Challenges of the Jordanian museums : the role of environment in preventive conservation

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INTRODUCTION

Introduction

1.1 General introduction

Museums are a collection of knowledge and ideas, connected to objects and artefacts that have been stored throughout the centuries. Museums can make visitors more aware of their heritage, history and culture.

Most museums hold in their custody collections of artefacts that must be curated as cheaply and efficiently as possible, as well as being displayed and safeguarded. Over the last few decades, the image of the function of museums has changed from being merely a place of storage focused on the past, to a forward-looking venue of social engagement and an agent of change.

Museums visitor numbers all over the world are increasing constantly and the numbers of museums themselves are augmented day by day. Museums have a key task to play in providing an understanding of identity and a sense of belonging to a place or community. In the face of immense and often painful cultural change in many countries, museums can provide a valuable sense of connection with the past and present and serve as a springboard for the future. Museums as a cultural phenomenon are of significant recognition. Their value has changed over time as political and cultural values have developed. Today, museums can play a major part in the cultural and economic life and well-being of a country. Taken as a whole, their collections represent a unique resource reflecting a country's achievements and progress and its historical development. Museums as part of the collective memory deserve to be supported for the range of benefits, which they bring. Museum workers have a special responsibility in acting as guardians of that memory. Without memory, we cannot go forward.

Recent years have witnessed a huge increase in the number and scale of archaeological excavations in Jordan. A large number of archaeological materials have resulted from these excavations. These irreplaceable and important material cultural remains are under threat of damage and destruction, even those that are placed in the various Jordanian museums. As long as the purchasing of archaeological artefacts remains illegal in Jordan and while donations remain scarce, the main source of objects for museums is excavations.

Objects retrieved through excavations need to be dealt with following a specific procedure, which includes: field documentation; movement control; a documentation and registration system; conservation and preservation; a system for the storage and removal of materials; the display and interpretation of objects. This procedure should be part of the obligation of every museum toward objects. However, Jordan is still in the phase of developing its procedures for dealing with objects from excavations.

The time has come to recognize the extreme importance of the archaeological sites in Jordan. They provide a wealth of evidence and precise information regarding ancient civilizations and cultures. Each archaeological site in Jordan yields archaeological objects and artefacts, which are ultimately destined for storage or display in museums. It is therefore necessary for Jordan to have the knowledge and expertise to handle, conserve, preserve and exhibit this rich harvest of archaeological treasures in the manner that they deserve.

This study will investigate the indoor environments that Jordanian museums provide for their collections, in order to determine whether these collections are being exposed to unsuitable environmental conditions, which might lead to their deterioration and damage. The significance of this study will become clear through a description of the current environmental situations at selected Jordanian museums and the exploration of the different parameters that are involved in the stability of indoor environments in museums. This study will provide a scientific basis for a government policy that would insure the safety of museum objects.

Moreover, this might put an end to any current situation in the museums that threatens the destruction of these valuable, but vulnerable objects.
Most of the artefacts excavated in Jordan end up in Jordanian museums, either on display or in their storage facilities. Conservation and subsequent preservation of these artefacts are of vital importance. The valuable cultural legacy represented in and by these artefacts should not be squandered as a result of a lack of knowledge of and expertise required for, their handling and display in the correct manner and environment. In addition, Jordan is about to establish a number of specialized museums and a new national museum that should be based on the international standards for museums. These new museums will require this knowledge and expertise.

1.1.1 Objectives

This PhD thesis seeks to investigate the current environmental conditions at Jordanian museums, through tracing, defining and evaluating the parameters of the local environments. The range of concepts that contribute to the stabilization of the objects displayed at Jordanian museums have been investigated using technical methods which will lead eventually to the long-term stabilization of these objects. This is after all one of the basic tasks of any museum. This research will also ask to what extent these museums comply with international museum standards, in terms of providing a safe environment for the exhibition and preservation of the valuable artefacts they host. The museums need to be provided with the necessary monitoring tools and environmental control systems to maintain temperature and relative humidity within the required ranges. The first step towards achieving this goal is through finding the most appropriate climate controls to suit these museums.
This doctoral study also aims to explore the current situation of the lighting systems within the selected Jordanian museums, in order to assess the total exposure of the objects to both natural and artificial light and determine whether the displayed objects are under threat of unsuitable lighting. The air pollution in the Jordanian museums has also been monitored in order to study the indoor environments of the museums and establish any correlation with the outdoor environment. This will help determine whether the museums provide an isolated environment, or whether the outdoors has an influence on the indoor atmosphere.

1.1.2 Justification

Jordanian museums contain important collections that require a controlled indoor environment, to ensure their preservation and minimize their deterioration. In absence of a controlled indoor environment, these objects would be in great danger. Thus, museums must provide at least the minimum requirements for keeping and preserving objects in their current shapes and conditions. Therefore, it seems important to conduct an inclusive study to cater to the needs of Jordanian museums and have these museums improved and developed, in order to portray the best possible image of Jordan and its history.
A museum audience expects to be able see the exhibited objects of a collection clearly and in an optimal condition. Therefore, it is the dual role of the museum administration to meet the visitor’s expectations and at the same time protect the objects from any deterioration which might occur from unsuitable environmental parameters. The importance of the indoor environment in museums cannot be neglected. It should be considered one of the major elements in the mission of any museum. In other words, museums are in need of a suitable indoor environment in order to maintain their collection and meet their visitors’ requirements and expectations. This will prevent any deterioration of collections in the future.

1.1.3 Presentation

This thesis will first introduce the subject of museums and give a brief history of Jordan and its museums. In addition, the first part of the study will present a concise overview of the regulations in place for the discovery and loan of museum objects in Jordan. A lack of available literature discussing Jordanian museums in general was the reason for the comprehensive visual description and evaluation of the selected Jordanian museums that is also presented in this work.

The main focus of this study is an investigation into the internal environmental conditions of seventeen Jordanian museums, one museum repository and one archive. These cultural institutions are: The Museum of Jordanian Heritage, The Natural History Museum, The Numismatics Museum (run by Yarmouk University), The Archaeology Museum, The National Heritage Museum (run by the University of Jordan), Ajloun Museum, Aqaba Museum, The Dar Alsaraya Museum. The Folklore Museum, The Jarash Museum, The Jordan Museum of Popular Traditions, The Jordan National Gallery of Fine Arts, The Karak Museum, The Madaba Museum, The Petra Museum, Salt Museum, The Umm Qeis Museum and the Department of Antiquities main repository and archive in Amman. All these cultural heritage institutions are located in Jordan. In each of these institutions, several factors of the indoor environment were measured: humidity, temperature, light (natural and artificial) and air quality. Our examination concerns the extent to which Jordanian museums conform to recommended conditions and international standards for housing collections, so that they provide a safe environment for the display and preservation of artefacts. At the same time, the study will conclude whether the monitoring and control systems are adequate for maintaining temperature and humidity within the required ranges. It is worth noting here that the museums are located in different climatic zones.

A literature survey, presented elsewhere in this thesis work (Chapter 2) and discussions with the responsible persons at the selected museums have revealed no published research regarding the effects of air pollution on museum objects in Jordan.

The first step towards achieving a safe environment for the objects, either displayed at museums or kept in storage, is finding the most appropriate climate controls to suit the museums. Therefore, light, humidity, temperature and air pollution were monitored over a specific time period, using modern methods and measuring devices: OnGuard^{TM} 3000, Atmospheric corrosion monitoring coupons and ELSEC 764 environmental monitor. Additionally, the variations in humidity, light, temperature and air pollution inside the museums were compared with the variations of these factors in the exterior atmosphere, to assess the degree of consequential fluctuations. And to determine whether there is a relationship between the indoor and the outdoor environments.

The chapters of this PhD thesis are connected through their focus on the indoor environment of Jordanian museums. In each chapter, selected Jordanian museums are investigated in order to have covered most of the Jordanian museums by the end of the thesis. The first one (Chapter 3) focuses on the visual and theoretical evaluation of the current situations at Jordanian museums. The location and history, building and interior, management, exhibition and collection and indoor environment are the main elements which are described and assessed for each museum. Chapter 4 discusses the light quality of fourteen museums by using the ELSEC 764 environmental monitor; Chapter 5 deals with air quality inside eleven locations using atmospheric corrosion monitoring coupons; and Chapter 6 is concerned with the overall environment quality inside one museum and one storage location by using the OnGuard^{TM} 3000 atmospheric corrosion monitor.

1.2 Museum characteristics

1.2.1 Collections

Almost everybody collects something or at least has a few objects that he is proud to have other people admire. Most communities have one person noted for his collection on display at his home that reflects his personality. These collections might be comprised of, for example, house plants, stamps, or even ancient antiquities. Along with this natural tendency to collect things comes the desire to show them to others, to seek admiration and respect. Many people who have spent their leisure hours accumulating objects decide upon retirement to open a museum. In this way, local museums are established (Burcaw 1983; Alghazawi 2003). If we trace the history of museums and how they were founded, we find in particular two factors which have stimulated the antiquities industry and encouraged amateurs in this field to collect objects, the economic and the religious factor.

Economic factor

Most ancient collections contained artefacts made from valuable materials, which had rare artistic and economic value. These collections belonged to kings, princes and wealthy people who used the goods to flaunt their affluence. As well as people who collected objects for self-promotion, there were amateurs who were interested in collecting valuable antiquities for trading. A notable example of the latter type of collector is the collection of Albrecht, Duke of Bavaria, who competed with other European royalty to amass art and oddities. His collection included some 800 painting (Burcaw 1983). Thus, the economic value of collected goods was one of the main factors that led wealthy and influential people to acquire such valuable artefacts.

Religious factor

During the emergence of Christianity, religious institutions depended on art to advocate religion and educate people about basic religious principles. Therefore, religiously-themed pieces of art were given the full support of the church. Here it can also be suggested that religious value was not the only reason for artistic collections, but that the manufacturing of valuable art added an economical importance, as artworks were given as gifts to religious institutions by ordinary people wishing to express their religious feeling (Dabbagh and Rasheed 1979).

1.2.2 Historical background

This section will briefly outline the history of museums. The museum most frequently cited as the forerunner of the present day museum was the museum at Alexandria, which was established by Ptolemaeus Soter (Ptolemy I) in about 290 B.C. It was a centre of learning dedicated to the muses and it consisted of a lecture hall, a mess hall, a court, a cloister, a garden, an astronomical observatory, living quarters, a library and held a collection of biological and cultural objects. The director of the museum was technically a priest. There were four groups of scholars: astronomers, writers, mathematicians and physicians. All were Greek and their salaries were paid from the royal treasury. Their main job was to conduct research. This was the first establishment ever set up by a state for the promotion of literature and science and acted as both museum and research centre (Burcaw 1983 ; Woodhead 1989). From the time of its creation in the third century until its destruction seven centuries later, it was the brain and heart of the ancient world. The Alexandria Library faced continuous destruction in the third and fourth centuries. Civil commotions damaged the library ar various times, and the collections and library housed in the museum proper were largely destroyed during an uprising or riot in the reign of Aurelian (A.D. 270-275) (Burcaw 1983). The part of the librtary located in the temple of Zeus was destroyed under the Odosius the Great in the name of Christianity when he destroyed all the heathen temples (about A.D. 380-390) (Burcaw 1983). The last scientist who worked in the library was a mathematician, astronomer, physicist and the head of the Neoplatonic school of philosophy her name was Hypatia. She continued to work until, in the year 415, on her way to work she was set upon by a fanatical mob of Cyril's parishioners, this was the ultimate destruction of the Alexandria Library. The last remnants of the Alexandria Library were destroyed soon after Hypatia's death. The loss was incalculated (Richeson 1940).

After the Greeks, museums as such disappeared for hundreds of years. During the Middle Ages, the great churches and abbeys accumulated natural curiosities and religious relics. Private collections, called ‘cabinets’, appeared in Europe in the 17th and 18th centuries and were the hobby of the wealthy. The emphasis was on the entertainment value of objects as a result of their strangeness or rarity. These private ‘cabinets’ show that a collection being on show to the public has not always been considered an important concept. The abbey of Saint Vincent, in Besancon, France, is one of the earliest known examples of public admission to a museum. Abbot Boisot on his death in 1694 left his personal collection to the abbey, with the provision that the public should be admitted regularly to see it (Burcaw 1983; Alghazawi 2003).

From the 16th century onwards, corporate bodies began to appear with the intention of making collections of objects available for public viewing. An important step towards the public museums of today was Britain’s first public museum. The Ashmolean museum, part of the University of Oxford, England, was opened in 1683. This was followed by the British Museum in 1759, which was opened by the British government (Woodhead and Stansfield 1989).

In revolutionary France in 1790 the Republicans who took over the royal palace at Versailles were amazed to find themselves in possession of the kings’ collections of artistic works. Instead of destroying these treasures, they decided to claim them for the common people and put them near the people in the former royal palace in Paris for democratic enlightenment and inspiration. Thus, it can be claimed that one of the most important museums in the world is the Louvre, the collection of which was enhanced by Napoleon through what he took from the foreign countries he conquered as he expanded the French empire (George and Sherrell-Leo 1986).

In the Arab region, the first museum was established in Egypt in 1858. Known as ‘Bollaq Museum’, all the exhibited materials were archaeological artefacts. In 1925, a museum was established in Iraq, which consisted of one small room (Dabbagh and Rasheed 1979).

1.2.3 Definition of museum

The word *mouseion* was first used by the Greeks in about 290 BC and was used to mean "a place of contemplation or shrine of the muses" (Dabbagh and Rasheed 1979). The word was also used by the Romans to describe "a place of philosophical discussion" (Woodhead and Stansfield 1989). By the 17th century the word ‘museum’ was used to describe collections of curiosities and by the 18th century the term came to mean "an institution set up to preserve and display a collection owned by and opened to the public" (Woodhead and Stansfield 1989). Today in practice, the word museum has many definitions but the two most widely adopted definitions are given here:

"A non-profit permanent established institution, not existing primarily for the purpose of conducting temporary exhibitions, exempt from federal and state income taxes. Open to the public and administrated in the public interest for the pursue of conserving and preserving, studying, interpreting, assembling and exhibiting to the public for its instruction and enjoyment objects and specimens of educational and cultural real, including artistic, scientific, historical and technological materials" The definition of the American Association of Museums (Ambrose and Paine 1993).
"A non-profit making permanent institution in the service of society and its development and open to the public, which acquires, conserves, researches, communicates and exhibits, for the purpose of study, education and enjoyment, material witness of man and his environment" The definition of the International Council of Museums (ICOM) (Ambrose and Paine 1993).
Among the numerous roles of the museum expressed in these definitions, two are of concern to this study: preserving and conserving. These tasks are considered to be the main tasks of a museum.

1.2.4 Classification of museums

Museums vary enormously in size, from great international museums to the smallest, one-room, village museum. They also vary enormously in their purpose, with some intended purely to amuse and entertain holiday makers, while others preserve the data on which scientific research is based. They vary in terms of their collections. They vary in who runs them. They vary in the public they seek to serve (Ambrose and Paine 1993).
The following table describes how museums are classified:

Table 1.1 Classification of museums (Ambrose and Paine 1993)

Classified by collections	
- General museums - Archaeology museums - Art museums - History museums - Ethnography museums - Natural history museums	- Geology museums - Science museums - Military museums - Industrial museums - Etc.
Classified by who runs them	
- National museums - Regional museums - Local museums	
Classified by the audience they serve	
- Educational museums - Specialist museums - General public museums	
Classified by the way they exhibit their collections	
- Traditional museums - Open-air museums - Historical museums	

1.2.5 Museum storage

In spite of the fact that in most museums the bulk of the collections is in store rather than on display, researchers have paid little attention to this issue. The same standard of care needs to be exercised for materials whether on display or in storage, because collections may be moved continuously from storage to the museum and vice versa.

Storages have special requirements: a secure building; a big and accessible entry and exit; suitable environmental conditions (in microclimates and throughout the whole building); systems and procedures for documenting the entry, exit and location of items and for auditing and stocktaking. Furthermore, there needs to be enough space for handling procedures and equipment.

1.2.6 Acquisition: Objects in a soil context

Archaeological museums largely obtain their objects from excavations. It is relevant to this study dealing with preservation of objects of all sorts of materials, to know about the influence of the soil context on the chemical and physical quality of these objects. It has been widely assumed that cultural materials excavated as part of the archaeological process had been kept in a relatively stable condition because of their long interment underground. However, the environmental pollution of the last century has created acidification of ground and lakes and caused serious damage to cultural heritage. Outdoor monuments suffer from this pollution, as do buried archaeological remains (Anders *et al*. 2005; Kars and Van Heeringen 2008).

It has been shown that modern industry and changes in agricultural methods have resulted in dramatic changes in the conditions of buried archaeological remains (Kars 1998). Soil is under threat of degradation, which is defined according to the International Organization for Standardization as “the process in which the land, due to natural processes or human activity, is no longer able to sustain properly an economic function and/or the original natural ecological function” (Standardization 2002).

This International Standard gives guidelines for the selection of and methods for appropriate tests for the determination of biodegradation of organic chemicals in soil samples. However, in recent archaeological excavations, artefacts have been found that, although deteriorated, have kept their original shape. This is one of the main goals that many museums strive to achieve (Standardization 2002).

The soil context and the underground environment change over time and providing a suitable environment for buried archaeological artefacts is not a function required of the soil context. However and perhaps somewhat surprisingly, archaeological excavations have revealed distinct cultural materials in their full shape. This could be because either the objects were buried in a fitting environment and kept that way, or these buried materials have reached equilibrium with their surroundings; ‘conformed’ to acclimatization demands. Thus, the study, prior to excavations, of the surrounding environment with respect to buried materials and of the connection between soil and materials is of vital importance (Kars and Van Heeringen 2008).

On one hand, archaeologists have observed an increasing tendency for recently excavated iron artefacts to deteriorate due to accelerated corrosion (Gerwin and Baumhauer 2000). On the other hand, excavation materials are generally exposed to a new environment. The mineral and humidity characteristics of the embedding environment might have resulted in the objects being saturated with moisture. They cannot absorb more moisture, but once removed from the

ground, this moisture can evaporate easily. Therefore, preventive conservation is required to help the materials to reach a new balance in the new context of a museum.
Excavated material culture needs to be hosted in a microenvironment that is as similar as possible to the environment from which it was removed. This microenvironment could be in the form of a showcase, or a frame for paintings, textiles and paper (Kars 1998).

1.3 The museum context in Jordan

The Jordanian museums contain important collections that require certain environments to ensure their preservation and minimize deterioration. In the absence of suitable and efficient indoor environmental controls, these objects would be in great danger. In the following chapters those indoor environmental aspects will be addressed. However all those indoor environments have a common connection with the outdoor climate environment, which varies strongly throughout the country, so this aspect should be dealt with first.
The museum collections in Jordan are generally housed in non-specific buildings; furthermore these collections are varied, resulting in a variety of types of museums, but with a large majority of archaeological ones. Therefore special attention should also be paid in this introductory chapter to archaeological collections and their acquisition.

1.3.1 Geographical aspects, geomorphology and climate of Jordan

Jordan lies in the extreme north-western part of the Arabian Peninsula. The location of Jordan in the Mediterranean region, combined with its climatic and historical characteristics, determines this country's high recreational potential (Ufimtsev 2007). Jordan occupies an area of approximately 96,000 square kilometres. In spite of this small area, it has a diverse terrain and landscape and therefore a varied climate (Casto and Dotson 1938). Jordan consists mainly of a plateau, which is between 600 and 1500 metres high and which is divided into ridges by east-west running valleys and gorges (Ufimtsev 2007), going down into the Rift Valley, which runs from Turkey southward alongside the Sinai Peninsula. The eastern edge of Jordan is part of this rift, the Jordan Valley, which falls to 400 metres below mean sea level, the Dead Sea and Wadi Araba into the Gulf of Aqaba. Although Jordan is an earthquake-prone region, no severe shocks have been recorded for several decades (Sharon 1979).
Jordan's plateau and mountains, together with the wide, deep valleys result in a strong diversity of climatic zones in this country. Thus Jordan can be divided into three main physiographic regions, described below, each with distinct climate regimes based on equi-topographical features.

