sensitive materials include textiles, paper-based objects, photographs, watercolors, manuscripts, dyed organic materials, and painted surfaces, which are particularly vulnerable to fading, discoloration, and irreversible chemical deterioration. Moderately sensitive materials may include wood, leather, composite objects, and certain painted archaeological materials. In contrast, less sensitive inorganic materials such as stone, ceramics, glass, and most metals generally tolerate higher light levels, although prolonged exposure may still affect pigments, painted decorations, and surface finishes (Heritage Collections Council, 1998; Thomson, 1986).

Sustainable lighting policies should therefore adapt exposure levels according to the sensitivity and material composition of each collection rather than applying uniform lighting conditions throughout all exhibition spaces.

5.5.2 Consider cumulative light dose, not only lux values

Management should account for the total exposure of objects over time rather than focusing only on lux values. Even relatively low light levels may become problematic if the duration of exposure is prolonged. Where possible, museums should regulate both light intensity and display duration (Heritage Collections Council, 1998; Thomson, 1986).

In exhibition spaces containing sensitive materials, artificial lighting systems are generally preferable because they allow better control of light intensity and exposure. Lighting should also remain switched off when exhibition spaces are closed or unoccupied in order to reduce

unnecessary cumulative exposure and minimize long-term deterioration risks (Heritage Collections Council, 1998).

5.5.3 Reduce exposure from natural light

Windows and other openings should be equipped, where feasible, with shading devices, curtains, blinds, or UV-protective materials. Direct sunlight should never fall on sensitive objects (Heritage Collections Council, 1998; Thomson, 1986).

5.5.4 Use selective display strategies

If resources are limited, museums can reduce cumulative light exposure through:

- rotation of sensitive objects
- shorter display periods
- selective highlighting of more robust materials
- use of replicas for highly sensitive items in permanent displays
- reduction of lighting intensity during periods of low visitor activity
- use of motion-activated lighting systems in selected exhibition areas
- storage of highly sensitive collections in dark or low-light environments when not exhibited
- use of protective glazing, UV filters, and controlled artificial lighting systems
- limitation of direct sunlight through curtains, blinds, shading systems, or architectural barriers
- prioritization of low-risk objects for long-term permanent display

These strategies allow museums to balance preventive conservation requirements, visitor experience, and financial limitations while reducing unnecessary cumulative light exposure (Heritage Collections Council, 1998).

5.5.5 Integrate lighting with interpretive planning

Good exhibition design should not assume that more light equals better access. Visibility can often be improved through contrast, positioning, and visitor flow rather than increased illuminance alone.

5.5.6 Treat light management as a conservation policy

Lighting decisions should be made in relation to the sensitivity of the material, not just aesthetics. This is particularly important in smaller museums, where display decisions are sometimes made without the input of environmental authorities.

A sustainable lighting strategy is one that reduces unnecessary exposure while maintaining a meaningful experience for the visitor. Light management should therefore be understood as a long-term preventive conservation strategy rather than a decision based only on visual presentation or exhibition aesthetics. Lighting choices should balance visibility, visitor experience, and the preservation requirements of collections, particularly in the case of sensitive materials vulnerable to cumulative light damage (Heritage Collections Council, 1998; Thomson, 1986).

Table 5.1: Sensitivity of Museum Materials to Environmental Factors

Material Type	RH Sensitivity	Light Sensitivity	Pollution Sensitivity
<i>Textiles</i>	High	High	Moderate
<i>Paper</i>	High	High	High
<i>Wood</i>	High	Moderate	Moderate
<i>Leather</i>	High	Moderate	Moderate
<i>Wax</i>	High	High	High
<i>Stone</i>	Moderate	Low	High
<i>Ceramics</i>	Low–Moderate	Low	Moderate
<i>Metals</i>	Moderate	Low	High
<i>Glass</i>	Low	Low	Moderate

5.6 Guidelines for Air Quality, Ventilation, and Pollution Control

Air quality is another essential element of preventive conservation, although it is often

overlooked in smaller institutions. Pollutants and airborne particles can cause chemical degradation, corrosion, contamination and increased cleaning needs. Outdoor pollutants may include dust particles, marine salts, vehicle emissions, sulfur and nitrogen compounds, and biological contaminants transported through air circulation and natural ventilation. Indoor pollution sources may also originate from building materials, wooden furniture, adhesives, paints, exhibition equipment, and even collection materials themselves through the emission of volatile organic compounds (VOCs) (Brimblecombe, 2013; Tétreault, 2003, 2021).