The Jordan Valley region (Ghor)
Along the western edge, the Jordan Valley region (*Ghor*) is part of the great Rift Valley that extends from southern Turkey through Lebanon and Syria to the salty depression of the Dead Sea, where it continues southwards towards the Red Sea. The Jordan Valley is the most fertile region in Jordan and it is the 'food bowl' for the country (Salameh 1996). At its highest point, the valley lies 32 metres below mean sea level and falls to about 405 metres below mean sea level at the Dead Sea, the lowest place on the earth's surface. This region is several degrees warmer than the rest of the country because of its location on the lee side of the West Bank mountains from which the prevailing dry and hot westerly wind descends into the region. The maximum temperature is rarely below 40 °C in summer or below 20 °C in winter (Sharon 1979; Altayyar 2009).

Mountain region

The mountain, or highland, region is located to the east of the Jordan valley, extending as a narrow strip from north to south, alongside the Jordan Valley. Parts of this region are rugged and are intersected by valleys and riverbeds. The majority of the population inhabits this region, suitable for agriculture because of its Mediterranean bio-climate. It receives the highest rainfall in Jordan, especially in the northern parts such as Ras Munif and Irbid, which are included in this study. This region, especially in the north, is exposed to the frontal depressions that invade the East-Mediterranean region mainly in winter. In fact, the area is considered to be the principal track of the Cyprus low depression (Altayyar 2009). In addition, the highland area is exposed directly to the sea track over the Mediterranean Sea, which intensifies the rainfall rates in this area. The southern heights, in comparison, have medium amounts of rainfall, since the area is not exposed directly to the frontal depression. Besides, the area is located to the east of the Sinai desert, where the frontal depressions follow a long land track and lose humidity (Casto and Dotson 1938). The elevation of the mountain heights varies from 600 metres to more than 1500 metres above mean sea level. Because of the abundance of water and its strategic location, the highlands are the most densely populated areas today, encompassing most of the major cities in Jordan (Ufimtsev 2007).

It is in these highlands that we find the major remains of ancient civilizations, from north to south, in the cities of Umm Qeis, Jarash, Amman, Madaba, Karak and Petra (Altayyar 2009).

The eastern semi-arid region or Badia region

The term *Badia* is used throughout much of the Middle East and refers to arid, desert environments, where there is little or no permanent vegetation, infrequent precipitation and intermittent surface water. In Jordan, the *Badia* is sub-divided into a number of areas. The eastern *Badia* extends from the margin of the Amman conurbation towards Iraq and between the international boundaries of Syria to the north and Saudi Arabia to the south (Allison 2000). This region comprises about 75% of the total area of Jordan. The eastern *Badia* is characterized by low, gently undulating topography. Altitude reaches a maximum of 1200 metres in the north, on the foot-slopes of the Druze Mountains in Syria, with a gradual decline in absolute relief to around 400 metres in the south. The aridity of the region is due to its location to the east of two mountainous terrains, the western hills in Palestine and the eastern hills in Jordan, where the westerly prevailing wind descends dry and hot into this region (Allison 2000). Mean annual temperature and precipitation figures for the eastern *Badia* highlight the seasonality of climate and the relief control of the Druze Mountains. Mean annual temperatures reach a maximum of 35 °C to 38 °C in August and a minimum of 2 °C to 9 °C. In winter, when cold air reaches the eastern *Badia* from the continental interior, it is not unusual for temperatures to drop below freezing. The highest and lowest recorded temperatures in the eastern *Badia* are 46 °C and −12 °C respectively. Mean annual rainfall ranges from less than 50 millimetres in the south to over 250 millimetres in the north (Allison 2000).

Summarising climate variability in Jordan

Jordan is located about 80 kilometres east of the Mediterranean Sea, between 29˚10 'N to 33˚45 'N and 34˚55 'E to 39˚20 'E with an area of 89 329 square kilometres and a population of 5.5 million. The western part of the country is the world’s lowest valley, which lies in a north–south direction between two mountain ranges and has a length of about 400 kilometres. The width of the valley varies from 10 kilometres in the north to 30 kilometres in the south and it lies between 170 metres and 405 metres below mean sea level (Ufimtsev 2007).

The Jordan River passes through this valley from north to south down to the Dead Sea and comprises approximately one-third of the border between Jordan, Palestine and Israel. The Jordan River is the main source of irrigation in the Jordan Valley (Sharon 1979). Just to the east of the Jordan Valley, the north–south mountain range rises to about 1150 metres above mean sea level in the north and to about 1500 metres above mean sea level in the south, reaching its highest peak of 1854 metres in the southern-most region. To the east of this mountain range is a semi-desert plateau that covers approximately 80% of the country (Salameh 1996).
With assistance from the Jordan Meteorological Department, I was in 2009 provided with the Jordan weather track information gathered from 14 precipitation stations, with record lengths ranging between 33 and 78 years and from 14 temperature stations, with record lengths varying between 30 and 78 years (Allison 2000).
The average temperature in Amman the capital ranges from 8 ?C in January to 25 ?C in July. The temperature in the city of Aqaba also varies significantly throughout the year, from 16 ?C in January to 33 ?C in July (Altayyar 2009).

1.3.2 Museums in Jordan

Buildings of Jordanian museums as containers of objects
Buildings in Jordan are usually constructed from concrete bricks, with the exterior façade made from stone bricks. This kind of building in general does not provide an adequate insulation environment for objects kept or displayed inside. Even providing these buildings with an air conditioning system to maintain proper temperatures according to the international standards of museum indoor environments is difficult to achieve. Furthermore, it is expensive to maintain (Abdellatif 1993).
The museums in Jordan are built in the same way. Many were not built as ‘museums’; they are restored historical buildings and therefore it would be difficult for these building to transform to a museum, and they great effort and expertise to make these buildings capable to provide a suitable environment for preserving objects from deterioration. By contrast, a new purpose-built national museum, the Jordan Museum, has recently been constructed in Amman, but not yet opened to the public. Also the Museum of Jordanian Heritage in Yarmouk University, was built with the purpose of being a museum. It has a specific style of architecture that replicates Islamic building concepts from the Ottoman period and, in this way, is distinct from other local museums (Abdellatif 1993).
Here it should be noted that this present study and research is applicable not only to museum buildings, but could also be applied to other institutions with collections, such as libraries, archives, churches and historical buildings. Therefore, these buildings have also been included in the literature review (see Chapter two).

Types of museums in Jordan

Museums vary in terms of the function they perform. Referring to Table 1.1, it can be seen that museums can be classified in many different ways. Thus, if museums are classified by their collection, Jordan possesses museums specialising in archaeology, art history, natural science, geology and ethnography. But it should not be forgotten that there are other ways of classifying museums, depending on, for example, the audience they serve, or by the area they serve, like the Museum of Jordanian Heritage (university museum) and the Umm Qeis Museum (site museum).

Types of archaeological collections

Most of the museums in Jordan are archaeological museums. That is because of the large number of archaeological sites in Jordan and the amount and scale of archaeological excavations. Large amounts of archaeological material have been accrued from these excavations. Each site yields archaeological objects and artefacts that are ultimately destined for either museum display or storage (Abdellatif 1993). It should be notes that under the current law all archaeological objects are owned by the Jordanian State, represented by the Department of Antiquities.

In general, objects exhibited in Jordanian archaeological museums vary in the form and historical periods they represent, ranging from the Stone Age up to the different Islamic Ages. Archaeological excavations carried out by the Department of Antiquities, both in collaboration with domestic institutions and foreign missions, are the main source of the existing collections. Other objects have been obtained by gift, donation, or through exchange with local museums. The objects in the archaeological museums include: handmade pottery from all over the country and belonging to different eras; stone quarrying, rock engravings, mined materials, inscriptions and seals; human and animal bones belonging to different historical periods; numismatics, accessories, agricultural implements, artefacts relating to transport and commerce, including saddles and supply wagons, tools representing craftsmanship and industry; different kinds of glass artefacts; papers and wooden objects; works of art, portraits, national fashions, cosmetics, medicine and ethnographical common amulets and mining detritus (Alghazawi 2003).

1.3.3 Acquisition of archaeological materials in Jordan

Most museums in Jordan are archaeological museums and they therefore depend on archaeological objects and artefacts, which are retrieved from archaeological excavations in Jordan, to enhance their assets. These excavations are usually carried out by the Department of Antiquities (DoA), local universities or foreign missions. The number and scale of excavations have increased significantly in recent years and as a result, the number of excavated archaeological materials has also increased and these are ultimately destined for display in local museums or storage at the DoA main storage.

Whenever archaeological objects are discovered at these excavations, they are transferred from the excavation site to either a museum or to the DoA main storage. Thus, particular laws and regulations that organize this process must be constituted. My inquiries at the DoA and the Tourism Ministry about the organisation of the transfer of objects retrieved through excavations made clear that this is not governed by any Jordanian law, despite the fact that archaeological excavations have been taking place in Jordan since the 1920s.

The number of excavations in Jordan is increasing constantly. At present, approximately 70 archaeological projects are active in Jordan annually and most of these are carried out by foreign missions (Alkhraysheh 2007). The annual journal of the Department of Antiquities (Munjazat) presents the total annual number of excavations held in Jordan. I went through Munjazat 2002-2008 in order to establish the number of the annual excavations in Jordan in this time period and to identify the sponsor of each excavation. Although some excavations were performed by Jordanian universities and the Department of Antiquities, the survey reveals that the majority of excavations were executed by foreign expeditions. This information is illustrated in Table 1.2.

Table 1.2 Excavations held in Jordan

Year	DoA excavations	Foreign mission excavations	Foreign mission excavations in collaboration with Jordanian missions
2002	34	31	4
2003	18	20	1
2004	25	19	1
2005	10	21	1
2006	12	29	3
2007	17	35	3
2008	14	31	3
Total	130	186	16
Ratio	41%	59%	5%

However, the DoA is still in the process of proposing a law to set the rules for excavations and the movement and treatment of the excavated materials. Presently, the director of the DoA is the only person authorized to give permits for excavations and the decision on the final destination of the excavated objects is made through a DoA representative at the excavation site.

Despite the fact that Jordan has signed the UNESCO world heritage convention and is therefore obliged to make good regulations for archaeological Discoveries and artefacts loans, these regulations are still preliminary. In 2008 the DoA submitted a law proposal to the Prime Ministery to regulate the excavation processes, but at present this proposed law is used only as a tentative guideline for excavations and is not mandatory. Furthermore, an exception to these guidelines can be issued by the director of the DoA. In addition, these tentative guidelines are only available in the Arabic language, although the vast majority of the excavations are carried out by foreign missions. Obviously, this makes it difficult or even impossible for foreign excavation missions to make use of these guidelines. For this reason and with the permission of the director of the DoA, the guidelines are included here in my (non-official) English translation. The guidelines are divided into two parts: the first outlines the regulations for archaeological discoveries, while the second deals with the loan regulations for archaeological artefacts.

The Archaeological Discoveries Regulations in Jordan

1- The term ‘archaeological discoveries’ refers to any archaeological object, specimen and archaeological material waste that results from excavations or surveys, for example pottery, glass, metal, bones, parchment, textile, paper, wood, gemstone, whether they are:
- A complete artefact or single sherds.
- A collection of sherds.
- Sherds or any other samples.

2- This regulation should be applied to both national and international missions.

3- The excavation director, authorized by the Department of Antiquities, should organize and duly record the excavated objects.

4- The representative appointed by the Department of Antiquities should supervise the recording of the excavated artefacts and their packaging. The delegate should also guide national and international missions.
5- All excavated materials should be cleaned and kept in a way that insures preservation during transportation and for long-term storage.
6- Archaeological specimens like pottery sherds, glass, bones etc., are to be organized with separate lists.
7- All excavated materials are to be handed over to the main Department of Antiquities storage curator or to an authorized museum, in the presence of the Department of Antiquities appointed delegate and under the supervision of the archaeological inspector in the same city/district, in accordance with the guidelines. After his examination of the objects upon arrival, the Department of Antiquities archaeological inspector should sign the attached documents for receipt.
8- The archaeological inspector of the same city/district and the Department of Antiquities storage curator keep a copy of the signed statements. Another hard copy and an electronic one are sent to the Department of Antiquities to be kept in the documentation section.
9- The Department of Antiquities storage curator fills in an entry form for the received artefacts and a copy of the entry form is to be sent to the documentation section of the Department of Antiquities. This excludes the artefacts that the excavation director would like to borrow. In this case, the storage curator or the museum should keep statements for these objects.
10- If the excavation director would like to borrow any of the excavated artefacts, he should fill in a loan application form according to the Archaeological Discoveries Loan Regulations (permanent and temporary loan).

Archaeological Discoveries Loan Regulations (permanent and temporary loan) in Jordan

1- These regulations are to be known as the Archaeological Discoveries Loan Regulations. The terms within these regulations will have the following explanations:
   - Archaeological discoveries: refers to any archaeological object or archaeological waste material that results from excavations or surveys, for example pottery, glass, metal, bones, parchment, textile, paper, wood, gemstone, whether they are:
     - A complete artefact or single sherds.
     - A collection of sherds.
     - Sherds or any other samples.
   - Loans: the loan of archaeological artefacts as a whole or as a part, are classified as two different types:
     - Temporary loan: whole artefacts, or artefacts that can be reassembled in order to be suitable for exhibition. The period of a temporary loan in this case is one year. This period can be extended.
     - Permanent loan: this is a loan for artefacts which are unsuitable for display in a museum, but are beneficial for research purposes, for example: pottery sherds, bones, soil samples, etc.
   - The curator of the archaeological storage or museum: the curator of the storage or museum, who holds archaeological artefacts under his custody.
   - The representative: the Department of Antiquities has a representative in national and international excavation missions.
2- The excavation director must fill out an official application form one week before the excavation mission ends, specifying the aim and the type of object or specimen the

director intends to borrow, in terms of type, number, description, measurements, current condition and a clear photograph. This must be done in coordination with the archaeological inspector in the same city/district, the storage curator and the Department of Antiquities representative. Two documents, a hard and soft copy, should be attached.

3- If a student or a researcher wishes to make a study of one or more of the excavated artefacts, he/she should apply to the Department of Antiquities for permission to borrow these objects. This application should include his research intentions. Attached to the application form must be a description of the type of study, with a declaration from the director of the excavation, a letter from the university/organization the student/researcher is representing and a list of the quantity and locations, alongside descriptions and photographs of the artefacts he/she wishes to borrow.

4- Any archaeological finds in the excavations storage that are to be borrowed, either whole objects or samples, will be examined by a committee from the Department of Antiquities. Therefore, a report with these examinations should be submitted to the general director of the Department of Antiquities.

5- If a loan application is accepted, the director of the excavation or the representative of the organization must sign an agreement with the director of the Department of Antiquities. This agreement should declare the type of loan, the aim of the loan, the loan duration and a borrowing organization guarantee for the safety of the borrowed objects. A copy of this agreement must be sent to the museum or storage curator and another copy must be sent to the curator of the excavation storage.

6- The curator of the excavation storage or museum will transfer the borrowed objects to the Department of Antiquities main storage in Amman, at the expense of the borrowing organization, to be examined by an appointed committee. The objects will then be delivered to the main excavation storage curator who will pursue with the lending and transferring process, under the supervision of the archaeological supervisor of the same city/district.

7- A copy of the loan agreement and another copy of the list of the borrowed objects must be sent to the research directorate, documentation section, the national relations department, the excavation storage, the archaeological inspector and to the curator of the storage or museum, to be followed-up.

8- The borrowing organization pledges to carry out any conservation treatment on the borrowed objects at their own expense.

9- The borrowing organization must submit a copy of the research on the borrowed objects, whether this research was published or not, to be kept at the documentation section of the Department of Antiquities.

10- The shipping company will take over the packaging process for the borrowed archaeological objects in the excavation storage and when dealing with the representative of the National Relations Department and customs representative if necessary.

11- The Department of Antiquities will inform customs about the borrowed objects, in order to allow their shipping offshore.

12- The borrowing organization bears the shipping expenses back and forth for the borrowed objects and any fees owed.

13- If the borrowing application is denied by the Department of Antiquities, the archaeological objects should be returned to the museum or storage curator and this must accordingly be entered in the storage or museum records.

A LITERATURE REVIEW AND RECENT ADVANCES IN MUSEUM ENVIRONMENT

A literature review and recent advances in museum environment

2.1 Introduction

The conservation of artefacts and buildings has a long history and in order to develop the study of museums' environment, promote its effects and making use of the available possibilities, a study of the available literature would be essential.
In spite of the importance of the museum study, local specialized researchers were absent from this field. As far, there are a few studies done about the subject of museum and above preservation of collection against the environmental conditions and climate control in Jordan. On the other hand, in the international area sufficient research all over the world has been achieved about the ideal methods to protect collections from being deteriorated and manage their environment.
The growth of the number of museums is related to the growth of the literature museum studies, which reflects the importance of preserving the museum objects in ideal conditions. In addition, the importance of preserving the museum objects on ideal conditions is also reflected by the growth of the literature in museum environment studies.
Considering the data collected regarding the currently available published articles on museology, the international guidelines and rules concerning museum tasks, ongoing research worldwide and the general and specific needs in Jordan, this chapter will provide a comprehensive, adequate and up-to-date database for Jordanian museums' specialists and interested researchers, of who there concern focuses on subject of museum environment. The collected articles are concerning the museum environment issue in general; the collected articles were studied, critically analyzed and compared with relevant situations at Jordanian museum, in the sense of providing an opportunity for a fundamental base in education in the field of museums in general.
This review is an attempt to map out the different approaches to understanding how museum environment as a discipline has been studied. The literature discussed in this chapter will be also reviewed in order to examine the types of subjects in the field of museum environment that specialists have researched and which areas have been rather neglected. In addition, reviewing this literature will be a great opportunity to enhance my own knowledge and to take advantage of aspects of the reviewed literature that may be applicable to Jordanian museums.
The available literature that will be reviewed includes specialized books and recently published articles. Previously published studies are often referred to in these recent articles and books.

2.2 Motivation for this review

The prevalence of museum worldwide is in itself a motivator to exploit them for learning. This literature review maps the different approaches to understanding the museum environment as a discipline has been studied. In addition of providing a basis for this study, it also highlights which additional areas need to be investigated. The fact that museums are a worldwide phenomenon potentially makes such a study widely relevant.
On the other hand, there was a need for enhancing and diversify my knowledge in this field and to be aware of what has been written in recent years and which fields need to be investigated in addition.
The close relation of museums to the context of museum environment and the situation in which the museum environment need arises has been widely discussed and the benefits came for museums (and objects) just-in-time.

Most previous reviews of the museum environment categorize examples of use according to curriculum area in museology. I believe that the role of the museum environment in maintaining the museum's collections needs to encompass more than just theoretical studies into the daily practical actions of most museums. There is thus a need for a wider review of new and emerging conservation, preservation and management practices and how these relate to theoretical and practical studies in the available literature and how they could be taught. The review considers publications from 2004 onwards because earlier literature is readily available in recent publications.

2.3 Factors of long-term deterioration

Various environmental factors, which can cause the deterioration and destruction of cultural materials and if left unchecked can make the conservation treatment of objects difficult or even impossible. Even in some cases, some conservation treatments themselves may induce further destruction. The main factors of long-term deterioration can be classified as follows:

2.3.1 Humidity

Humidity is defined as "the amount of moisture in the air" (Thomson 1986). It has been known for over the last three decades that air exchange rate is fundamental to hygrometric performance of display cases (Thickett *et al*. 2007b). Relative humidity (RH) is an important factor in many biological and chemical processes; therefore, its control is vital. In nature, when dew point is reached, precipitation occurs as rain, dew, etc. In an enclosed space, warm moist air condenses on cool surfaces such as windows, so even the exhalations of museum visitors are a hazard. Extremes of either high or low humidity are harmful and potentially disastrous in the museum (Thomson 1986). The absorption of moisture from the surrounding air makes objects swell and vice versa and if the size of an object changes there will be a resultant change to its shape, causing it to warp. This distortion tends to be more pronounced if the museum objects are made of different materials and can lead to breakages due to different rate of contraction or expansion.