Airborne pollutants may contribute to corrosion processes in metallic objects, black crust formation and gypsum formation on stone surfaces, dust accumulation, discoloration, and chemical deterioration of sensitive organic materials. In Mediterranean and coastal environments, the interaction between humidity, airborne salts, and atmospheric pollutants may significantly intensify deterioration processes (Brimblecombe, 2013; Tétreault, 2003).

Sustainable air quality management should therefore combine controlled ventilation, reduction of dust accumulation, regular maintenance, appropriate filtration where feasible, and careful selection of low-emission construction and display materials (Tétreault, 2021).

5.6.1 Control pollutant entry where possible

Even when advanced filtration systems are not available, museums can reduce pollutant ingress by: (Tétreault, 2003, 2021).

- limiting ventilation during dusty or polluted periods
- improving window and door sealing
- regular cleaning of exhibition and storage spaces to reduce dust accumulation
- careful maintenance of ventilation openings and air circulation systems
- minimizing the introduction of pollutant-emitting materials within exhibition environments

5.6.2 Use ventilation strategically rather than continuously

Natural ventilation can be useful, but if used without timing or control, it can introduce moisture, pollutants or dust. Therefore, ventilation should be adapted to external climatic conditions and used during more favorable periods (ASHRAE, 2023; Tétreault, 2021).

5.6.3 Address internal sources of pollution

Display cases, storage materials, paints, adhesives, and construction elements can emit harmful compounds. Museums should therefore select inert or low-emission materials whenever possible, particularly in enclosed exhibition cases and in storage environments where sensitive collections are kept (Tétreault, 2003, 2021).

5.6.4 Reduce soiling through preventive housekeeping

Dust accumulation is not only an aesthetic issue, but also an issue that must be taken into account in nature conservation. Regular and careful cleaning, especially of upper surfaces, corners and poorly ventilated areas, should be considered as part of environmental management (Canadian Conservation Institute, 2020; Heritage Collections Council, 1998).

5.6.5 Connect air quality to collection type

Dust and dirt control is particularly important for waxed surfaces, fabrics, painted objects, metals, porous stone materials, paper-based collections, and composite objects, since airborne particles may contribute to surface contamination, abrasion, chemical deterioration, and corrosion processes over time (Tétreault, 2003, 2021).

Air quality management does not always require expensive technology. In many cases, strategic ventilation and careful cleaning can make a significant difference, while air quality management may also be improved through simple and well-targeted preventive measures (Tétreault, 2021).

Pollutants are a significant, but often underestimated, risk factor in small museums. As noted in conservation literature, pollutants may originate both externally and internally and may lead to chemical deterioration, including corrosion of metals, weakening of organic materials, and surface deterioration of porous materials. In Mediterranean environments, museum buildings are also frequently affected by marine influence and airborne salts

pollutants may intensify deterioration processes, particularly in stone, ceramic, and metallic collections. Therefore, even in the absence of advanced filtration systems, basic preventive strategies such as controlled ventilation, careful material selection, reduction of dust accumulation, and regular cleaning remain essential (Brimblecombe, 2013; Tétreault, 2003, 2021).

5.6.6 Guidelines for Biological Risk Management

Biological deterioration represents a major preventive conservation risk in museum environments, particularly in regions characterized by elevated humidity levels and seasonal environmental fluctuations. Mold growth, insects, microorganisms, and pest activity may affect organic materials such as textiles, wood, paper, leather, and composite objects (Canadian Conservation Institute, 2020; Heritage Collections Council, 1998).

In small museums, biological risks are often intensified by limited environmental control, insufficient ventilation, dust accumulation, and unstable relative humidity conditions. High humidity combined with elevated temperatures may create favorable conditions for biological activity, especially in poorly ventilated storage or exhibition spaces (Canadian Conservation Institute, 2020; Camuffo, 2014).