2.3.2 Light

- *Natural light*

Harnessing daylight as an exhibition source of light has many advantages: it is free, it is natural and it gives the displayed objects their natural colour. In addition, it is available most of the working hours of museums in general.

However, it has its disadvantages: Heat and light are forms of energy. Energy is defined as "it is conserved, which means that the total amount of energy in a closed system always remains unchanged" (Thomson 1986).

"Light can be divided into three regions by wave length: ultraviolet radiation (300-400 nm), light or visible radiation (400-760 nm) and infrared radiation (beyond 760 nm)" (Kuhn 1986). Both visible and ultraviolet light (300-760 nm) is a form of energy. The ultraviolet region is considered being the main cause of damage such as fading or degradation of organic materials; while the main harm comes from the infrared regions through bringing out heat for the entire indoor environment, causing dehydration and damage of shrinkage of all organic materials (Huber 2007).

The deleterious effects of natural light on the indoor climate mean that sun-exposed windows, together with the exhibition lighting, will lead eventually to an increase in the indoor temperature in summer (Huber 2007). The sun emits a "wide spectrum of electromagnetic radiation" and a significant part of these radiations create thermal effects on the indoor climate of a building (Druzik and Eshoj 2007).

- *Artificial light*

Lamps: the most common form of lighting in many countries is the ordinary round tungsten light bulb. In addition, there is a variety of different lamps designed specially for display purposes.

Here it should be noted that only absorbed energy causes damage. Therefore, museums can minimize light damage by minimizing the energy absorbed by artefacts, by using good lighting design to lower overall light levels (Miller and Miller 1994). Taking into consideration it will not reflect the exhibition role, because it is widely known that poor lighting always creates poor exhibits (Miller and Miller 1994).

2.3.3 Temperature

Fluctuation of temperature is the main reason for damage to artefacts because of the expansion and contraction of some of the museums objects at different rates. As temperature rises in an enclosed space at a constant absolute humidity, RH drops and vice versa (Grattan and Michalski n.d.; Thomson 1986).

High temperatures accelerate chemical reactions; i.e. the higher the temperature, the more rapidly objects will age and deteriorate. Abrupt changes in temperature cause stress in materials, which may result in damage. Such temperature changes may be caused by exposing objects in closed showcases to direct sunlight, or to spotlights. On the other hand, low temperatures in themselves do not generally cause damage to museum objects, in fact they can be of real benefit, e.g. by reducing bio-deterioration problems (Thomson 1986). However, low temperatures may affect objects through causing loss of brightness (Thomson 1986), in addition, low temperature will raise RH and it is impossible to control RH without taking account of temperature (Al-rousan 1998).

2.3.4 Air pollution

Air pollution is associated with towns and industry and is almost entirely caused by burning fuels. In addition, the car is responsible for a distinctly modern form of pollution known as the oxidant type. Not to forget here as well is that sulphur dioxide appears in the air as a result of burning fuels (Thomson 1986).

Ozone has a specific and complete effect on unsaturated organic compounds; *i.e.* it breaks every double bond of a carbon chain with which it comes into contact.

Dust is also an enemy to most museum exhibits. Composed of minute particles, when dust comes into contact with water it can become an active chemical agent that is corrosive and detrimental to most museum objects. Unfortunately, traditional methods of cleaning objects, *i.e*. through dusting, shaking, wiping, or washing, accelerate wear and tear, thereby increasing the risk of damage (Cronyn 1990).

2.3.5 Microorganisms

Microorganisms are sensitive to changes in the environment but certain species have adapted to tolerate extremes of RH, desiccation and the absence of oxygen. Their metabolism is not efficient and they excrete organic acids that are broken down to provide further energy. The three factors required for the growth of these organisms are nutrients, temperature and humidity, so it is possible to reduce and/or prevent their activity by controlling other factors such as humidity, temperature, dust and light (Cronyn 1990). The application of biocides against microorganisms is always accompanied by risks to health and to works of art, especially when used indoors (Krus *et al*. 2007).

2.3.6 Pests

Pests are defined as "any animal or insect that detracts from a museum's mission by damaging collection items or making locations unsuitable for work or visitors" (Lanier and Ford 2005). Insects are small, not easily visible and are usually found in tiny microclimates, such as under skirting, behind backboards and embedded in materials, which are difficult to reach during normal human activity. Pests are particularly destructive of organic materials. Successful insect development is dependent on a number of factors – the availability, quality and quantity of suitable food is a primary one and thus controlling these factors is of vital importance. Nevertheless, other factors such as light and having access to their destinations are another. The other factors such as temperature and relative humidity can affect objects through the content of the insect food materials.

Some pest insects such as Australian spider beetle and some cockroaches require liquid water to survive, while others such as silverfish and the furniture beetle require their food to have high moisture. Pests' infestations can destroy most of the museums objects or even cases where objects are kept. In addition, their metabolism will effect negatively on the objects, they excrete organic acids, which can be harmful for museum objects (Roberts 2004).

2.4 Studies on the reviewed literature

In spite of the importance of museology, there are only a few studies on the preservation of collections and the impact of environmental conditions and climate control in Jordan. Fortunately, research of this kind has been carried out in many places throughout the world, yielding information about and strategies for efficient and sustainable methods of managing collections.

The importance of preserving museum objects in ideal conditions is reflected by the growth of the literature on museum environment.

The existing literature in the field of museology reveals that every museum should carry out its own interior environmental study, in order to examine how far the museum provides a suitable environment for the valuable objects and artefacts in its custody and to conform to the international standards for museums, if they want to preserve their collections.

In order to be able to assess the environmental issues in Jordan's museums it is essential to carry out a thorough review and assessment of literature on this subject.

Most of this literature concerns case studies for a specific museum and are, therefore, not always applicable to other buildings, collections and contexts. The aims and objectives of these studies include the following:

- *Goals*

All of the reviewed publications were aiming to provide a proper indoor climate for the specified building and collections housed within it, from different perspectives.

- *Methods*

Most of the published papers measured the long-term effects on the environment from such agents as humidity, temperature, light, dust, air pollution and microorganisms. Humidity and temperature inside the buildings were always compared with the outside atmosphere. Also measured were the effects of the varying environmental conditions on specific objects.

- *Results*

The results in general revealed how far these museums, churches, libraries and archives required indoor climate control. In most of the studies, solutions and suggestions were given as to how to apply effective climate control, with emphasis given to passive climate control. In many cases, passive climate control was taken as a good solution, because of its easy application, low costs and sustainability.

The main hazards within museum environment that were discussed in the reviewed literature can be classified as follows, with summaries of the studies and their results:

2.4.1 Light

Twelve daylight fluorescent watercolour paints from the Dr. Ph. Martin Radiant Concentrated Watercolour line of products were studied by Connors-Rowe *et al.*
(2005), to evaluate their appearance and light sensitivity under the following lighting conditions: high and low correlated colour temperature sources, simulated daylight sources with ultraviolet light both included and excluded and black light (Connors *et al*. 2005). The tests showed that all the watercolours experienced a significant reduction in fluorescent emission when a low correlated colour temperature light source was used compared to a high correlated colour temperature source. Some of the watercolours when under exposure to black light had similar fading rates when under exposure to simulated daylight.

Druzik and Eshoj's study (2007) dealt with the issue of how the deleterious effects of light on materials has been the subject of academic study since the first systematic tests of lightness were carried out by Dufay in 1733. The study looked at how the results of scientific investigations have been used to preserve the colours of museum specimens, (Druzik and Eshoj 2007). The researchers investigated some important topics these topics are:

1- Improved understanding and use of colour rendering metrics.
2- Response to new lighting technologies that evolve from national or international energy conservation policy.
3- Acquisition of a larger number of damage spectra. Emphasis on acquiring sensitivity data on aged and new objects – including anoxic protection.
4- Consensus protocols for human assessments including issues of aesthetics and visual performance.

However, their relevance to the subject of the study was not explained. For that reason this study has little applicability.

Huber (2007) discussed the mechanisms of chest windows, which is an outer shading device similar to a closet with a sun protection, in museums. Chests of windows can be used as a heating source if they are maintained properly. When solar radiation meets a window pane, part of it is reflected, depending on the angle of incidence and a small part gets absorbed by the glass and is released to the environment as thermal radiation (Huber 2007). The author proposed an outer shading device in order to reduce the effects of sun radiation in a building, so that the running costs of an exhibition during summer can be reduced.

2.4.2 Microorganisms

The effects of temperature and relative humidity on insect activity have been largely neglected in specialist research into museum environments. Child's 2007 study provides us with very important information on this key issue (Child 2007). The author presents many relevant details through a field study. About the many ways of insects to obtain water and that for a high percentage of insects high humidity is not preferable, nor extreme cold or heat temperatures (Cronyn 1990), etc. Despite the unpopularity of this subject, the importance is shown by their field study, which the author makes a great effort in bringing this subject to the light and giving it the attention it deserves. This study lacks any suggestion for the use of pesticides, which could be the solution for many types of insects.

Krus *et al.* (2007) focused on the development of an instrument that predicts the formation of mould fungus (Krus *et al*. 2007). Most of the damage to collections of works of art in historic buildings is still caused by unfavourable climatic conditions, which cause the proliferation of mould growth. This problem is further exacerbated by world-wide climate change. In addition, the application of biocides, which are often used as a treatment, presents risks to human health as well as to the works of art themselves.

2.4.3 Passive air conditioning

Broecke's 2007 study described the problems encountered by the National Museum of Art in Maputo, Mozambique, with air conditioning and dehumidification units and efforts to establish an alternative, simple and cheap means of reducing the relative humidity (RH). This paper also focuses on the difficulties involved in ensuring the sustainability of the passive climate control strategy (Broecke 2007). The conclusion of Broecke's study may confuse the reader in terms of whether it was the shutting or opening of doors that made the RH drop. Another unclear aspect of the study was that it also mentioned that air conditioning and dehumidifiers were installed at an earlier stage, but the author did not mention if they were in use at the time the study took place.

Rasmussen (2007) considered in detail the shared storage facility of the Centre for Preservation of Cultural Heritage in Vejle, Denmark and how it is constructed in a way that supports the concept of passive climatization. The stores consist of four halls. In each hall a mezzanine floor was built (Rasmussen 2007). The idea is that the construction and the physical properties of the building materials can contribute towards establishing a stable climate on the basis of the outside climate. This is generally considered a better alternative to no climatization at all.

2.4.4 Airpollution

The 10-year-long study conducted by Cornelissen and De Jong (2004) examined whether ventilation contributes to the concentration of pollutants deposited on exposed materials. Materials were measured and tested against established guidelines (Cornelissen and De Jong 2004). For this project two archives were tested concerning their air change rates and the air velocity. The results indicated that the change rate and velocity were less than was recommended in the guidelines. In addition, air circulation was deemed insufficient.

Havermans (2004) inspected the quality assurance and the permeability of purified and non-purified storage of archival materials. The reference archival materials storing rooms have under-pressure and therefore all the air comes from the shaft, which is in direct connection to the outdoor air, so, it was proposed that the air inside is non-purified. The permeability of the filter systems or SO_2, NO_x and O_3 for example depends on the saturation of the filter particles. From the author results, it was shown that the media does indeed filter the impurities away from the archival records (Havermans 2004). This paper also assessed the advantage of using sealed pouches as storage places, which has the advantage of not being in a direct contact with the polluted air. It appears that the pouches themselves produced volatile compounds. Based on the results, it was suggested to avoid long-term storage in Archipress Archival Pouches. Also it was suggested, that wrapping papers in alkaline covers and the use of alkaline boxes is recommended.

In 1984 a National Research program, ACBAM, was initiated in The Netherlands to assess the effects of air pollution on objects stored in archives, museums and libraries. Havermans and Steemers (2004) studied these. The ACBAM program went through several stages: stage 1 included the study of the indoor air quality in selected museums and archives. Stage 2 studied the application of a pollution chamber and the water activity during the ageing of paper that was explained by the authors in there final conclusion that the storage conditions of paper should not exceed 60% RH and should kept as constant as possible. Stage 3 investigated the effect of ventilation on the levels of air pollutants in museums and archives; stage 4 measured the deposits of SO_2, NO_2 and O_3 on representative samples of paper; the last stage (ANSI/ISA-S71.04-1985) studied the effects of selected cellulose-containing materials (Havermans and Steemers 2004). The study revealed that acceleration of the absorption of pollutants was highly affected by the presence of light. It also found that the recirculation of interior air significantly decreased the indoor content of outdoor pollutions such as NO_2 and SO_2. The presence of NO_x resulted in an accelerated uptake of SO_2 in all the used papers. In addition, it was noticed that RH played a significant role in increasing the deposits of SO_2 and NO_x and subsequently the increase of the rate of deterioration. Therefore, it was recommended that the storage conditions of paper should not exceed 60% RH and should be kept at a constant level. However, the study neglected the effects of temperature, which is always related directly to the relative humidity level.

The ratio of gaseous pollutants in museum environments is well illustrated in (Kang *et al.* (2004). Their study assessed the effects of an often used decorating means as a prelude to using this treatment technology for removing pesticides from wooden artefacts, such as the supercritical fluid carbon dioxide extraction on the luminosity of various pigments used to decorate wooden artefacts. In spite of that the fact that the colour changes were slight and often difficult to detect visually (Kang *et al*. 2004). The results of the study showed that supercritical carbon dioxide removed only 60% of the original DDT (1-trichloro, 2-bis(p-chlorophenyl)-ethane) which can be taken as a promising result for further research in this field. However, the value of this study would have increased if more than one kind of sample were considered. It would have made clear that the depth of penetration of supercritical carbon dioxide varies according to kind of wood used for the wooden objects.

Lloyd *et al.* (2007) investigated the extent to which dust affects libraries. Libraries are a particular challenge because of the very large number of books. Books are made of organic materials and many books in historic libraries are now fragile and are potentially damaged by dust, handling and by the abrasive process of repetitive cleaning. Dust often contains mould spores, which have the potential to damage the human immune system (Lloyd *et al*. 2007). Unnecessary handling by volunteers and a lack of care in the process, can cause abrasion to books. The valuable recommendations of the study suggest that “cleaning can be delayed until dust has reached the identified critical levels, which means once every three years” and advise that a library should “remove accumulated dust before periods of high humidity”. As the cycle of humidity levels takes 12 months to fluctuate from highest to lowest, this advise can be read as a recommendation for annual cleaning.

None of the Jordanian museums selected for this present study feature in the literature on the subject of air pollution in museums. Therefore, this urgent subject is dealt with in this study, particularly in chapters five and six.

2.4.5 Relative Humidity

Knight and Thickett (2007) examined the response of historic furniture to fluctuations in temperature and relative humidity (RH). The pieces of furniture studies were two tables, with carved and gilded wooden frames, which support heavy inlaid carved marble tops. Visual examination and radiography showed that the decorative elements were made of several blocks of wood glued and nailed together before being carved. Differential movement of these blocks had led to cracks in the gesso overlying the joints (Knight and Thickett 2007). As the results show, there was a clear relationship between RH and the width of the cracks. The authors stated, that "the effects of temperature changes are insignificant", as the temperature only fluctuated between 16 ?C and 18 ?C, which is not sufficient to show the impact of temperature changes. The fluctuation in RH was between 32% and 74%, which allowed its effects to become clearer in a shorter period.

Ligterink and Di Pietro (2007) explored the phenomenon of the sharp transition in the condition of canvas and paint layers in the regions directly adjacent to the stretcher, referred to as the 'stretcher effect'. Thermal shielding and hygroscopic buffering are investigated both theoretically and experimentally (Ligterink and Di Pietro 2007). In addition, the researchers focused on elucidating the mechanism of the stretcher effect on canvas and paint layers in the regions directly adjacent to the stretcher. Therefore, the researchers investigated the mechanisms responsible for the occurrence of local differences of relative humidity near the canvas. The ultimate aim was to understand whether the 'stretcher effect' is related to the use of backing boards in the conservation of paintings.

Richard (2007) evaluated the benefits and disadvantages of employing silica gel in microclimate packages. While microclimate packages have been used extensively, the inclusion of silica gel has been a subject of debate (Richard 2007). A number of institutions have used microclimate packages routinely for panel paintings, in order to minimize environmental fluctuation during transit. The study recommends that packing cases should be insulated to minimize temperature changes and large quantities of silica gel should be used to stabilize RH within sealed cases even with temperature fluctuations during transit.

Thicket et al. (2007) addressed the issue, known for over thirty years, that air exchange rate is fundamental to providing a safe environment for the contents of showcases. The development of affordable methods has allowed air exchange rates to be measured in a large number of showcases (Thickett *et al*. 2007a). The major drawback of tightly-sealed showcases, besides costs and time, is the concentration of off-gassed products from showcase or construction materials. The resulting data can be used to design specifications of exchange rates of enclosed air . If coupled with rigorous testing and refitting as necessary, this will provide good internal environments to keep RH and off-gassed products from external materials under control.

2.4.6 Microclimates

Bratasz *et al.* (2007) sought to establish target indoor microclimates for organic materials susceptible to fracture and deformation, such as wood and paints. Both temperature and relative humidity (RH) are key control variables to ensure proper conservation (Bratasz 2007). This research consisted of three case studies: a wooden church in Poland; a large, unheated, brick church in Rome; a stone church in the Italian Alps. A novel approach is proposed to establishing target indoor microclimates for organic materials susceptible to fracture and deformation. Thus the focus was on specifying optimum target microclimates which would replicate the past average level of RH. An alternative approach presented in this study assumes that it is impossible to establish *a priori* the best RH level for the conservation of collections composed of organic moisture-absorbing materials. The three case studies were located at different geographic places and the buildings varied in construction materials. This study provided examples of how past indoor conditions can provide useful information on the tolerable fluctuations in RH to which organic materials susceptible to fracture and deformation have acclimatized. Although this article did not mention what kind of materials susceptible to RH were used inside the three microclimates, the fluctuations of the monitored RH was harmful for most historical materials. It should be added, that this study would have been of greater importance if it had also included temperature monitoring, because of the strong correlation between temperature and relative humidity.

Schieweck *et al.* (2007) focused on cultural artefacts, which were stored and exhibited in showcases, storage boxes and cabinets to protect them against mechanical and climatic influences (Schieweck *et al*. 2007). These casings create their own microclimate, which is not necessarily suitable for the museum environment because of the almost static condition inside them. The authors' efforts were clear in presenting a new study, although they indicated at the end of the paper that further investigation of selected materials will be carried out, which will be of vital importance.

Shiner (2007) surveyed in detail microclimates of museum display-cases, that involve enclosure and states that this survey must start with the development of the museum enclosure itself, which is worth to be mentioned here. By 1850 the National Gallery in London was glazing paintings to protect them from airborne pollutants. These paintings have remained undisturbed since then and when compared to their companion paintings they now look in far better condition. By the middle of the nineteenth century, it was recognized that polluting coal gas was harming the leather bindings in London's libraries. The effective control of a building's humidity levels, however, would have to wait until the early twentieth century. Dust and airborne pollutants could be kept off the cases using positive pressure systems and individual showcases could be controlled to provide the optimum environmental conditions for their contents. By the late 1970s, there was a lot of interest in active microclimate control. The Heating, Ventilation and Air-Conditioning (HVAC) systems were too big to control and more than a little dangerous to sensitive artefacts. This historical review reflects the changes in approaches to museum micro-environmental control that have arisen with new technologies over the past hundred years, with emphasis on recent developments in active microclimate control systems (Shiner 2007). The ultimate state of the art active microclimate control system would be capable of supplying a dust, pollution and oxygen-free, humidity and temperature controlled environment.

In many cases, a simple microclimate control system providing constant humidity with some pollution control is an adequate protection. Silica gel manufacturers have developed new and more efficient formulations. Specialized display lighting developers experiment with new light sources and technologies and conservation scientists continue to develop new tests for known threats. The researcher indicates that a common responsibility remains the development and perfection of methods for ensuring the long-term stability for the objects that our society considers extraordinary.

Toledo *et al.* (2007) demonstrated the efficiency of using glass boxes for the exhibition and conservation of modern paintings in Brazilian museums. Testing a simplified type of box and evaluating its performance as a protective device for unvarnished paintings is the main aim of this article (Toledo *et al*. 2007). The results show that, in warm humid museums, a glass box is efficient in creating a safe microclimate and protecting exhibited paintings from microbial deterioration. The glass boxes, thus, presented many advantages.

Watts *et al.* (2007) inquired into the practical application of the theory of museum showcases, including the contradictions within the researchers' own specifications; how the management of the contract affects the final product; when interpretation, conservation needs and budget confront each other (Watts *et al*. 2007). There are certain risks associated with specifying airtight cases that need to be communicated and understood. An understanding of the comparative risks to objects from a leaky case or from internally generated gaseous pollutants is important.

2.4.7 Materials aging

Balazic *et al.* (2007) focused on how the increase in demand for paper in the nineteenth century led to several changes in its production. High quality rag fibres were replaced by inferior wood-derived ones (Balazic *et al*. 2007). Acid manufacturing technology was used until the end of the twentieth century due to its simplicity and low cost. Thus, the amount of degraded paper through normal ageing as a result of being exposed to the ambient environment is reaching enormous proportions. This research was based on an experiment, which determines the rate of chemical reactions in paper at a given temperature. The result shows that the ratio of degradation rate was constant because of deacidified paper and untreated paper were kept at 20 °C that provide a stabilization factor. This will enable the development of preservation of paper and decrease the amount of decay in the paper collections in museums or even in archives.

Brokerhof (2007) reflected on the research that has been carried out in the area of museum collections and indoor climate. She deals mainly with applied studies about the deterioration of materials due to interaction with their surroundings. This can provide insight into the mechanisms and rates of decay and lead to the development of solutions for conservation problems (Brokerhof 2007). This study mainly dealt with four main subjects: mechanisms of decay, dose-effect relationships, measuring and monitoring and standards and guidelines. It provides information on why, how and how fast the changes in materials happen due to interaction with the museum climate. Understanding the mechanisms of decay enables specialists to find ways of slowing down the decay process or even preventing it from happening.

Brysbaert (1998) put to the test a waterlogged hafted sickle, which was excavated in 1995 at Shinewater Park, England. The skeleton of a child, antler artefacts and several copper alloy objects were found also in the same excavation. The pottery from the site gives a date of around 800-600 BC, Late Bronze Age (Brysbaert 1998). After many stabilizing methods were taking into consideration, the alcohol-ether treatment was decided upon. A three-dimensional mould was produced and a design for a display mount was suggested. The desired aims were to adopt a conservation process that would render the object stable, to learn about the conservation and analysis of composite and waterlogged objects and finally to experience how to work and function in the framework of an ongoing project. These aims appear to have been achieved at long term.

Cigic *et al*. (2004) investigated the best technique for providing relevant information about the effects of volatile organic compounds on paper properties. At the beginning of the experiment, there was a need to separate the volatile compounds and therefore the gas chromatography technique was used, which enabled the researchers to determine the major volatile components (Cigic *et al*. 2004). Two different methods were used in this experiment: solid micro-extraction sampling (SPME) and static headspace (SHS). The results reveal that SHS requires a piece of paper as a sample which makes SHS a destructive method. In comparison, the SPME method is considered to be a non-destructive method.

Costa and Dubus (2007) applied electrochemical techniques to evaluate the environmental impact on the conservation of metallic artefacts (Costa and Dubus 2007). Three different metallic sensors were used; sterling silver, copper and lead. In order to make homogeneous surfaces the metallic sensors were prepared by abrading both of their sides with a glass bristle. Auxiliary electrodes were platinum wire and mercury sulphate. This research is based on an experimental study for some metallic objects. The results reveal that it is possible to evaluate the environmental impact on metallic coupons using electrochemical techniques. The three metal sensors reacted differently, depending on the environment. This confirms the harmful effect of particulate matter, probably caused by absorbing humidity and catalyzing surface reaction.

Dirksen (1997) examined the tanning processes used in the manufacturing of leather and the implications such processes have on the deterioration of ageing leather (Dirksen 1997). The researcher provided some suggestions for leather conservation and made clear that it would be better to focus on preservation rather than on conservation, as preservation is easier, takes less effort and is much safer for objects. The researcher gave some recommendations from the Canadian Conservation Institute for a suitable preservation environment for storing leather objects, which might be easily implemented even in small museums.

Hackney (2007) discussed the foundation of the Tate Gallery Conservation Department, which was established in 1956, initially to restore major paintings. In 1967 the London Conference on Museum Climatology addressed the subject of the protection of works of art on display. It was recognized that glass frames provide physical protection for the painting they house. They protect the painting from excessive interference and allow handling without direct contact with the painting (Hackney 2007). The researcher discussed a very important subject in a detailed manner and helpful for others pursuing a study of this kind. However, it was not clear in the results which kind of gaskets is recommended and whether the researcher used the rubber gaskets or not in the method of using glazing for protecting paintings.

Korenberg (2003) examined the resistance of polyester to different environmental changes in museums. Polyester was discovered in 1941 and first commercially used in 1953; this means that the oldest polyester object in a museum is approximately 50 years old (Korenberg 2003). The author exposed samples of polyester to different climatic rates and monitored any changes that occurred to the samples. The samples showed no change throughout the experimental tests, which suggests that polyester may be invulnerable to estimated climatic change in the future.

Mecklenburg (2007) introduced some of the mechanisms that cause damage to canvas paintings, which mostly occurs through exposure to high humidity while on display or in storage (Mecklenburg 2007). Moisture can also condense on the inside façade of exterior walls, giving a higher humidity to a painting on that wall than the humidity inside the room itself.

Finding a method of observing reactions in painted wood exposed to varying climates in churches is the main aim of Olstad and Haugen's research (2007). The authors also examined whether an intermittent heating system would damage polychrome wooden objects in churches. Two hundred objects were investigated (Olstad and Haugen 2007). Most of the studies in this field consider relative humidity as the most effective factor on wooden materials but not temperature. That is because temperature has no effect at the surface of the wooden material, which leads to an assumption that it needs longer time to be discovered but at the contrary humidity effect starts from the surface of the wood thus it appears faster and it is assumed that relative humidity damage is much bigger. The research was of a great value but the practical experiment did not appear to be reflected in the findings. In addition, it was not clear whether the different types of wood would reacts differently to handle the climate fluctuation more than other kinds or all the wood of the same susceptibility for fluctuation. The researchers focused at the end of this paper on the harm coming through transportations of these objects, which misleads the reader of the main issue and the expected results from this research.

Padfield *et al*. (2002) brought to light the issue of framed pictures behind glass are at risk from unsuitable temperatures and relative humidity. A picture hanging against an outside wall may cool, leading to condensation occurring within the frame, or on the wall behind it (Padfield *et al*. 2002). This research is of great value but the practical experiment did not appear to be reflected in the findings. In addition, it was not clear whether the different types of wood would react differently to climate fluctuation or not. The researchers focused towards the end of the paper on the harming of objects through transportation and this change in subject misleads the reader regarding the main issue and the expected results from this research.

Padfield *et al.* (2007) mainly discussed the fundamental requirements for natural stability in a building, which is rarely found as deliberate design of the building, it frequently happens unintentionally. This paper took into consideration two case studies: The first one of an almost natural archive climate is the military archive of the Fortress of Segovia in Spain. Moreover, the second one is the Suffolk Record Office. The building consists of two storeys, with a cavity brick walls (Padfield *et al*. 2007). After some experiments, the authors have some useful recommendations which I think will be of great appreciation especially for art museums. There was one point, however, that could be marked as being not properly explained; the authors mention “there are very few environments where a sealed backboard is more risky than a porous back”, but no information is given on how or when this could be more risky or how one can estimate the risky environments. Such information, therefore, should not be mentioned without a justification or at least further explanation.

Padfield (2007) Verified that the climate records in museums are evidence of care. The researcher also proposed that the use of thermo-hygrographs has now been lost, as digital sensors have nearly universally replaced this long-lived instrument. However, the digital records of thermo-hygrographs are vulnerable to erasure. These records are doomed to be lost by format obsolescence unless converted into a durable standard format (Padfield 2007). This research is of great importance, because of the continuous need for indoor climate measurements in doing any practical study regarding museum environments. The outside weather history could be easily found but climatic records for inside museum buildings are scarce, despite the importance of these records.

Strlic (2007) concentrated on the development of a non-destructive Near Infra Red (NIR) instrument, which promises to replace the traditional destructive methods of determination of chemical and mechanical properties and pH of historical papers (Strlic 2007). The SurveNIR project was set out to build a dedicated NIR spectroscopic instrument, which would enable the user to determine a variety of chemical and mechanical properties of paper. Thus, the project intends to provide museums, libraries and archival collections with a non-destructive, chemical free, low cost surveying tool that would provide more in-depth information about paper than traditional methods.

2.4.8 Indoor environment control in general

Bouwmeester (1996) estimated the value of regular monitoring by museums of the basic factors such as temperature, humidity, light, pollutants and pests in order to control them (Bouwmeester 1996). This control can be achieved if several questions have been answered: what is the effect of uncontrolled factors? Why should uncontrolled factors be monitored?

How can uncontrolled factors be monitored? On the other hand, monitoring is not an end in itself and must be supported by effective remediation if necessary.

Bradley (2005) discussed the British Museum conservation scientists' program of research that reviewed the effects of uncontrolled indoor environment at the British Museum collections and whether control of temperature and relative humidity is vital to safeguard the museum objects. One of the main reasons behind this research was the importance of the historical building of the British Museum, London and how to install a central air conditioning system without destroying the structure of the building (Bradley 2005). It is difficult to provide one environment to suit different types of objects that are sharing the same hall. Much of the collection was stable and thus the need for an air conditioning system was limited. The research noticed the negative effect of uncontrolled relative humidity and temperature on ethnographical objects and stone sculptures, especially fading of colours of ethnographical objects and surface flaking of sculptures. In this respect, the author suggested the use of Peltier Cells instead of humidifiers and air conditioning system, which can control to any range of relative humidity by feeding air into the showcases at the required midpoint at a slow rate. The author did also a noticeable effort by studying indoor pollutants gases, especially sulphide gases and organic acids, using different methods and aspects. Finally, the researcher recommended using metal rather than wood storage units and glass and metal showcases.

The Chicora Foundation (1994) clarified the importance of a museum's environment in insuring the long-term safety and preservation of its collections. The safe environment for objects is provided by having a heating, ventilation and air conditioning system (HVAC) in order to control the indoor environment. Even small institutions with limited resources can achieve this. However, the study showed that museum directors are sometimes not convinced that controlling the environment is all that important (Foundation 1994), The anonymous author claimed several occasions that RH is more important than temperature and tried to separate the two. However, I think it is hard to separate temperature from RH, because they are related and any change to one will affect the other. I disagree with the author when stating that the presence of visitors (would) raise the temperature and increase the RH. On the contrary, the heat input would lower the RH, while moisture would raise it (Thomson 1986).

Coxon (2007) described the design and implementation of a climate control system at the Royal Ontario Museum, Canada, beginning with an assessment of the required level of RH for the museum. More than 19,000 objects were destined for display in the new galleries. Therefore, planning the controlled cases and piping layouts had to take into account the varying needs of the objects, the large volumes of some of the display enclosures, the power of the control systems in relation to the distance the air must travel and the leakage rate of the cases (Coxon 2007). This paper follows the course of the process from the ideals of the initial planning stage to the reality of the final implementation. It offers a limited look at some of the problems that had to be overcome when setting up RH systems in the new Royal Ontario Museum such as the annual fluctuation in RH.

Erhardt *et al.* (2007) examined the history and development of climatic control in museums. It is made clear that early specifications for museum climate were based on little evidence and it was revealed that there was minimal scientific support for the fluctuation ranges of temperature and relative humidity. The researchers also suggest that many recommendations for museums in the past have been based on considerations of issues other than the permanence of the objects, especially regarding the ranges of variation for temperature and relative humidity (Erhardt *et al.* 2007). The researchers focused on the availability of any new changes in knowledge of relative humidity and temperature, which were implemented and adopted in museums and institutions. They divided the aspects of damage and deterioration into two main sections: the first includes fire, flood, pollution and earthquakes and the second includes relative humidity, temperature and light. The researchers mentioned that there were no reports of damage to collections due to the implementation of newly developed guidelines by the Smithsonian Institution. However, because such damage may only become visible over time, more studies should be conducted on the subject over a longer period. These guidelines were only implemented after 1994, to see whether the recommended RH range of fluctuation is safe for collections. The authors also mention that these new guidelines gained a wide acceptance, but this could be because they are easier to implement, less time consuming and less expensive than previous guidelines, making them attractive to most limited-budget museums or institutions.

Fry *et al.* (2007) discussed the progress of the development of the risk assessment and condition audit of the organisation English Heritage (EH). The authors intended to design a database and methodology integrating risk assessment and condition surveys. They focused on the methodology behind the audit and the refinements made during the competition of over 100 site surveys, in order to find results that would work in the EH context (Fry *et al*. 2007). The audit results will guide the work of the conservation team for collections for the next 10 years. The authors' focus was shifted from data gathering to writing, promotion and implementation of EH and original report. Interpretation of the data allowed for the prioritization of collection care solutions across multiple locations, pinpointing the collections at greatest risk and the appropriate actions required.

Kaplan *et al.* (2005) reported on the program of preventive conservation that was successfully achieved in the process of moving objects from the National Museum of the American Indian in the Bronx, New York, to the museum's cultural resources centre elsewhere in New York (Kaplan *et al*. 2004). The authors highlighted the training courses for staff and hired personnel, the regular training refreshment sessions and the communication between staff members, all of which resulted in the most efficient practice and safest environment during transportation of the objects.

Larsen (2007) presented a summary of considerations reported by other authors, followed by a few case studies about museum indoor temperature and relative humidity in which unconventional solutions have been tested as a compromise between the conflicting interests of researchers in the field of indoor environment. A risk assessment analysis would identify the indoor climate as the main threat to the preservation of museum objects. The author also pinpoints the first permanent heating installation in Danish churches. This heating system used cast iron stoves, which cause soot contamination. Another central heating system was installed at the beginning of the twentieth century (Larsen 2007). The researcher suggested two ways of moderating the relative humidity (RH) in Danish churches. One method is to control the water vapour content in the air and another method is to adjust the air temperature to an annual cycle. RH can be controlled by temperature regulation, either by a hygrostat or by adjusting the temperature. The author also noted that single-glazed windows lead to condensation in winter, which can cause corrosion of the metal frames of the windows. This study requires further investigation in order to locate the source of passive humidification.

Lithgow *et al.* (2007) attempted to bring forward for consideration an investigation into the control of environmentally caused deterioration of decorative surfaces in a small stone building, which was built in the UK in the 1920s and decorated in 1934. The internal walls have been rendered and painted and embellished with slate and terracotta wall plaques. The internal surfaces have been deteriorating ever since they were completed. After wartime neglect, the original artist himself restored the 1934 decorations in 1949 and the designs were repainted again in 1981. By 1997 the decorative surfaces had deteriorated again through algae growth, erosion by water, cracking, flaking and loss of the paint layer (Lithgow *et al*. 2007).

Noticeably, this article was missing a comparison between the effects on the walls at different locations; one can assume that the wall facing the sun will have less water vapour condensation coming through, whilst the wall facing the rain and wind will have more inner humidity as well as more water penetrating through.

Maekawa *et al.* (2007) studied the large visitor impact on the environment at Our Lord in the Attic museum, the Netherlands. Visitors have a direct impact on increasing temperature, relative humidity and CO^2 concentration. This five-storey, seventeenth century Dutch canal house museum has seen an increase in visitor numbers from 36,000 in 1990 to 75,000 in 2005 (Maekawa *et al*. 2007). The museum and the church were both found to have high infiltration rates that limited heat and moisture accumulation and were not able to maintain humidity at a constant level. The researchers also examined some condensation found in the building, but this was not emphasised in this research, as the authors claim that it is not a critical problem and it only affects the window frames and sills.

Muething *et al.* (2005) carried out a risk assessment of collection material at the exhibition facility of the Victoria Memorial Museum Building, Canada. Specific risks were considered within 21 collection units for a total of 1,498 artefacts. The nine highest risks discussed in this paper are: damage through exposure to light; damage through exposure to UV radiation; pest infestation; damage from smoke; damage from soot; physical forces; dust accumulation; theft; sporadic water leaks (Muething *et al*. 2005). In order to identify risks, there were some estimated variables for each risk. These variables are fraction susceptibility; loss in value; probability and extent. The researchers also interviewed members of staff and in order to insure consistency, information used during these interviews included monitoring records and exhibit design plans.

There are a few notes about this assessment of the Victoria Memorial Building that are worth mentioning in this review. It was proved that fire results in soot, which deposits on objects. However we may add that, apart from this aesthetical damage to the objects, the real destruction comes from cleaning the objects (Cronyn 1990). This should have been mentioned in the section discussing mishandling and physical forces. The researchers determined the risk of pests, which result in chewing and bore holes, but did not mention the metabolism of pests, which appears to be more harmful to organic objects because of the excreted organic acids (Cronyn 1990). This is highly destructive to sensitive materials like paintings.

The discussion on physical forces should include mishandling in conservation measures or in moving objects within the museum facilities and out of the museum during transportation, because museum objects in general are weaker than they appear and most are fragile (Cronyn 1990). Furthermore dust, which is composed of minute particles, is not a risk by itself. The real risk appears when it comes into contact with water (humidity), because it can then become an active chemical agent. In addition, cleaning the objects by dusting, shaking, wiping or washing accelerates wear and tear, eventually increasing the damage (Cronyn 1990).

Ntanos and Bell (2007) set out the environmental standards maintained at the National Archives (TNA) in London (the United Kingdom’s official archive) containing 900 years of historical records and holding in its custody more than 10 million parchment and paper-based records. TNA was opened in 1996 (Ntanos and Bell 2007). This project aimed to determine whether there is a difference between the deterioration of historic parchment records, that are kept in two different environments. A climate mapping exercise was used to develop TNA’s environmental monitoring program. The environmental conditions at the TNA were assessed in the building that was specially built for hosting parchment and paper based materials. This assessment took into consideration the effects of temperature and relative humidity, but unfortunately neglected the effects of light, which is a basic factor in ageing paper-based materials. Light can be harmful to paper-based materials in two ways: by transforming light into heat and through emitting ultraviolet light and both ways damage paper-based materials (Thomson 1986).

Odlyha *et al.* (2007) assessed the performance of dosimeters to estimate cumulative damage to indoor cultural heritage due to the environment. Artists' materials – resin, mastic, varnish and egg tempera – were selected because the degree of oxygenation of the egg lipid components in egg tempera is directly related to the duration of light exposure. Lead coating was also used because it is the main constituent of historic organ pipes. Another objective for this project was to adapt piezoelectric-based dosimeters to detect the presence of organic acids, which are corrosive to organ pipes (Odlyha *et al*. 2007). The researchers examined to what extent resin-mastic crystals have provided dosimeters that are sensitive to light and oxidizing agents. Some of the results show that emissions from new wood contribute to the damage on the lead coupons.