Sustainable biological risk management should therefore include: (Canadian Conservation Institute, 2020; Heritage Collections Council, 1998).

- regular inspection of storage and exhibition areas
- monitoring of humidity and condensation
- preventive cleaning practices
- reduction of dust accumulation
- integrated pest management strategies
- isolation of contaminated objects where necessary

Biological management strategies should focus primarily on prevention, since biological deterioration may spread rapidly and affect large parts of a collection if left uncontrolled (Canadian Conservation Institute, 2020).

5.7 Guidelines for Environmental Monitoring

No environmental management strategy can be effective without some level of monitoring. Monitoring is essential because it transforms assumptions into evidence and allows museums to identify seasonal patterns, critical areas, and emerging risks. However, in small museums, monitoring must be realistic and proportionate (ASHRAE, 2023; Heritage Collections Council, 1998).

In addition to internal environmental measurements, small museums may also benefit from the use of external climatic data obtained from nearby meteorological stations, regional weather services, and publicly available environmental databases. Such information may help museums identify seasonal climatic patterns, temperature and humidity trends, periods of increased environmental risk, and broader regional environmental conditions. Since these data sources are often freely accessible, they represent a practical and sustainable monitoring resource for institutions operating with limited financial and technical capacities (ASHRAE, 2023; Lionello, 2012).

5.7.1 Prioritize simple and continuous monitoring over complex but unsustainable systems

Even basic data loggers can provide valuable information if used consistently. A small number of reliable devices placed in critical locations is often more useful than sporadic advanced measurements (ASHRAE, 2023; Heritage Collections Council, 1998).

5.7.2 Focus on strategic locations

Monitoring should prioritize spaces that are:

- environmentally unstable
- poorly ventilated
- highly exposed to sunlight
- used for storage
- housing sensitive collections

5.7.3 Record seasonal and daily patterns

Short-term spot measurements are helpful, but they do not provide the full picture. Museums should aim to understand how temperature and RH change over time, especially during summer and winter extremes (ASHRAE, 2023; European Committee for Standardization, 2010).

In small museums, even short training seminars or basic preventive conservation workshops may help museum staff better understand environmental monitoring data, recognize seasonal environmental risks, and apply simple corrective or preventive measures more effectively (Council of Europe, 2017; Heritage Collections Council, 1998).

5.7.4 Use monitoring results to support decisions

Monitoring should not be treated as a technical formality. The data should guide practical changes, such as adjusting ventilation times, relocating sensitive items, or identifying areas that require protective solutions.⁴ Use monitoring results to support decisions (ASHRAE, 2023; Heritage Collections Council, 1998).

5.7.5 Integrate monitoring into routine museum operations

Staff should be familiar with what is being monitored, why it is important and how to interpret key findings. Environmental monitoring becomes much more effective when it is integrated into daily practice (Heritage Collections Council, 1998; Michalski, 2004).

5.7.6 Accept gradual development

Museums without previous monitoring systems do not need to implement a full technical program immediately. A phased approach is more sustainable: first identify the most vulnerable areas and then expand as resources allow (Council of Europe, 2017; Heritage Collections Council, 1998).

Monitoring is the foundation of evidence-based preventive conservation and should be considered a priority even in low-budget institutions.

Environmental monitoring is essential for informed decision-making and long-term preventive maintenance.

5.8 Guidelines Related to Building Performance

In small museums, building performance is often as important as mechanical systems. Since many institutions operate in historic or adapted buildings, environmental management must work with existing architectural conditions rather than against them (ASHRAE, 2023; Camuffo, 2014).

5.8.1 Use the building as part of the environmental strategy

Thermal mass, shading, room orientation and interior zoning can all contribute to more stable conditions. Environmental management should therefore start with understanding how the building behaves seasonally (ASHRAE, 2023; Camuffo, 2014).