In an anonymous report (OSSGDAH 1997) is was stated that, as most objects in museums, paper records in storage will degrade more quickly in the presence of heat, humidity, light and dirt, than those stored in conditions that are cool, dry, dark and clean. The Office of the Secretary of State for Georgia's Department of Archives and History produced a report mainly concerned with the preservation of paper and concluding that paper should be stored at a temperature of 68˚F. +/- 2˚F and with 40% +/- 5% of relative humidity. This environment should be kept stable with minimal fluctuations, to be achieved by installing heating and cooling systems with programmable thermostats that can keep conditions at a consistent level as desired (OSSGDAH 1997). The study gave also some recommendations for dealing with paper-affecting pollutants from the ambient air. It should be noted that high quantities of paper are not only found in archives but also in museums.

In 2004 Reilly *et al.* (2007) undertook a project to assess the preservation quality of the existing collection storage facilities at the National Museum of Denmark (NMD). Theyattempted to determine whether existing facilities were delivering conditions appropriate to its stored collection (Reilly *et al*. 2007). The environmental assessment was nearly completed in 2007 and resulted in the development of a prototype for a web-based system of environmental assessment and reporting. This research illustrates how a computer-based program can be applied to collection management techniques that identify and minimize risks to objects. In addition, the program can divide collections into different categories based on their value. When the NMD project is finished, it will be of great help for specialists efficiently dealing with museum collections. Moreover, a variety of useful collection management information will be useful.

Roberts (2004) presented an exploratory analysis of humidity and temperature data that was collected to document the environment of the Bowdoin College Museum of Art, USA. The museum is located in the Walker Art Building at Bowdoin College, Maine (Roberts 2004). The researcher gave a sufficient description of the museum building and the distribution of the main halls and galleries. All the museum facilities are heated in winter except the storage room, which depends on the outside atmosphere. The author also explained the difference between relative and specific humidity and 'absolute humidity'. This explanation is an important contribution to the subject, as it clearly illustrates the difference between the two types of humidity for the reader.

Ryhl-Svendsen (2007) illustrated the effect of air exchange and sorption reactions, as well as mechanical ventilation with active filtration, by using data from pollution measurements in three Danish museums and archive buildings. Air pollutants were measured at all buildings by passive sampling. Ozone was sampled using the analyst diffusive sampler system. Polluting particles in air were measured by using a Track Particle Counter. The air exchange rates were determined by measuring the concentration decay rate of a tracer gas. Both indoor and outdoor weather conditions were measured (Ryhl-Svendsen 2007). The researcher found that the pollutants, which are generated inside showcases and cannot escape, may reach a very high concentration level. In addition, surface reactions resulting from air pollutants, are the main destruction mechanism. So, it was concluded that passive surface removal, by the use of reactive wall paper, can provide a surface removal rate equal to the pollution dilution provided by several air exchanges per hour, by the help of mechanical filters units, the ventilation would be even better.

Thickett *et al.* (2007a) evaluated the preventive conservation of library and archive material in close environments within historic buildings. The major environmental parameters had been assessed in a representative set of five historic libraries and three archives. These libraries and archives exhibited very different environments and manually controlled conservation heating, comfort heating, dehumidification and a high thermal mass (Thickett *et al*. 2007a). The chemical lifetimes calculated from extensive monitoring of environmental parameters are actually lower than lifetimes predicted from a maximum allowed temperature and a relative humidity under the known standards. Light was found to be under the levels anticipated. The authors found that dust deposition is of critical importance and dust penetrating into bookshelves was observed. The researchers also found that gaseous pollution causes chemical damage. The concentration ratio of the gaseous pollutants compared to the outdoor concentrations appears to be comparable with figures published for chemically filtered buildings. The researchers dealt with the whole subject in a good way, trying to make it as clear as possible. However, they did not give importance to the high level of sulphur dioxide, despite the fact that this can cause damage in the presence of humidity above 60% (Cronyn 1990).

Toledo and Price (1998) inspected three museum buildings, selected in hot and humid regions in northeast Brazil, as case studies for an indoor museum environment study. These three museums were monitored for one year. Temperature and relative humidity were recorded throughout the period in order to assess the buildings' performances against the outside atmosphere and ultimately in safeguarding their collections (Toledo and Price 1998). The two museums have high humidity levels, which will react with dust resulting in a destructive enemy for most of the museum objects (Thomson 1986). Even cleaning the objects by dusting, shaking, wiping, or even washing will accelerate wear and tear, eventually increasing the risk of damage (Cronyn 1990). This article focused on the results of the evaluation and the monitoring processes. Nevertheless, it was almost void of recommended solutions or alternatives for the existing environmental conditions, in order to enhance these museums.

UNESCO (2006) reported the achievements of a UNESCO project regarding the endangered objects of the Sudan National Museum and Jebel Barkal Museum, Sudan (UNESCO 2006). This report is a summary of the achievements of the UNESCO project and since its appearance, many changes have been made in order to restore the Sudan National Museum and to enhance the collections of both museums. It clearly describes the improvements that were made to the Sudan National Museum building, but does not mention how old the building was or what materials were used in its construction. The project installed new showcases supplied with humidity control, security locks and UV filtered laminate glass, which limited the need to purchase expensive lights to reduce UV emissions. Although some fires happened through electrical short-circuits, this was not taken into consideration by the authors, nor were their cause and frequency mentioned. Notably, labelling was done after the objects were displayed, but it was not clear whether these were old interpretation labels or new ones. Finally, I was left curious as to what type of museum the Jabal Barkal Museum is and what type of objects it hosts.

2.5 Discussion

From this literature review it is clear that the researchers have different interests and emphases within the field of museology and that not only museum buildings have been considered, but also libraries, churches, archives and historical buildings.

In the review, special consideration was given to the literature that was deemed particularly relevant or applicable to the Jordanian situation. Indeed several of the studies shared many characteristics some Jordanian museums. For instance, Broecke (2007) described the problems encountered by a museum in Mozambique with air conditioning and dehumidification units and the efforts to establish an alternative, simple and cheap means of reducing the RH. He also focused on the difficulties involved in ensuring the sustainability of the passive climate control strategy. Lessons learned here could be advantageously applied to the situation in the Numismatics Museum at Yarmouk University in Jordan, where an air-conditioning system was installed without any environmental monitoring in order to pinpoint the presence or absence of climatic problems. Huber (2007) discussed the mechanisms of chest windows in museums. This subject could be of great value for the current situation of Jordanian museums in general, firstly because of the hot and dry weather six to ten months a year and secondly because of the fact that most of the Jordanian museums have exterior windows.

Richard (2007) pinpointed the benefits and disadvantages of employing silica gel in microclimate packages. This practice is common in Jordan, especially in closed lockers where numismatics are kept, as well as during the transportation of objects to and from museums. Therefore, knowing how well this method helps to maintain humidity at desired levels would be of value to Jordanian museums.

Korenberg (2003) pointed out the resistance of polyester to different environmental changes. In 'the cave', part of the main storage of the Department of Antiquities in Jordan, all the archaeological objects are kept in polyester boxes. Therefore, a study of the effects of these boxes on the archaeological objects they hold would be very helpful.

The research of Bradley (2005) is of relevance to the general state of the Numismatics Museum.

The study in Georgia, USA (OSSGDAH 1997), is relevant to the assessment of the monitoring devices that were installed between January and July 2009 in the storage of the Department of Antiquities in Amman, in order to determine whether the storage space was 'hot, humid and dirt' or 'cool, dry and dirt'. A similar study can be carried out at this storage, because most of the time it is kept closed with little human activity and it is located in a very busy and polluted urban area.

It should also be mentioned here that the archive of the Department of Antiquities in Amman holds different types of library and archive materials without any environmental controls, thus it is important to monitor the indoor climate in that archive.

The two tables below illustrate the main topics that have been summarized in the literature review. Table 2.1 shows what topics were popular among the literature reviewed in this chapter. Table 2.2 shows the materials discussed in this literature. These tables also indicate the relevant topics in the field of museology that were more or less neglected. For a more detailed view see Annex 2, tables A2.1A, a2.1B and A2.2.

Table 2.1 Topics discussed in the reviewed literature

The topic of the articles	The percentage of articles in the literature review that discuss the topic
Artificial light	3.5%
Dust	5.5%
General evaluation	27%
High RH	9%
RH fluctuation	10.9%
Material aging	18%
Micro climates	9%
Micro organisms	9%
Natural light	7%
Passive air conditioning	3.5%
Pests	7%
Polluted indoor air	5.5%
Polluted outdoor air	2%
Storage	9%
Temperature	9%
UV	0%
Ventilation	9%

Table 2.2 Materials discussed in the reviewed literature

The material used in the articles	The percentage of articles in the literature review that discuss the material
Bone, ivory	2%
Glass	5.5%
Glue	2%
Leather	2%
Metals	7%
Paints	11%
Paper	11%
Pottery	0%
Stone	5.5%
Textile	2%
Wood	9%

2.6 Conclusion

There are various environmental factors, which can cause the deterioration and destruction of cultural materials. Moreover, if these factors are left unchecked can make the conservation treatment of objects difficult or even impossible. The main factors that can cause the deterioration of museum collections are temperature, light, humidity, air pollution, microorganisms and pests.

The soil context and the underground environment change over time and to provide a suitable environment for buried archaeological artefacts is not a function required of the soil context. This environment in the soil context could be a result of one of two reasons; either objects were buried in a ‘proper’ environment and kept that way, or these buried materials have reached an equilibrium with the surrounding environment. Thus, the study of the surrounding environment with respect to buried material prior to excavations and the connection between soil and materials, is of vital importance.

In spite of the fact that in most museums the bulk of the collections is in store rather than on display, researchers have paid hardly any attention to this issue. The same standard of care needs to be exercised for materials whether on display or in storage, because the collection is continuously moved from storage to the museum and vice versa. This kind of study and research is applicable not only to museum buildings, but could also be applied to other institutions with collections, such as libraries, archives, churches and historical buildings. Therefore, these have also been included in the literature review.

The importance of preserving museum objects in ideal conditions is reflected by the growth of the literature on museum environment studies. Most of the studies in this area are case studies of a specific museum and, therefore, are not always applicable to other buildings, collections and contexts.

Most of the articles reviewed here have examined the topic of indoor environment in general, measuring the indoor humidity, temperature and have compared it with the outside atmosphere to identify how far the selected museum buildings provide a suitable environment for the valuable materials held within them. However, there were gaps in terms of which topics researchers have focussed on. Neglected topics include: the effects of ultraviolet light on organic-based materials; the link between polluted outdoor air and indoor air of museums; the effects of dust and other destructive pollutants in the air on indoor climate and possessions of museums.

JORDAN MUSEUMS

Jordan museums

3.1 Introduction

The growth of interest in museums is indicative of the fact that the museum is focus around which many of our global and local preoccupations can coalesce.
Alongside the expansion and diversification of the museums in Jordan, particularly since 1990's, has raise the awareness of Jordanian local community about museums and the subject of museology in general, which lead the government in one hand to pay more attention to the current situation of the existing museums, and on the other hand to reconsider establishing new specialized ones. This was the result of the massive increase in the amount of critical commentary upon museums.
Throughout human history, Jordan has witnessed successive ancient states (for a convenient site-oriented overview see Kennedy and Bewley 2004) and has undergone significant developments, thus the country has played an important role in hosting ancient civilizations through the ages. Although the significance of Jordan's role has varied from time to time, the many underground antiquities, remains and monuments found indicate permanent importance (Scheltema 2008). By the turn of the past century, increasing interest in archaeology had resulted in more excavations and explorations of archaeological sites. Nowadays approximately 70 missions are annually held, most of them by merely foreign missions (Alkhraysheh 2007). At the same time we see an increase in the quantity of monuments and objects discovered. In response to this increase, it became necessary and urgent to establish museums to aesthetically display such remains and protect them at the same.
Notwithstanding the advancement of museology, Jordanian museums are still lacking a well-developed infrastructure. At the same time, the museums lack most of the requirements to be able to address, criticize and analyze such necessities. Therefore, it seems important to conduct an inclusive study to cater for the needs of Jordanian museums and have them improved and developed, in order to portray the best possible image of Jordan and its history.
Jordanian museums contain important collections that require a controlled indoor environment, to ensure their preservation and minimize their deterioration. In absence of museum environmental control, these objects would be in great danger. Thus, museums must provide at least the minimum requirements needed for keeping objects in their current shapes and condition.
Ten Jordanian museums were studied as part of this research, located in most of the different geographical regions in Jordan as shown on the map (Figures 2.65 and 2.66). The selected museums include eight Archaeological Museums and two Educational Museums.
Objects become decayed and deteriorate over time, consequently museums must plan to slow down the rate of decay by reducing the impact of the factors that affect the objects. Environmental conditions inside a museum are among the most significant of these potentially damaging factors (Cassar 1995).
In spite of the great development Jordan is undergoing, the subject of museology remains fairly unknown, thus it was important to conduct this study in order to increase the public and governmental awareness about museums in Jordan. The selected museums were visited and photographed and interviews were made with staff members.
This study is an attempt to visually evaluate the current situation at Jordanian museums from different aspects. The location and history, building and interior, management,

exhibition and collection and indoor environment are the main elements, which are described and assessed for each museum.

The location and the history of each museum are described because Jordan has a diverse terrain and landscape, which makes each spot in Jordan unique in its geographical location and its climatic aspects. The dates of establishment of the museums in Jordan vary, from 1951 to the present day. Also the construction techniques of the buildings differ from one museum to another. Moreover, some museums were built for the purpose of being museums while others were not. These were the main reasons behind describing the museum buildings and interiors in this chapter. Because of the lack of museum specialists and trained staff, in addition to the great responsibilities that museum workers have, the management situations at Jordanian museums are also evaluated. Ambrose (1993) mentioned that every museum should have expertise staff, for instance in administration, documentation, fieldwork and building maintenance. The diversity of the collections that each museum in Jordan exhibits makes describing the exhibition and collection important in this chapter. And finally, because of the importance of the subject of indoor environment in museums and as an introduction to the analytic phase of this thesis, it is important to visually evaluate the current environmental conditions at the selected Jordanian museums as far as possible.
Throughout the visual evaluation of these museums I refer to standards that would be of great value if adopted in every museum, in order to assist in the comparison of the existing situations with the standards mentioned in the literature. The standards to which I refer in this chapter are found in Garry Thomson's The Museum Environment (1986). These standards provide us with a base of environmental issues concerning museums and in his book, Thomson discusses most of the environmental problems that museums may face. Timothy Ambrose and Crispin Paine in their book *Museum Basics* (1993) provide comprehensive information about the function of a museum and its structure. Finally, this chapter relies heavily on the International Council of Museums (ICOM) Ethics. ICOM issued its Ethics of Acquisition in 1970 and a full Code of Professional Ethics in 1986. The present edition - and its interim document of 2001 - owes much to that early work. The Code of Ethics for Museums provides a means of professional self-regulation in a key area of public provision, where legislation at an international level is variable and far from consistent. It sets minimum standards of conduct and performance to which professional museum staff throughout the world may reasonably aspire and also provides a statement of reasonable public expectation from the museum profession. The whole ICOM Code of Ethics is presented in the appendices (Annex 4).

Although the selected museums in this present study are all archaeological museums, they represent different types of collections. The selected museums fall in three categories:

- National museums
- Local museums
- Site museums

The difference between these museums is in the scope of objects they display. The national museums, for example the Jordan Museum, display archaeological objects excavated in Jordan in general. Local museums, for example the Aqaba museum, display objects that are found in the same city as the museum. Site museums, for example the Petra museum, only exhibit objects that belong to the same archaeological site on or at which the museum is located.

The museums selected in this study were divided into two main categories:

3.1.1 Archaeological museums

- Aqaba Archaeology Museum
- Irbid Archaeology Museum
- Jarash Archaeology Museum
- Jordan Archaeology Museum
- Karak Archaeology Museum
- Madaba Archaeology Museum
- Petra Archaeology Museum
- Salt Archaeology Museum

3.1.2 University museums

- Museum of Archaeology / Jordan University
- Museum of Jordanian Heritage / Yarmouk University

Most of the museums in Jordan are dedicated to archaeology, since archaeological excavations by either local or foreign missions are the main source of the objects displayed at the Jordanian museums (see Chapter 1). The purchasing of archaeological artefacts is illegal in Jordan and donations rarely occur. It is noteworthy that most of the Jordanian museums do not have enough information about their contents.
The following table (Table 3.1) displays the basic information for each of these museums, in order to provide the reader with a hint about the presented study.

Table 3.1 Brief overview of the Jordanian Museums – Situation 2009

Name of the museum	Sponsored by	Working hours	Entrance fee	Founded in	Managed by	Type	Location	Publications
Aqaba Archaeology museum	Ministry of Tourism	9a.m.-3p.m. Friday & Saturday holidays	Free	1987	Ministry of Tourism	Archaeology	Aqaba	Museum leaflet
Irbid Archaeology museum	Department of Antiques (DoA)	9a.m.-3p.m. Friday & Saturday holidays	Free	1988	Department of Antiquities (DoA)	Archaeology	Irbid	Nothing
Jarash Archaeology museum	Ministry of Tourism & (DoA)	9a.m.-3p.m. open during summertime Tuesday holidays	Included in site fee	1985	(DoA)	Archaeology & site museum	Jarash	Nothing
Jordan Archaeology museum	Ministry of Tourism & (DoA)	9a.m.-5p.m. Tuesday holidays	foreigners 50p Jordanians 25p	1951	(DoA)	Archaeology	The Citadel Mountain Amman	Museum Guide
Karak Archaeology museum	Ministry of Tourism & (DoA)	9a.m.-5p.m. Friday & Saturday holidays	Included in site fee	1981	(DoA)	Archaeology & site museum	Karak	Included with the Karak castle Brochure
Madaba Archaeology museum	(DoA)	9a.m.-3p.m. Friday & Saturday holidays	Free	1979	(DoA)	Archaeology	Madaba	Nothing
Petra Archaeology museum	(DoA)	9a.m.-3p.m. Friday holidays	Included in site fee	1963	(DoA)	Archaeology & site museum	Petra	Nothing
Salt Archaeology museum	(DoA)	9a.m.-3p.m. Friday holidays	Free	1981	(DoA)	Archaeology	Salt	Nothing
Archaeology museum	Ministry of High Education	9a.m.-5p.m. Friday & Saturday holidays	50 piaster	1962	University of Jordan	Educational	Amman	Brochure
Jordanian Heritage museum	Ministry of High Education	9a.m.-5p.m. Friday & Saturday holidays	Free	1988	Faculty of Archaeology& Anthropology, Yarmouk University	Educational	Irbid	Brochure, Publications Museum guide

3.2 Aqaba Archaeology Museum
3.2.1 Location and history

Aqaba city lies about 390km south of Amman with about 101,736 inhabitants (DOS 2004). The Aqaba Archaeology museum was established in 1987 in the house of *Al-Sherrif Hussein Bin Ali* near the Aqaba Castle. This museum, in addition to the Madaba Museum, is considered a 'historical building' type. It has a distinctive location because near the beach, governmental institutions, department stores, hotels and other tourist spots in the city centre. This museum was originally built from cement and granite brought from *Wadi Al-Yutum* and the building has been restored many times. Stones from the sea were used on the outer facades of the walls to give them a pleasant look.

Figure 3.1 The Aqaba Archaeology Museum Photo by R. AlGhazawi

3.2.2 Building and interior

The plan in Figure 3.53 shows the museum's interior. This includes:

- Exhibition Halls: There are three different rooms forming a line.
- Administrative Offices: These are the offices, which are used for reception and as the office of the Tourist Supervisor, because the house belongs to the Ministry of Tourism and Antiquities.
- Facilities and services: Some of the rooms are used as bedrooms for the Tourist Police and other rooms are used as kitchen and as bathrooms. In the middle is an open courtyard surrounded by rooms. This courtyard is planted with palm trees and other plants.

The exhibition halls have different ceiling heights. Some ceilings are of cement, which is painted white and some are of wood. These ceilings look flat. The walls differ in thickness and are painted white. These walls contain transparent glass windows of different sizes with frames made of wood. These windows are higher than the visitor's sight level and their frames need restoration, because some of the iron bars are loose or even sticking out. The administration offices also have the same window style.

The exhibition rooms overlook the open yard, but the interior side has no doors.

The main entrance of the museum leads the visitor to the open courtyard. The main gate of the museum, which was recently restored, is wide and high enough to allow any object into the museum.

The floors of the display halls are paved with tiles, which are darker in colour than the walls and the ceiling, adding more coherence to the view. Nevertheless, the surface of the ground is not levelled and so some of the halls appear to be higher than others. The floor of the courtyard is higher than the floor of the inside halls, which affects the movement of the museum visitors.

Figure 3.2 The courtyard at the Aqaba Museum. Photo by R. AlGhazawi

3.2.3 Management

The organization of the museum staff is illustrated in the following chart:

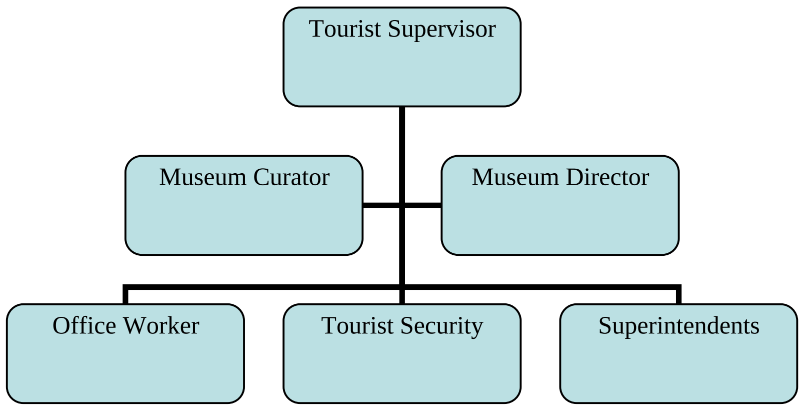

Figure 3.3 Aqaba museum hierarchy chart

From the chart, it is noticeable that no specific specialized staff is included, competent in the areas of conservation, display and interpretation, administration, documentation and education. The work of the museum mainly depends on the curator, who is an archaeologist. The museum is administratively directed by the Ministry of Tourism and Antiquities through the Department of Antiquities.

The museum gives the only archaeological view in Aqaba city. Thus, it should provide the visitor with a sufficient overview about the archaeological history of Aqaba and Jordan in general; especially with the importance, Aqaba has gain in recent years, as it has become the first 'tourist' destination in Jordan or indeed within neighbouring countries.

The safety provisions of the museum include the presence of tourist police inside the museum. There are portable fire extinguishers, but there is no electronic equipment such as alarm sirens or security cameras. In addition, there are no signs indicating forbidden actions.

3.2.4 Exhibition and collection

The exhibition depends mainly on discoveries of the excavations at Aila (ancient Aqaba). Because of this, the museum is supposed to be called The Exhibition of Aila Discoveries (Basyoni 2009). There is a record of the objects and another one of visitors, but without any duplication of the copies, which makes it difficult to recognize the artefacts in case of theft or intentional damage.

Figure 3.4 Shows different types of showcases used at museum. Photo bv R. AlGhazawi

The objects are displayed inside showcases of different shapes and sizes; others are on wooden stands. In addition, there are small cases hanging on the walls for exhibiting small and light objects such as photos, maps and pots. It is worth mentioning that the cases of the exhibition have a typical Jordanian design. The surfaces of the showcases are varied. Some of them are wooden and some are made from coloured cloths that are not fire resistant. In addition, many cases use small pebbles from areas near the sea to add an aesthetical value to the showcases surface. The supporting stands are different: some are metal others are acrylic. Zink metal boards as well as some wooden boards and cylindrical stands made of acrylics are fixed inside the showcases. Some exhibitions are displayed in the open area.

The method of exhibition does not follow a definite style. Therefore, the exhibited objects representing Aila discoveries are exhibited regardless of type or period. The exhibition represents by exhibiting objects belong to different historical periods: Roman (63 BC-324 AD), Byzantine (324-636 AD) and Islamic (Umayyad 640-750 AD, Abbasid 750-969 AD, Fatimid 969-1071 AD) (Basyoni 2009; Kennedy and Bewley 2004). For example, materials belonging to different historical periods may be found together in the same showcase (stone, pottery, coins etc). This method of exhibition does not comply with the modern way of exhibiting museum objects (Ambrose and Paine 1993).

From the list mentioned above it is clear that this museum lacks comprehension of the historic periods it represents and so this museum must enhance its collections by exchanging artefacts with other museums so that it achieves an organized and comprehensive display.

Demonstration aids, including cards of different sizes printed in black containing detailed explanations about the objects, are neatly written in English and Arabic and the cards are installed in proper places. There are also tables showing different historical periods, particularly the Islamic period in Aila. There are also photographs, maps, paintings and schemes. However, some cases seem to lack interpretation labels and this reduces the usefulness of the visit to the ordinary visitor. In addition, the exhibition does not contain audio devices. The museum does not contain a storage room among its facilities for the objects, which are not exhibited. These objects are instead kept at the Department of Antiquity’s storage in Amman. If the number of objects at the museum increases, the wooden cases could be used for this purpose.

The exhibition does not have any direct educational activities, but it is housed in a historic building, which fosters patriotism and cultural awareness among the local people and deepens patriotism especially of students. The museum does not do any restoration or conservation because it lacks the necessary equipment, laboratories and workshops.

3.2.5 Environment visual assessment

The ventilation in the museum depends on doors and windows as well as some ceiling fans. There is no heating equipment and so temperature and humidity are not controlled. The light in the building is mainly from natural light coming through windows and doors. There are also some incandescent lamps hung from the ceiling and directed towards the cases and the objects inside. Generally, the lighting is sufficient, but not adequate for museums (Thomson 1986).

Figure 3.5 The artificial lighting used at the museum.
Photo by R. AlGhazawi

3.2.6 Recommendations

Based on the above information about the Aqaba Museum, the following changes and additions are recommended in order to improve the current condition of this museum:

- The building should be improved to suit the requirements of a modern museum and provide the museum with the services and essential facilities necessary to perform its function properly. In addition, this museum should be connected with the archaeological castle to form one archaeological historical site. An exhibition hall should be dedicated to the exhibition of the materials and tools used by the citizens of Aqaba for fishing. There should be some demonstrative paintings about the life of *Sherrif Hussein Bin Ali* as the museum is located within his house and a specialized library containing books about the *Sherrif's* life and the *Hijazi* area in general. There should be one hall dedicated to the city of Aila in order to exhibit some of its objects. Exhibitions in other halls should contain some objects from different Jordanian sites. As a result, the exhibition will not only be dedicated to the Islamic discoveries from Aila but visitors will also be supplied with information about different Jordanian archaeological sites, because of the touristic value of Aqaba. Visitors should be introduced about Jordanian archaeology in general.
- There must be a qualified and specialized staff, which has the ability to deal with the tourists and visitors in aspects such as interpretation. This can be achieved by organizing training courses for the museum's employees.
- It is necessary to install some electronic equipment to guarantee the security and protection of the collection from theft.
- The museum must be attached to the Department of Antiquities instead of the Ministry of Tourism in order to participate more in excavations and archaeological activities.
- Supplying the museum with audio-visual apparatus, as well as providing interpretation cards dedicated to each object, would provide better information. At the present time some cases have not got any cards at all.
- Educational and recreational activities should be increased and there should be more concern for children and the disabled. This could be done by organizing lectures and by preparing training workshops about different handicrafts.
- It is necessary to install climate control devices to control the indoor environment, particularly because the museum is located near the sea with its chemically rich humidity. It is of vital importance that the humidity be controlled in order to prevent objects from deterioration or degradation.

3.3 Irbid Archaeology Museum

3.3.1 Location and history

Irbid city lies about 90km North of Amman with a population of 925,736 (DOS 2004). Its archaeology museum was established in 1966 when it was housed in a rented building downtown. In 1988, it was moved to a building in the southern outskirts of the city close to Yarmouk University. The building is modern and built of white stone and has no marked local style of architecture (Zoubi 2009).

3.3.2 Building and interior

Notably, the museum is housed in the same building as the DoA's office of Irbid by which it is managed.
The museum building as shown in Figure 3.54 consists of the following sections:
- Display hall: The primary main hall, rectangular in shape.
- Management offices: A number of rooms devoted to multiple purposes, the museum curator's office and officials and typing room, drawing office and library. It is noteworthy that the 'library' was merely a small bookcase with very few volumes, altogether a small-scale affair of little practical value.
- Utilities: Housed within the building there is a warehouse in the basement with a kitchen and bathroom. Necessary facilities such as a seminar and lecture room are not available in the building. The museum is situated at a distinguished area in Irbid city, but it is not easily reached neither by pedestrians nor by public transportations, it can only be reached by private vehicles taxis. The surrounding garden makes it a wonderful natural place with a pleasant atmosphere. The garden is used as a display area but objects are placed arbitrarily, without any particular regard either for the object or for the garden itself.

The walls and ceiling throughout most of the building are white and the rooms are of a reasonable height. However, the walls have received no special treatment such as plastering or painting with oil-based emulsion which would have facilitated both cleaning and general upkeep.
There are a number of large metal-framed glass windows differing in width. There is also an aluminium and glass door (pull and swing type) leading to a kitchen.
The floor appeared to be of a uniform level, paved with plain tiles of a rather darker colour than that of the ceilings and walls. It is uncomfortable to walk on and this type of tile accumulates dust and quickly becomes dirty.

3.3.3 Management

The museum management, staff and employees hierarchy is shown in the following chart:

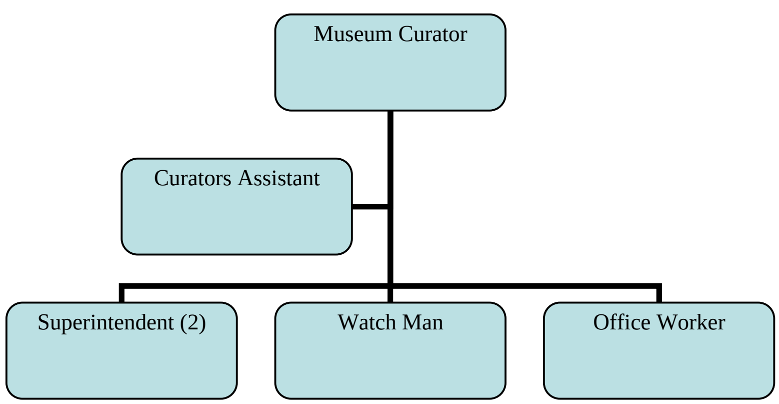

Figure 3.6 Irbid Archaeology museum hierarchy chart

It is clear that the museum lacks a competent staff of specialists, evidenced by the fact that the curator does most of the work himself. Therefore, it is unreasonable to expect the museum to expedite its important role and function positively and effectively.

Security provisions include a security officer on duty at night, iron bars on the exterior of windows and manual fire extinguishers. On the other hand, there are no signs denoting any prohibitions such as ‘No Smoking’, ‘No Touching’, or ‘No Photos’. Safeguarding exhibits depends on the presence of an official or in the exhibition hall. Above all, the museum lacks modern electronic equipment or alarms of any kind for safety and security.

3.3.4 Exhibition and collection

Objects and antiquities housed in this museum have been acquired from excavation work done by the Archaeological Department of Jordan, national universities, or even foreign scholars. The museum does not receive any private funding such as donations or legacies, but the occasional exchanging of objects between the Department and other national museums, in particular campus museums, do occur (Zoubi 2009).

As regards documentation, the museum keeps regular records of displayed objects but no duplications are made, so in the case that any were stolen, lost, or damaged, identification would be very difficult.

The display units are locally made glazed showcases with frames made of aluminium and they come in a variety of sizes and shapes. Some of the showcases were brought from Yarmouk University. While the sides of these cases are made of wood and the shelves of glass, the interior bases were covered with sackcloth fabric that is not fire-resistant, such as velvet.

Figure 3.7 Showcases in the Irbid Archaeology Museum.
Photo by R. AlGhazawi

As for the methods of display used in the museum, one can see that the chronological sequencing method was mainly used, the Stone Age up the Umayyad times being represented by a variety of objects. Some times the qualitative principle as a display method is also followed. This can be identified throughout examining cases designated for the display of specific types of objects.

Information cards of white pasteboard are printed in black ink with clear Arabic and English language texts. Notably, some objects, sometimes, whole shelves have no identification cards, while others have cards that are inappropriate to their importance. Sometimes expositions are insufficient or even wrongly placed, objects have been wrongly identified or placed behind or far away from the exhibits. In addition, another way of illustration is to display an object outdoors and this method is one of the environmental illustrations, which is necessary in modern museums.

Figure 3.8 Objects displayed on bare ground.
Photo by R. AlGhazawi

Concerning the displaying of objects outside showcases, the objects are placed on metal pillars, stone pedestals or even on the bare ground as in the cases of a mosaic and a stone and basalt statue.

In general, it can be said that the display process is not done properly. While some showcases seem to be crowded, others seem to be somewhat empty. In some showcases, objects are arranged inconsistently.

Through the Curator, the museum participates in excavations in certain regions within Irbid City and on a narrower scale the museum exchanges objects with other museums through the Department, or lends them to either local or national exhibitions. Currently, attempts are being made to publish a museum-related manual. Finally, one can conclude that the interaction between the museum and the local community is not all effective, since there are not enough activities such as lectures, meetings and social events that deepen and strengthen links and connections on a personal level. A somewhat divergent point, but a very important one, is the need to provide ramps, in order to facilitate access for the disabled.

3.3.5 Environment visual assessment

The museum is completely void of the necessary facilities such as laboratories and workshops for restoration and conservation processes. The ventilation of the museum is through doors and windows and central heating used in winter. Sunlight enters the building through large windows on exhibits. There are also artificial lights hung on ceiling fixtures directed towards showcases, but the cases themselves have no interior lighting. Consequently, as light is sufficiently available, there is a perceived need to install curtains that control the amount of light coming in, particularly in summer. Obviously, the museum lacks the modern equipment needed to control humidity and temperature. Moreover, it lacks even the simplest equipment to control humidity, such as silica gel.

Figure 3.9 Objects kept in the basement. Photo by R. AlGhazawi

Objects that are not currently exhibited are stored on metal shelves in a store located in the basement or on the bare ground. As excavations and discoveries have increased, objects have accumulated and have been packed in boxes and arranged on the bare floor in geographical order. Generally speaking, conditions inside store rooms are incompatible with those needed for the safety and security of objects and the conditions in fact hinder the work of scholars and researchers.

3.3.6 Recommendations

As a result of the condition of the museum, suggested solutions for the problems, regardless of the cost, are as follows:

- Establishing a new museum at a proper location that meets the requirements of a modern museum.
- Specialized, well-trained and highly technical staff members so that the museum can realize its mission and goals.
- As security provisions are largely insufficient, electronic security devices such as warning sirens, cameras, etc. should be installed.
- Properly organized methods of display, whether internal or external, leading to more consistency and balance in distributing displayed objects.
- Assigning an identification card for each object and shelf, provided that they appear consistent and harmonized in terms of size, position and colour as well as having sufficient relevant data. It is necessary however; to have available advanced audio

descriptions, as well as other accompanied media such as models, charts and overhead projections.

- Increased interaction with the local community and the establishment of strong relations and ties with other institutions and local museums. This can be achieved through organizing training courses on artefacts, holding lectures, seminars, social events and temporary fairs, exchanging objects, taking care of disabled persons and children, servicing interested researchers and scholars, as well as publishing leaflets and publications. This would obviously foster educational, cultural and leisure activities, which may increase visitor numbers.
- Offering more advanced equipment for controlling the environmental conditions in terms of temperature, relative humidity, air pollution, micro organisms and light, whether natural or artificial, in order to preserve antiquities from being damaged or destroyed. The primitive, traditional methods followed in the restoration are entirely insufficient.
- It is necessary to provide signs which indicate the location of the museum and these should be placed at all entrances to the city, in order to guide visitors, since the museum in its current location does not represent a well marked place.
- The eastern window of the museum should be filled in permanently.
- Curtains or adjustable blinds should be used for the other windows.
- The main entrance is always open and this may be the main source of outside climate interaction. Therefore it should be kept closed as much as is possible.
- Signs for prohibited actions, such as ‘No Smoking’ should be installed inside the museum.
- Some of the artefacts are displayed randomly in locations without any protection and can be obstacles for visitors, so they should be re-located.

3.4 Jarash Archaeology Museum

3.4.1 Location and history

Jarash city locates about 45km North of Amman with about 153,650 inhabitants (DOS 2004). Jarash is one of the three great classical city sites of the Near East. Set in a wide, fertile valley high in the hills of Gilead, Jarash is also the best preserved of the cities of the Decapolis. The Jarash Archaeology Museum was first established in 1962. It was located in the basement of a building near The Temple of Artemis in Jarash. In 1985, the museum was moved to another building under the name “Jordan Through History”. Then, under the supervision of Yarmouk University and the Ministry of Tourism and Antiquities, it was relocated to another place, which had formerly been used as a rest house (Owais 2009). The current building does not represent any local architectural type of building, even though it was once a part of an important ancient city. It lies on the eastern hill overlooking the old city forum as well as modern and old Jarash and this makes it a prominent, distinguished place.

Figure 3.10 The main gate at the Jarash Archaeology Museum.
Photo by R. AlGhazawi

In addition to the Karak and Petra museums, the Jarash Archaeology Museum is considered a site museum as it is related to a specific archaeological site. It is located in the same area where archaeological objects were excavated. The discoveries are usually kept in the same area as the excavations so that visitors can see them in their original environment. This enables the visitors to know their origin and maybe how these objects were used. The museum has no nearby buildings and has flexible boundaries, so it could be easily expanded in the future, as no legal or technical difficulties exist. If the building was expanded, however, it could cause damage to the beautiful surrounding environment. The problems the museum faces are mainly connected to enticing visitors to the museum and ensuring that the footpaths and roads within the archaeological site are well-kept, in order to enable pedestrians to reach the museum.

3.4.2 Building and interior

The structure of the museum is shown in Figure 2.55.
The museum consists of the following parts:

- The main entrance hall:
  This is an irregular-shaped hall, which acts as an information centre as well as being a place to display some paintings and artefacts before visitors reach the display hall.
- Display hall
  As can be seen in the museum building plan, the museum consists of one large display hall which has some display cases at the sides of the hall adjacent to the walls with other cases located in the middle of the hall. It has a triangular shape. In early 90s some modifications and expansions were applied to this display hall.

Figure 3.11 The main hall of the museum. Photo by R. AlGhazawi

- Administrative Offices
  There are two rooms: one for the director and the other one for the superintendent.
- Necessary services and utilities
  The storage room is still located in the basement of the Artemis temple (the previous museum building), which is fairly far from the current museum building. The Jarash museum includes a kitchen and a bathroom within its facilities. A garden and wide plots of land, which gives it a beautiful atmosphere, also surround the museum. Trees contribute to the pleasant atmosphere and protect the museum from the effects of the wind. The garden is devoted to outdoor displays. Despite this, the museum lacks some necessary utilities.
  The ceiling is levelled and painted white, the outside facades are constructed of white stone and the indoor walls are painted white.

The walls have windows, with panes of glass and metal frames, of various sizes, shapes and heights. These windows are quite near the ceiling and are in rectangular shapes in the display hall. The doors are either wooden or metal with no ornaments on them. They are of different sizes and heights and their upper surfaces are levelled so that they can be closed tightly. Ordinary tiles are used for paving the floors, which makes them seem flat and darker than the ceiling and walls. The tiles are uncomfortable to walk on and are easily polluted.