5.8.2 Improve performance through minimally invasive measures

Where structural interventions are possible, they should focus on:

- reducing uncontrolled air infiltration
- improving shading
- managing solar gain
- increasing buffering capacity in critical rooms

5.8.3 Respect heritage values in building intervention

In historic buildings, conservation requirements may limit invasive changes. Therefore, environmental improvement strategies should be compatible with the cultural heritage significance of the building itself (Council of Europe, 2017).

5.8.4 Use internal zoning

Not all museum spaces need to be managed in the same way. More stable rooms can be reserved for sensitive collections, while durable materials can be displayed in spaces with greater environmental diversity (ASHRAE, 2023; Michalski, 2004).

5.8.5 Recognize the limits of the building

Some buildings simply cannot support strict environmental control without significant

intervention. In these cases, museums should adjust their collection placement and display strategy rather than trying to impose unrealistic performance targets (ASHRAE, 2023; European Committee for Standardization, 2010).

Building-aware management is one of the most cost-effective forms of sustainable preventive conservation.

Building performance should be integrated into environmental management strategies to maximize sustainability.

5.9 Operational and Institutional Guidelines

Environmental management is not only a technical issue. It is also an organizational issue. Small museums often depend on a small number of staff members, and many environmental decisions are made informally. For this reason, institutional routines and staff awareness are central to successful implementation (Council of Europe, 2017; Heritage Collections Council, 1998).

5.9.1 Develop simple environmental management protocols

Even basic internal procedures can improve consistency. These might include: (Heritage Collections Council, 1998).

- when to ventilate
- when to use dehumidifiers or air conditioning
- how to respond to high humidity alerts
- how to regulate lighting for sensitive objects

5.9.2 Train staff in basic preventive conservation

Museum staff do not all need to be conservation specialists, but they should understand the significance of temperature, RH, light, pollutants, and handling practices. Awareness improves response capacity (Council of Europe, 2017; Heritage Collections Council, 1998).

5.9.3 Integrate visitor management into environmental strategy

Visitor flow affects microclimate, especially in smaller enclosed spaces. Museums should therefore consider group size, duration of stay, and crowding in environmentally sensitive rooms (ASHRAE, 2023).

5.9.4 Prioritize low-cost high-impact actions

Small museums cannot do everything at once. They should identify actions that significantly reduce risk without major investment, such as moving objects away from windows, improving shading, or starting systematic monitoring (Ashley-Smith, 1999; Heritage Collections Council, 1998).

5.9.5 Build gradual conservation planning

Environmental improvement should be approached as a gradual process rather than a single technical upgrade. This makes the strategy more realistic and more sustainable over time (Council of Europe, 2017).

Building performance should be integrated into environmental management strategies to maximize sustainability.

5.10 Sustainability, Energy Efficiency, and Climate Adaptation

A central argument of this position is that preventive maintenance in Mediterranean museums must be linked to sustainability. Environmental protection cannot be based solely on energy-intensive mechanical systems, especially in small institutions with limited budgets. Instead, museums need strategies that are sensitive to conservation and energy (International Council of Museums, 2019; International Energy Agency, 2020).

5.10.1 Balance conservation and energy use

The goal is not maximum mechanical control at any cost, but balanced protection. Museums should identify where passive or semi-passive solutions are sufficient and where targeted mechanical intervention is truly necessary (ASHRAE, 2023; International Energy Agency, 2020).

5.10.2 Promote passive-first strategies

Passive measures such as shading, zoning, thermal buffering, controlled ventilation, and

object relocation should always be considered before more energy-intensive options (ASHRAE, 2023; International Energy Agency, 2020).

5.10.3 Use selective rather than universal control

Not every room requires the same environmental precision. Selective control of critical spaces is often more sustainable than attempting to regulate an entire building equally (ASHRAE, 2023).

5.10.4 Integrate climate adaptation into museum planning

As climate change intensifies, museums must prepare for:

- more frequent heatwaves
- greater humidity variability
- increased extreme weather events
- rising energy costs

Adaptation planning should therefore become part of long-term collections care (International Council of Museums, 2019; UNESCO World Heritage Centre, 2007).