3.4.3 Management

The hierarchy of the museum management, staff and employees is shown in the following chart:

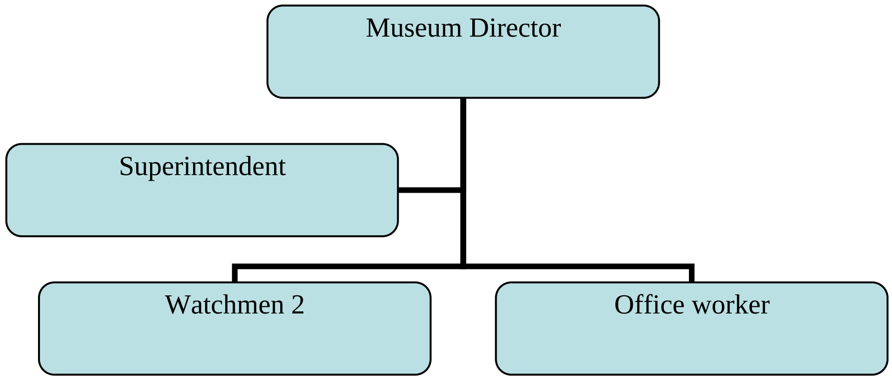

Figure 3.12 Jarash Archaeology museum hierarchy chart

It is evident that the museum lacks the qualified and specialized staff needed for the work. It relies on the director doing most of the work himself. This affects the development of the museum. Security provisions include two guards, who work during the day and windows and doors reinforced with iron bars.

Some prohibition signs, such as "No smoking", "No photographs" are present and there are manual portable fire extinguishers, but the museum lacks modern apparatus for security and safety.

Objects and artefacts housed in this museum were obtained through excavations in Jarash City carried out by the Department of Antiquities or foreign missions. Some of the objects have been purchased and others were confiscated from local citizens (Owais 2009).

In regards to documentation, records are available for the objects, including photos and descriptions of them and there is a record for visitors and another one for notable persons. All of these documents are kept inside the museum, but no duplication of the copies is available. This would be a problem in the case of robbery, loss, or damage.

3.4.4 Exhibition and collection

The display method in this museum based on chronological sequence. Objects are displayed in wooden showcases, which have panes of glass of various sizes and shapes. The General Department of Antiquities designed all of these showcases. The objects may be displayed either inside the cases or outside them in the middle of the hall. They are exhibited on metal pillars, wooden stands, or even stone pedestals, which are placed directly on the floor or on the walls. The flooring used in the display cases, in addition to using glass shelves, is either sand, cloth, or colourful velvet which is not resistant to fire.

Figure 3.13 Interpretation labels inside showcases.
Photo by R. AlGhazawi

The display cases contain objects referring to several historical periods starting from the New Stone Age (Neolithic) (7500-5700 BC), Iron Age

(1200-300 BC), Hellenistic (332-64 BC), Roman (64 BC-324 AD), Byzantine (324-640 AD), Umayyad (640-750 AD) and Mamluk (1263-1516 AD) periods (Kennedy and Bewley 2004). Some ages, such as Chalcolithic and Bronze, are excluded from the display in the museum (Owais 2009). It should be noted that the new discoveries are displayed in showcases placed in the middle of the hall.

Concerning information cards, several styles are used. White pasteboards placed inside the showcases are used to describe the period they represent. Cards are written in black ink, in both Arabic and English. There are also cards of different sizes to give more information about the objects in display cases or outside them. Some objects do not have adequate information and cannot be easily read. There are other kinds of descriptions methods, such as paper pamphlets, which are placed on wooden stands that contain drawings or graphs, sometime for a certain industry such as basalt stone industries. There may also be photos or maps depicting an archaeological site or excavation. At the same time, some objects have no cards. That has a negative effect on the visitors.

The museum director plays the role of guide for groups of visitors, whereas the guards walk with ordinary visitors. Concerning the open-air area display for large objects such as coffins, altars, crowns and stone statues, this is considered a modern way of displaying objects in their original environments. The not displayed objects are kept in the store lying below the Jarash Antiquities Office, in the Temple of Artemis. The drawers of display cases are also used for this storage purpose. The storage area is of no use for researchers and scholars, because it lacks the prerequisites of a specialized storage area.

The museum contributes to some excavations carried out in the old city of Jarash. In addition, the museum participated in the Fourth Jarash Festival, through a photo exhibition related to Jarash excavations and the museum reconstruction in 1986 (Owais 2009).

The museum's staff members sometimes accompany local and official missions in exploring the old city. These explorations involve school students and other groups of people. With this exception and the Fourth Jarash Festival, the museum takes part in no other activities that may strengthen interactions with visitors or the local community, such as taking care of disabled people by securing special entrance ramps for them, organizing training courses in handicrafts, meetings, or lectures focusing on the importance of ancient Jarash.

3.4.5 Environment visual assessment

The museum is completely void of the necessary facilities, such as laboratories and workshops, for restoration and conservation processes. This is an obstacle in terms of the museum’s duties and goals. Ventilation of the museum is achieved through doors and windows because of the lack of an air-conditioning system or central heating. Sometimes the showcases are opened for the same purpose of ventilation. Moreover, the museum lacks the simplest equipment needed to control high humidity, such as silica gel. Even if it was available, the staff members lack the experience of using it. In addition, if there were a need for some conservation work, the museum would have to request the help of the architects of the Department of Antiquities.

Sunlight penetrates through the windows of transparent glass, as there are no curtains or blinds. The installation of curtains or blinds is always a recommendation for museums to limit the amount of light. In addition to artificial light from the ceiling and wall fixtures directed towards the objects, there are also additional tungsten spotlights inside the showcases, which may cause fading in some organic-based materials.

3.4.6 Recommendations

Suggested solutions for the problems faced by the museum, regardless of the cost, are as follows:

- Build a new museum designed especially for the aim of being a museum, because the present museum lacks all necessary public utilities. It would be better if the museum was built at the entrance of the archaeological site. The southern area of the city may be suitable for this purpose. If this situation is difficult to achieve, then it is advisable to expand the museum display hall and divide the space according to an appropriate sequence for the display.
- The museum is in need of specialized, well-trained staff members, in order to pursue its mission and due to the city's historical and tourist importance.
- Security provisions are insufficient, as the museum mainly depends on human intervention. Therefore, electronic security apparatus must be installed to secure the safety of the museum and its objects.
- Although the objects are displayed according to chronological sequence, objects referring to some periods are vacant, especially the Chalcolithic and Byzantine periods. This can cause confusion for the visitors. This problem can be solved through borrowing, exchanging, or even purchasing objects in order to have all appropriate time periods fully displayed.
- Concerning the importance of explanation, every object must have a separate card or shelf to provide the visitor with sufficient information. In addition, it is strongly recommended that audio-visual aids be used.
- It is important to increase the museum's interaction with the local community and visitors, paying attention to children and disabled and elderly people. This may be achieved by conducting handicraft-training workshops, organizing lectures, meetings, fairs and social events and also by issuing leaflets and printed articles.
- The museum should take more advantage of the Jarash Festival, which takes place in the Archaeological site annually in August, to market the museum and recruit more visitors by extending the working hours to tie-in with the festival timetable.
- Special free-of-charge entrance should be offered to visitors of the museum who are not interested in visiting the ancient city.
- Advanced devices should be installed for controlling the environmental conditions in terms of temperature, humidity, micro-organisms, air-pollution and light in order to preserve the objects from being deteriorated, degraded or damaged. This is cheaper than conservation methods that would inevitably be needed at a later stage if these measures were not put in place.

Figure 3.14 The main entrance at The Jordan Archaeology Museum.
Photo by R. AlGhazawi

3.5 Jordan Archaeology Museum
3.5.1 Location and history

The Jordan Archaeology Museum was established in 1951 and lies on the Castle Mountain ancient *Rabbat Ammon* of the Iron Age. The architect Austen St. Barbe Harrison, who also designed the Palestinian Antiquities Museum in Jerusalem, designed this museum (DoA 1994). The reason why the Castle Mountain was selected as the site for this museum was the fact that it is, itself, an archaeological site containing antiquities dating from the Bronze, Iron, Roman, Byzantine and Islamic Ages. In addition, from Castle Mountain visitors can see the splendid and spectacular landscape of the capital city Amman.

In addition to being a site museum, the Jordan Archaeological Museum is primarily a national one. This kind of museum is often found in the city center, especially after this has extended its boundaries. In this respect, a question may arise whether there are any arrangements or provisions for leisure, cultural, educational, economic, or social facilities that would enable the museum to have influence in the community, either directly or indirectly. Therefore, any hindrance that may cause negative effects on the relationship between the museum and community, such as the existence of governmental institutions or administrative offices around the museum that may hinder the traffic of visitors, especially at rush hours, should be avoided. Additionally, inner-city land prices are prohibitive, making it almost impossible to acquire adjacent plots of land for expansion.

The advantages of the inner-city museum type are the services and activities they provide, such as public symposiums, lectures, intellectual services for children, a library and musical evenings.

The design of the museum is largely inconsistent with modern design protocols and generally has no prevalent traditional style of architecture, despite the fact that it is a national museum. Moreover, since the visitor has to climb flights of stairs, it is unsuitable for wheelchair users and those with mobility difficulties.

3.5.2 Building and interior

The museum building consists of two floors; the ground floor is the display halls and the basement, which is representing storage. The basement of the museum building is only accessible through the main showroom hall, whereas the showrooms, management offices and services are housed on the first floor. The whole building was designed in the shape of a Greek cross. Halls with manuscripts, statues and sarcophagi showrooms were built and attached to the museum at a later date.

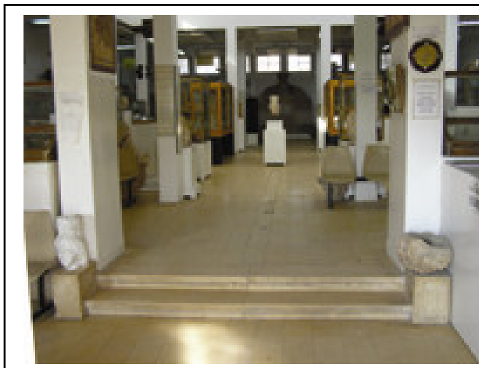

Figure 3.15 The main display hall. Photo by R. AlGhazawi

The interior of the museum is shown in Figure 3.56 and described briefly below:

- Entrance Hall: This is the first hall seen by visitors after entering through the main gate of the museum. From here, there is access to the offices, halls and utilities.
- Display Halls: There are multiple halls of varied sizes and shapes. These halls take up a large portion of the interior space, perhaps in excess of 80% of the whole

museum space. The halls act as the main showrooms, while at the same time they serve as a thoroughfare leading to the other facilities of the museum. This is not necessarily the case in modern museums, where the showroom halls are kept completely separate from offices, facilities and utilities. In modern museums, workflow disruption and confusion are reduced to the minimum.

Objects displayed belong to periods ranging from the Stone Age to the Nabataean Era and there are also on display a group-chamber tombs, a Nabataean Artefacts Hall, a Dead Sea Scrolls Hall, an Islamic Artefacts Hall and a hall for pottery, sarcophagi and stone-made sculptures. Although there are many showroom halls, the museum seems to have insufficient display space, particularly since it receives objects from a variety of regions. Consequently, the display cases and halls appear overcrowded.

- Administrative Offices: The administrative offices occupy a small area of the interior space. There is an office for the Curator and offices for his assistant, staff members and clerk offices.
- Vital Utilities and Facilities: Inside the entrance hall, there is a small room for information and tickets. The storage area in the basement can be accessed from the main showroom. This design, however, is inconsistent with modern design demands, which stipulate that the entrance of a store should be set apart from the main showroom. Around the museum, there is a garden and a courtyard, which adds much to its beauty and eventually might be used for occasional external exhibitions. At present, it serves as a parking lot.

Figure 3.16 Administration offices. Photo by R. AlGhazawi

There are no doors between exhibition halls, but the lintels are almost of ceiling height, giving easy access for large artefacts such as stone sculptures. Offices and other facilities have unornamented wooden doors. The floor in the showroom halls is covered with ordinary tiles, which are rather darker than the ceiling and wall slabs.

Figure 3.17 Windows near the ceiling. Photo by R. AlGhazawi

The ceiling, constructed from waffle slabs, is of varied heights. It appears very high in the main hall compared with that in some halls, while it appears to be the same height as some other halls. Both the walls and ceiling are white, but the walls have not been treated in order to enable easy cleaning and maintenance. The walls have too many windows of various shapes and height. Some are located near the ceiling and others are at a moderate height, with metal or wooden frames and transparent panes of glass.

The design of this museum is acceptable in terms of displaying objects, but not in terms of walking or easy cleaning. Notably, the doorsteps between the Entrance Hall and other showrooms have a negative influence on visitor traffic.

In conclusion, the designs of the museum, now six decades old, are inconsistent with the essential conditions and requirements of modern museum design. A showroom, for example, should never be more than 50% of the total building area (Ambrose and Paine 1993), for if it exceeds this limit the increase would be at the expense of administrative offices, facilities and utilities, resulting in a dysfunctional museum. This should be taken into account, especially due the building's importance as the national museum and the multiplicity of purposes, activities and functions it serves.

3.5.3 Management

The following chart shows the organizational hierarchy of the museum employees:

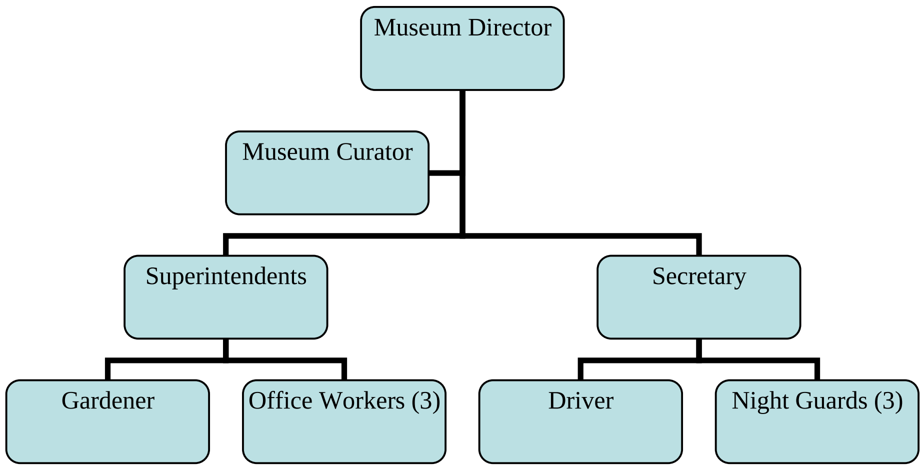

Figure 3.18 Jordan Archaeology museum hierarchy chart

Although a national museum should employ a staff of specialists, the Jordan Archaeology Museum falls short since there are insufficient technicians and many administrators.

Security provisions depend heavily on a number of guards and securely locked metal safes for keeping coins and valuable objects are, often located in the office of the museum curator. Manual fire extinguishers are also available. The fire extinguishers, which are randomly placed, would obstruct the traffic of visitors and transportation and would expose the museum to risks. Other provisions taken for security purposes are some signs indicating prohibitions such as smoking and photography. Notably, the museum is completely void of modern electronic devices, such as security cameras, used for safety and security purposes.

Archaeological excavations carried out by the Department of Archaeology, both in collaboration with domestic institutions or foreign missions are the main source of the objects in this museum. Other objects have been obtained through purchase, gifts, donations, or exchanges with local museums in coordination with top management personnel (Nagawai 2009).

Concerning records, there is a record with a sequenced numbering system for each of the objects, whether displayed or stored. These records also include a visitor's book and another for honoured guests. As there is no other copies of these records available, some objects such as stolen or lent are at risk of being lost completely. Worst of all is the fact that no computers are used for registering data electronically. This is essential for national museums, if they are to work effectively and efficiently.

3.5.4 Exhibition and collection

The exhibited objects are displayed in cases of varied sizes and shapes. these cases are made from a variety of materials. Most are made of wood and glass and are old; they were imported from England. Some of the showcases are made locally of wood and glass or aluminium and glass. These were later additions to the museum. Inside the cases, fixed glass shelves are used in the bases of the cases, which are also furnished with white pebbles. In addition, there are exhibits on wooden pedestals or directly on the ground. A showroom is devoted to a group exhibition of Jericho (Middle Bronze Age). In addition, there is an outdoor exhibition, particularly for various stone objects such as capitals, columns and statues. Furthermore, a showroom is devoted to the function of displaying stone statues and pedestals, metal stands and wooden bases are used.

Primarily, chronological sequencing is the method of exhibition followed, together with the quality principle method. The latter method is most obvious in the statues and sarcophagi hall. Notably, too many objects are crowded together in a relatively small area; therefore showrooms seem crowded, which in turn results in visitors being confused and distracted.

Historical eras covered by the objects housed extend over more than eight thousand years and one can say that the objects form a semi-complete collection covering most if not all periods of history in the region, starting from Pre-History (Paloeolithic) up to the different Islamic Ages (636 AD-present) (Nagawai 2009). The collection is made up of as many as twenty thousand pieces representing the Hellenistic to Late Islamic periods. These pieces record political transformations, ruling regimes and political situations among dynasties and descendants. The objects displayed can be categorized as follows:

Table 3.2 illustration of the distribution of objects in the museum by ratio, for each of the Historical Ages (Nagawai 2009)

Historical Ages	Ratio	Historical Ages	Ratio
Pre-History Age	7%	Iron Ages	15%
Chalcolithic Age	5%	Nabataean Period	10%
Early Bronze Age	15%	Hellenistic Period	3%
Middle Bronze Age	10%	Roman Period	15%
Late Bronze Age	5%	Byzantine Period	5%
Islamic Period	10%		

It is worth mentioning that the museum lacks freestanding objects from the Byzantine Period in particular, despite the fact that large parts of mosaics could be displayed.

Figure 3.19 One of the wooden cabinets used for storing.
Photo by R. AlGhazawi

It should also be noted that objects of the Islamic period fall short of making a sequence of more than one thousand years (700 AD – 1700 AD) (Nagawai 2009). Objects from Abbasid, Fatimid, Ayyubid and Mamluk periods are few. There is also an overlapping and duplication in the displays of some objects, which could confuse visitors. Further confusion is caused by stone objects of the Islamic Period being displayed beside plaques in the Nabataean Hall made of mud and plaster.

There are also four wooden cabinets with brown drawers in a corner of the Nabataean Art Hall, for storing not exhibited materials. Written explanations are either kept in white wood panels immediately behind display cases, or hung from the ceiling, or posted on walls just above the cases. Such explanations clarify historical periods, the number of each display case and the objects displayed. There are pasteboard cards of different sizes painted in bold black letters with clear inscriptions in Arabic and English. Another type of card is of white plastic on which inscriptions appear in a single language (Arabic). Some cards are very small, making them difficult to read. As some showcases have few of these cards, some objects, both in and outside cases may lack such cards. The lack of standardised and numerous explanations may have decreased the potential of the museum (ICOM 1974). Larger sheets of paper printed in both Arabic and English containing information about the objects and sites where they were found are usually found posted on the outside of a case or on walls. In addition, there are mosaic pictorials, maps, illustrations and charts, together with some relief objects such as relief maps for archaeological sites in both Palestine and Jordan and plaster replica versions of some objects. Mirrors are used to make views of reverse sides possible for some small objects, which contain inscriptions or engravings.

Objects in the basement are stored in wooden cases, laid out geographically, according to the excavation or site name.

Despite the fact that it has importance as a national museum depicting the cultural heritage of the country, the museum has not organized up-to-date instructional activities. Activities, events and contributions are limited to participation in excavations with the Department of Archaeology and Antiquities and foreign missions. There have also been occasional temporary exhibitions, both internal and external, for example in Belgium, France and Germany. Except for the Museum Manual, published in 1975, there are no publications. Currently, it is intended to arrange for a new manual in cooperation with the Friends of Archaeology Society.