5.10.5 Redefine success realistically

For many small museums, success should not be defined as strict adherence to idealized international values, but as the ability to reduce significant risks, maintain relative stability, and preserve collections by feasible means (ASHRAE, 2023; Council of Europe, 2017).

Sustainable preventive conservation is therefore not a compromise with lower standards. It is a more realistic and resilient conservation model for institutions operating under climate and economic pressure (Council of Europe, 2017; International Council of Museums, 2019).

5.11 Concluding Remarks

The analysis developed in this thesis demonstrates that small museums in Western Greece and similar Mediterranean environments require environmental management strategies that

are flexible, realistic and sensitive to collections. Case studies have shown that environmental instability, building constraints, limited technical infrastructure and financial constraints are recurring conditions. At the same time, they have also demonstrated that

museums are capable of developing adaptive strategies based on practical knowledge, local context and low-cost interventions.

The guidelines proposed in this chapter respond directly to these realities. They do not aim to replace international standards, but to reinterpret them in ways that are applicable to small institutions. By emphasizing stability, prioritization, monitoring, passive measures, and sustainability, these guidelines support a model of preventive conservation that is both scientifically sound and institutionally feasible.

In this sense, the main contribution of this research lies in showing that effective care of collections in Mediterranean museums does not necessarily depend on highly sophisticated technological control. Instead, it depends on informed decision-making, adaptation to the context, and the ability to balance conservation needs with the actual capabilities of the institution. This approach is essential not only for the current management of museum collections, but also for the long-term resilience of cultural heritage in the face of climate change.

5.12 Risk-Based Environmental Prioritization

A key challenge identified throughout this thesis is the inability of small museums to fully comply with stringent environmental standards due to financial, technical, and structural constraints. In this context, a **risk-based prioritization** approach becomes essential for effective and sustainable environmental management (Ashley-Smith, 1999; ICCROM, n.d.).

Rather than attempting to control all environmental parameters equally across all sites, museums should identify and prioritize the most critical risks affecting their collections. This approach aligns with modern preventive conservation theory, as discussed in Chapter 1, and allows institutions to allocate limited resources more effectively (Ashley-Smith, 1999; ICCROM, n.d.).

Risk prioritization should be based on three main factors:

- the sensitivity of the materials
- the level of environmental exposure
- the potential severity of damage

For example, in the case of the Pavlos Vrellis Museum of Greek History, waxworks and organic materials are significantly more vulnerable to temperature and humidity fluctuations than stone or ceramic objects. As a result, environmental control efforts should be focused on areas that house these materials.

Similarly, in museums such as the Archaeological Museum of Arta, where resources are limited, priority should be given to areas that face the greatest environmental volatility, such as rooms with poor ventilation or areas exposed to direct sunlight.

A risk-based approach also allows for *differentiated environmental targets*, where not all collections are treated equally. This is particularly important in mixed collections, where applying uniform conditions may not be effective or even appropriate (Ashley-Smith, 1999; Michalski, 2004).

Ultimately, this strategy supports a more realistic and sustainable model of preventive conservation, where decision-making is guided by risk assessment rather than strict adherence to generalized standards (Ashley-Smith, 1999; Council of Europe, 2017).

5.13 Practical Implementation Framework for Small Museums

While the guidelines presented in this chapter provide a theoretical and strategic basis, their effectiveness depends on their practical implementation. For small museums, the transition from theory to practice must be gradual, realistic and adapted to institutional capabilities. The implementation of environmental management strategies can be structured in three main stages:

Phase 1: Initial Assessment

The first step involves identifying the current environmental conditions and key risk factors within the museum. This includes: (Ashley-Smith, 1999; Heritage Collections Council, 1998).

- basic monitoring of temperature and relative humidity

- identification of sensitive collections
- identification of high-risk areas (e.g. areas with high humidity, intense sunlight or poor ventilation)

Even simple observations and basic measurements can provide valuable information at this stage (Heritage Collections Council, 1998).

Phase 2: Prioritization and Low-Cost Interventions

Once the key risks have been identified, the museum can implement targeted interventions that require minimal resources. These may include: (Council of Europe, 2017; Heritage Collections Council, 1998).

- moving sensitive objects out of direct sunlight
- using shading systems and curtains
- controlled ventilation practices
- using silica gel or local temperature-regulating materials
- improved cleaning and dust control

These measures are particularly important because they provide immediate benefits without requiring significant investment (Heritage Collections Council, 1998).

Phase 3: Progressive Improvement and Monitoring

The final phase involves the gradual development of a more structured environmental management system. This may include: (Council of Europe, 2017; Heritage Collections Council, 1998).

- expansion of monitoring systems
- improved recording of environmental conditions
- training and awareness-raising of staff
- evaluation of existing strategies and adaptations based on the data collected

This step-by-step approach ensures that environmental management becomes part of the museum's daily practice and not a one-off intervention (Council of Europe, 2017).

Importantly, this framework reflects the realities observed in the case studies presented in Chapter 4, where environmental management is often implemented incrementally rather than through large-scale technological solutions.

5.14 Future Research and Implementation Opportunities

While this thesis provides a framework for sustainable environmental management in small

museums, it also highlights several areas that require further research and development.

An important direction for future research is the **collection of long-term environmental data** in small museums. The lack of systematic monitoring remains a major limitation, making it difficult to assess environmental trends and evaluate the effectiveness of management strategies over time.

Another area of interest is the development of **low-cost monitoring** technologies and simplified tools that can be easily used by small institutions. Advances in digital

technologies may offer new opportunities to improve environmental management without increasing operational complexity.

Further research could also explore the adaptation of international standards to Mediterranean climates, with an emphasis on developing region-specific guidelines that reflect local environmental conditions and institutional constraints.

Furthermore, comparative studies involving a larger number of museums in different **Mediterranean regions** would provide a broader understanding of environmental challenges and adaptive strategies.

Finally, there is a need to explore the relationship between **visitor experience** and **environmental control**, particularly in museums that rely on natural lighting and open spatial arrangements.

The findings of this thesis suggest that future research should continue to focus on the intersection of preventive conservation, sustainability and climate change adaptation, with particular attention to the needs of small and medium-sized institutions.

These approaches demonstrate that practical and scalable solutions can significantly improve environmental management in small museums.

Conclusions

This thesis examined the management of indoor environmental conditions in small museums operating under Mediterranean climatic conditions, with particular emphasis on museums located in Western Greece. The study explored the principles of preventive conservation and demonstrated their importance in supporting the long-term preservation of museum collections while balancing operational and financial constraints.

The findings confirmed that environmental factors, particularly temperature, relative

humidity, light exposure, air quality, pollutants, and biological activity, play a significant role in the deterioration of museum collections. The impact of these factors varies according to the nature of the collections, with organic and composite materials generally showing greater sensitivity to environmental fluctuations than many inorganic archaeological materials. At the same time, archaeological collections remain vulnerable to corrosion, salt crystallization, pollutant-related deterioration, and moisture-related damage.

The research also examined the applicability of international standards and professional recommendations, including those developed by ICOM, ICCROM, ASHRAE, and European standards. The analysis showed that while these standards provide valuable guidance, their direct implementation may be difficult for small museums with limited financial and technical resources. As a result, flexible and risk-based approaches are often more realistic than strict adherence to ideal environmental conditions.

The case studies highlighted several common challenges faced by small museums in Western Greece, including environmental instability, seasonal fluctuations in temperature and relative humidity, limited monitoring capacity, building-related constraints, and restricted financial resources. The comparative analysis further demonstrated that collection type, building characteristics, and local environmental conditions significantly influence environmental management priorities and conservation risks.

The study identified a range of current environmental management practices, including passive environmental control measures, natural ventilation, localized climate control, monitoring activities, preventive conservation practices, and practical low-cost conservation strategies. Although the level of environmental control differed among the case studies, all museums relied to some extent on adaptive management approaches designed to balance collection preservation with available resources.

Based on the findings, this thesis developed a set of practical, sustainable, and cost-effective guidelines for improving internal environmental management in small museums operating under Mediterranean climatic conditions. The proposed recommendations emphasize preventive conservation, environmental monitoring, risk reduction, visitor comfort, energy efficiency, and the use of realistic management strategies adapted to local conditions and institutional capacities.

The main contribution of this thesis lies in the integration of theoretical principles, international conservation guidance, and case study evidence into a practical framework

specifically tailored to the needs of small museums. The study demonstrates that effective preventive conservation does not necessarily require technologically advanced systems but can also be achieved through informed decision-making, appropriate monitoring, adaptive management, and sustainable environmental practices.

Future research could further investigate the long-term effectiveness of low-cost monitoring systems, the use of regional climatic data in environmental management, and the development of site-specific conservation strategies for museums located in Mediterranean and coastal environments.

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Appendix A: Case Study Data Summary

This appendix presents a summary of the environmental observations and qualitative data collected for the case studies included in this dissertation. The data are based on literature review, observational analysis, and previously conducted academic work.

Museum	Climate Issues	Main Risks	Management Practices
Moyseio Ellinikis Istorias Pavlou Vrelli	High RH (winter), high T (summer)	Mold, wax deformation	Dehumidifiers, shading
Archaeological Museum of Nikopolis	Solar gain, humidity	Corrosion, fluctuation	Partial HVAC
Archaeological Museum of Arta	Poor control	Instability	Basic ventilation
Museum	Climate Issues	Main Risks	Management Practices
Folklore Museum of Preveza	Humidity fluctuations, marine influence	Mold growth, light damage, biological activity	Passive ventilation, cleaning, preventive monitoring

Appendix B: Questionnaire for Museum Professionals

B.1 Introduction

This questionnaire has been designed to collect qualitative information from museum professionals regarding the management of internal environmental conditions in small and medium-sized museums operating under Mediterranean climatic conditions.

The aim is to gain insight into current practices, challenges, and decision-making processes related to preventive conservation and environmental management.

Participation is voluntary, and responses are intended for academic purposes only.

B.2 Questionnaire

Section 1: General Information

1. What is the name of your museum? (*optional*)
2. What type of museum do you work in?
 - Archaeological
 - Folklore

- Historical
 - Other
3. What is your role in the museum?
- Curator
 - Conservator
 - Administrator
 - Technical staff
 - Other
4. Approximately how many employees work in your institution?
- 1–5
 - 6–10
 - 10+

Section 2: Building and Environmental Conditions

5. What type of building houses the museum?
- Historic
 - Modern
 - Adapted building
6. Does the building have insulation?
- Yes
 - No
 - Partially
7. How would you describe the indoor environmental conditions?
- Stable
 - Moderately stable
 - Unstable

Section 3: Environmental Management Practices

8. Does the museum use any climate control systems (HVAC)?
- Yes
 - No
 - Partially

9. How are temperature and humidity managed?

(open-ended)

10. Do you use any passive environmental control strategies (e.g., shading, ventilation)?

- Yes
- No

11. Is environmental monitoring conducted?

- Yes (continuous)
- Yes (occasionally)
- No

Section 4: Environmental Challenges

12. What are the main environmental challenges in your museum?

(open-ended)

13. Which environmental factor is the most difficult to control?

- Temperature
- Relative humidity
- Light
- Air quality

14. Have you experienced any of the following issues?

- Mold growth
- Material deformation
- Corrosion
- Light damage
- None

Section 5: Resources and Limitations

15. What are the main limitations affecting environmental management?

(open-ended)

16. Is energy cost a limiting factor for climate control?

- Yes
- No

17. Do you have access to conservation specialists?

- Yes
- No

Section 6: Sustainability and Future Needs

18. Are sustainability and energy efficiency considered in your environmental management decisions?

- Yes
- No

19. What improvements would you consider most important for your museum?
(open-ended)

20. Would you be interested in adopting low-cost environmental management solutions?

- Yes
- No

Author's Statement:

I hereby expressly declare that, according to the article 8 of Law 1559/1986, this dissertation is solely the product of my personal work, does not infringe any intellectual property, personality and personal data rights of third parties, does not contain works/contributions from third parties for which the permission of the authors/beneficiaries is required, is not the product of partial or total plagiarism, and that the sources used are limited to the literature references alone and meet the rules of scientific citations.