Since the museum lacks many facilities and services such as laboratories, restoration workshops and a library, it assumes no role in conservation and restoration processes and depends heavily on those engineers and technicians sent by the Department if needed. Sometimes objects are dispatched to laboratories within the Department for conservation.

3.5.5 Environment visual assessment

First, the ventilation of the building depends heavily on a variety of windows. Heating, on the other hand, is central, but the heating system is hung from the ceiling and is thus easily seen, disrupting the general spectacle and possibly constituting a hazard to officials, visitors and objects. The overhead central heating system was installed in 1969, due to the fact that the display cases stood against the walls. In the storage area, ventilation also depends heavily on the existence of windows. There is no central heating system in the storage area and for that reason, the storage lacks many necessary requirements for environmentally safeguarding objects. At times, silica gel is used to reduce high humidity levels, but modern devices for this purpose are not available.
The light in the museum was planned to be natural and readily available from various windows. Curtains with transparent fabric or internal blinds limit the amount of light coming in, thus reducing its detrimental influence on exhibits. Additional light sources are electric neon lamps on ceilings or on walls. Other neon lamps are found inside some showcases. This artificial lighting system is unsuitable because of its negative effect in the case of relative humidity and temperature fluctuations and because the light intensity is not carefully specified for each of the objects.

3.5.6 Recommendations

The essential requirements for this museum, based on its condition, are listed briefly below:

- The present building is incompatible with prerequisites of a modern museum since it lacks too many essential conditions and facilities. As a national museum, a new building should be built. Since a large number of objects have been added to the museum’s collection in recent years, the current showcases will be of no value in respect of the proposed museum.
- At present, the museum is inaccessible for handicapped people, so it is necessary to make it easily accessible by connecting it through corridors or walkways.
- As this museum is the national museum and therefore representative of the civilizations of the country, a competent and specialized educational, technical and administrative staff should be available to perform its objectives in serving visitors and tourists. In this respect, training programs should be prepared for training museum staff members on how to treat a variety of visitors.
- A modern security system should be installed, rather than relying solely on guards.
- Attention should be paid to the organization of exhibits and their layout, to avoid overcrowding. Better use should be made of free-standing objects on display, especially those from the Byzantine period. A special effort should be made to acquire more examples representative of the various Islamic periods. This should ideally form a complete display, arranged through exchanging, borrowing, or purchasing items. Special care needs to be taken in the Nabataean hall, to avoid overlapping and inconsistency in the display.
- The information cards should provide more information for the visitor, be of uniform size and format and should be placed on every shelf and exhibit. Further information should also be available through audio aids. These improvements will add to the visitor's enjoyment and appreciation of the objects on display.

- Increasing interaction between the museum and the community should be achieved by paying attention to both educational and leisure activities and taking special care of the needs of children, the elderly and disabled people.
- A modern system for controlling relative humidity and temperature is required for the preservation of the objects on display. This should include up-to-date methods of control of environmental factors (temperature, relative humidity, air-pollution and lighting) to be used in conjunction with traditional methods. In particular, the present heating system installed on the ceiling should be removed, since it obstructs the visitor's view, is unsafe and aesthetically unacceptable.
- The main entrance door at the Jordan Archaeological Museum is always open, it should be replaced by an electronically controlled door, which opens and closes automatically. This would effectively reduce the adverse effects of various environmental aspects from outside.
- The display cases should contain objects made from the same materials and displaying two or more different materials in the same case should be avoided so that the environment inside the showcases can be customized for one particular material.
- Blinds should be used instead of fabric curtains, in order to minimize the amount of UV radiation from the sunlight.
- Fragile collections like the Dead Sea Scrolls should have a special intensive care program.
- Administration offices should be separated from the museum and should have their own entrance.

3.6 Karak Archaeology Museum

3.6.1 Location and history

From the mid twelfth century to the present day, Karak has played an important role in the political and economic life of Jordan (Milwright 2008). The city of Karak is now the administrative centre of *Liwa al Karak*. It lies 110km South of Amman with a population of 204,135 (DOS 2004), 1000m above sea level (Milwright 2008). It is a road junction and an agricultural trade centre. Ancient Kir Moab (also mentioned in the Bible as Kir Hareseth, Kir Haresh and Kir Heres), was the walled citadel of the Moabites. Karak played an important role in Crusader time. The lordship of Karak was one of the chief baronies of the Latin Kingdom of Jerusalem. A 12th-century castle built by the Crusaders is the major tourist attraction especially for those interested in bible related remains. For tourists the city is also a stop on the way to Petra, but only to spend a few hours for a visit of the castle and a lunch(Tanaka *et al*. 2005).

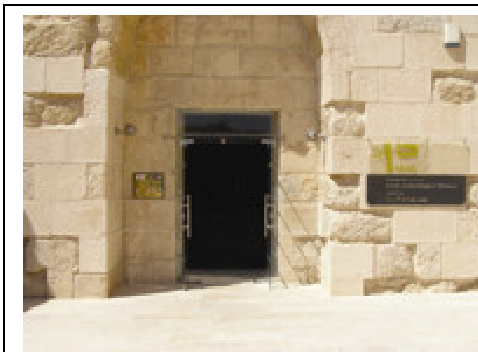

Figure 3.20 Main entrance at the Karak Archaeology Museum.
Photo by: R. AlGhazawi

The Karak Archaeology Museum was established in 1981 in a basement of the Karak citadel, in Karak city. It is a site museum, as is the Jarash Museum. The museum had one long basement as the only exhibition hall. In 2001 the museum was renovated and refurbished, with financial support from the Japan International Cooperation Agency *(JICA*) and the Japanese Bank of International Cooperation (Masadeh 2009). The process of conservation included the conservation and restoration of the front courtyard and the restoration of the western cellars so that they could be used as a storage room. Most importantly, another display hall, with a cylindrical shape ceiling, was added to the museum. The museum was in need of these improvements and the renovation made it possible for the museum to display more objects.

3.6.2 Building and interior

Figure 3.21 The cylinder-shaped ceiling at the main display hall.
Photo by: R. AlGhazawi

The museum's front façade shows no distinctive architectural design. One of the corners near the main entrance is used as an information and observation office and as a centre for selling admission tickets. Beside the basement, there is a bathroom and a storage room for keeping artefacts. The museum has no other utilities or services. The interior of the museum is shown in Figure 3.57.
The ceiling is cylinder-shaped which does not fit the usual design of display halls in museums. This kind of ceiling creates an echo, which may disturb the visitors. The ceiling seems relatively high. The walls have a number of windows of different sizes. Some of them are battlements made of transparent glass and metal frames. It must be noted that the ceiling has several vents, which allow light to penetrate through. These vents are wide and relatively high. The main entrance is accessed up several steps. This is a hindrance for wheelchair users or people with mobility difficulties. The floor of the display areas is level and paved with ordinary tiles. These tiles are a recent addition to the basement and their colour does not correspond with the colours of the ceiling or walls. The floor is difficult to walk on and is difficult to clean. The main gate is the only door in the museum. It has an iron frame with transparent glass.

3.6.3 Management

A number of officials and employees are responsible for managing the museum:

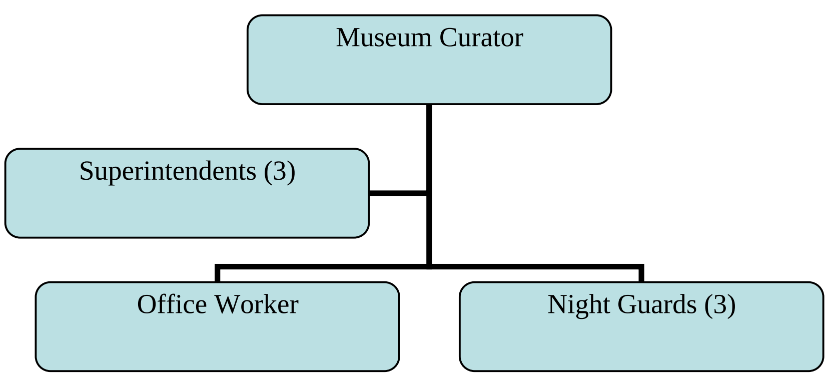

Figure 3.22 Karak Archaeology museum hierarchy chart

It is obvious that the museum is in need of specialized personnel. This has had a negative effect on the work and advancement of the museum.

The safety precautions depend mainly on the availability of a night guard and on signs indicating prohibited behaviours such as photographing and smoking. Portable fire extinguishers are available.
Electronic apparatus necessary for protection and safety are unavailable in the museum.

3.6.4 Exhibition and collection

The excavations carried out in the Karak Governorate by the Department of Antiquities or foreign missions are the only sources of the displayed objects in the museum.
The objects are displayed either in showcases of different sizes and shapes or outside them in the wall cavities. These showcases are made of aluminium and glass placed on a wooden stand. The materials used in showcases may be the same wood as the showcases' frames, or cloth or velvet of different colours. These materials are not resistant to fire. The backgrounds of the cases also vary, as some are made from wood and some from glass.

Figure 3.23 Showcases of the display.
Photo by: R. AlGhazawi

The display is arranged according to geographical order. In spite of this, a chronological order is sometimes applied, but it is not well-organized. The order of the display is as follows: the New Stone Age "Pottery Neolithic" (7500-5700 BC), the Chalcolithic Age (5000-3600 BC), the Early Bronze Age (3600-3000 BC), the second and third periods of the Early Bronze Age I (3000-2300 BC) and the Second Iron Age (1000-539 BC) (Milwright 2008). This causes confusion to the visitors. The objects exhibited according to geographical order are displayed in separate showcases and not connected with the general chronological order. They are from the archaeological sites of *Feinan (wadi Araba), Bab Al-Dhra', Buseirah, Khirbet Balua, Karak, Al-Heditha, Al-Rabbeh, Al-Numeira* and the Dead Sea area discoveries (Masadeh 2009).
It should be noted that the display lacks coordination. Some cases are overcrowded with objects, whereas others are vacant.
The most important means of information about the displayed objects are the interpretation labels. These are made of pasteboard paper, printed in black ink in Arabic and English. The cards contain neither adequate nor sufficient information for example some shelves and objects have no interpretation labels. Other cards contain descriptive sketches of objects and implements and photos of their excavations.
Paintings and maps are displayed either inside the showcases or on the walls. The museum's curator sometimes acts as a guide and answers the visitors' inquiries. Modern techniques of interpretation devices providing information about objects are not used in the museum, such as the objects are stored on metal shelves in a storage area in a nearby basement.

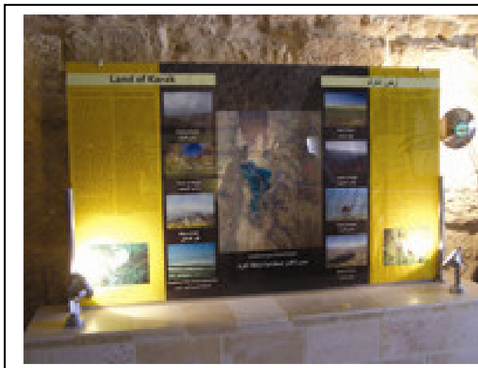

Figure 3.24 Example of some Sketches displayed against walls.
Photo by R. AlGhzawi

3.6.5 Environment visual assessment

The museum lacks the necessary apparatus for controlling humidity, temperature and other environmental conditions and it lacks a light filtering system.
Windows are the main source of ventilation and central heating, which is necessary due to the cold weather in that area, is not available.
The lighting is also insufficient and the museum mainly depends on artificial light. There are spotlights fixed to an iron rail, which is attached to the ceiling. There are also neon lamps fixed on the wall and inside the cases. This does not correspond to modern exhibition methods and may in fact add to the deterioration of the objects. The light provided naturally is weak because the windows are small in size and few in number.

3.6.6 Recommendations

Based on the museum's condition, the following solutions are suggested:
- This museum should be relocated to a new building designed specifically for the purpose of being a museum with all necessary requirements and utilities.
- Qualified administrative and technical staff should be provided to ensure the museum could fulfil its aims.
- Modern electronic safety equipment such as fire alarm horn, video watch cameras and theft prevention siren should be installed.
- Audio-visual aids should be provided. In addition, the information cards should be standardised and the information given should be elaborated. Moreover, every shelf or object must have a separate card.
- More attention should be paid to the museum's educational role and amusement activities. The museum should increase its interaction with the local community and provide better access and resources for visitors, especially including children and disabled people.
- Up-to-date apparatus should be used to control the various environmental conditions such as temperature, humidity, ventilation and lighting, in order to insure the preservation of the objects.

3.7 Madaba Archaeology Museum / Madaba folklore museum
3.7.1 Location and history

Figure 3.25 Outside view of the Madaba Archaeology Museum. Photo by R.

The town of Madaba lies about 25km southwest of Amman with about 129,792 inhabitants (DOS 2004). The establishment of the Madaba archaeological museum synchronized with the establishment of the Madaba folklore museum in 1979. The two museums are located in a house in the centre of the town of Madaba, which was previously owned by a Jordanian family until it was possessed by the government in 1966 (DoA 1994). The two museums will be dealt with here as one unit, because they share the same building and have many aspects in common, they also include a 'popular' house and an open-air mosaic display area. The museum building itself is not representative of any local architectural style. The museum building is a historical one of a type, that is usually built in the centre of old cities and tends to become part of the historical landscape of that city. Any project aimed at extending the boundaries of the museum would face challenges. Thus, changing this museum into an up-to-date one is not possible.

There are several other problems that may arise in this museum, such as: the difficulty of accessibility for pedestrians, furthermore, vehicles overcrowding the streets leading to the museum. The effects of high humidity, which can clearly be seen on the walls of the museum, can damage the displayed objects. The natural light may be sometimes insufficient and sometimes too strong. Moreover, the internal space may not be sufficient and the museum may not be able to bear an increase in the number of visitors. It is important to take the safety and security provisions of the museum into consideration. This museum seems to be more exposed to theft and fires than other museums described in this essay (Hawawreh 2009).

3.7.2 Building and interior

The layout of this museum is shown in Figure 3.58 and is briefly described below,

- Display halls:
  There are four main halls, of different sizes and heights.
  After entering the museum through the main gate visitors come to the first hall. From this hall visitors can access the other halls.
  The second hall is the same shape as the first but rather smaller in size.
  The third and the fourth halls are connected by open doorways and both have mosaic floors.
  All of the display halls are rectangular in shape.
- Offices:
  The museum offices are located upstairs in an adjacent building, which also belongs to the Madaba Antiquities Department, above the Popular House.
- Utilities and Services:
  The museum building has bathrooms, a kitchen and a storage room, which are found beside the offices. There is also a garden and a courtyard area, which is surrounded by the museum. Sometimes it is obvious that the museum focuses on external display, especially for mosaics. The museum lacks a car park, library and conservation laboratories.

The ceilings of the display halls are level and painted white. The walls are thick, relatively high and painted white. There are electric cables on the walls, which looks ugly. There are a number of windows of various sizes and at different heights that are made of metal frames and transparent panes of glass. The halls are connected, with no doors in the doorways. Notably, the doorsteps between halls have a negative influence on visitor traffic.

Figure 3.26 The main display hall adjacent to the other facilities. Photo by R. AlGhazawi

The gate at the main entrance of the museum is made of unornamented metal together with panes of glass. It is of moderate height about two meters. There is a narrow metal door in the first hall, which leads to the garden. Wooden doors are used in the utility rooms. The flooring differs from one hall to another. In the first two halls, the floor is covered with light-coloured tiles, which do not suit the colour of the ceilings and walls. In addition, the level of the floor is higher in some halls than in others. This hinders to some extent the movement of children and elderly people and would also prevent wheelchair users from reaching the fourth hall in particular. This kind of flooring is not safe to walk on, because it consists of slapping and different level tiles, which the visitor might not pay attention to. Beside that, it may quickly become dirty. The third and fourth halls are paved with mosaic floors, which distinguish the Madaba museum from the other museums in Jordan: the city of Madaba saw a flourishing of mosaic art during the Byzantine Age.

3.7.3 Management

In cooperation with the Madaba Antiquities Department, a number of employees run this museum. This can be seen through the following diagram, which describes the administrative and security staff. It must be noted that there are a number of employees specialized in archaeology working with the Madaba folklore museum and the Madaba archaeological museum.

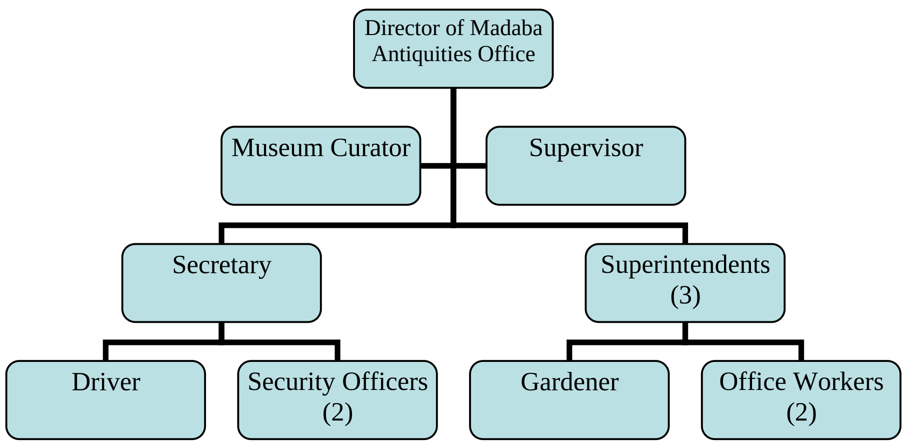

Figure 3.27 Madaba Archaeology museum hierarchy chart

Safety and security provisions are represented by the assignment of guards during the day and night, iron bars on some widows and manual fire extinguishers. The museum lacks safety electronic apparatus such as fire alarm and also signs denoting forbidden actions.

The excavations carried out in the *Madaba* area, either by the Department of Antiquities or in cooperation with foreign scholars, are the main source of the museum's contents. It is worth adding here that some objects have been purchased from local citizens, while other objects have been donated to the museum as gifts.

The museum has a guest book and a record of displayed and stored objects. Duplication of these records is not available. For this reason, the records could not be replaced if they were stolen or destroyed.

Figure 3.28 Showcases in the Madaba Archaeology Museum.
Photo by R. AlGhazawi

3.7.4 Exhibition and collection

Objects are displayed in locally made glass showcases with frames made of metal. These showcases are of different sizes and shapes, containing glass shelves with wooden interior bases, which are sometimes covered with ordinary coloured cloth that is not resistant to fire.

The displays are arranged according to the geographical method. This is applied to the showcases that are used for displaying discoveries from a certain site or excavation, such as *Mekawer, Hesban, Umm Al-Rasas, Madaba and Khirbet Iskander* excavations. Every showcase contains a variety of objects such as pottery, glass and metal objects (Hawawreh 2009). This causes confusion for visitors and also makes it difficult to provide suitable environmental conditions within the showcases in order to preserve the contents. A replica of the Mesha stele, along with other stone and pottery objects are displayed outside the showcases on the bare ground (Hawawreh 2009). Some of these objects are hung on walls or placed on metal pillars.

The displays refer to several historical periods beginning with the Stone Ages and continuing to the Islamic periods. However, some periods are not represented. Therefore, the museum should cooperate with other museums in Jordan to possess objects that would complete the collection. Some shelves in the showcases are vacant, which really distorts the coherence of the display.

Figure 3.29 Some shelves without any interpretation cards. Photo by: R. AlGhazawi

Transparent cards have been pasted on the fronts of showcases with a number indicating the showcase and site name, clearly printed in black ink in Arabic and English. Each card also describes a certain object or all of the shelf contents. However, some shelves have no interpretation labels or explanations and some of the labels may even have been wrongly placed. The only educational and teaching facilities that the museum provides are information cards and posters.

Charts, pictures, paintings and stickers are hung on the walls identifying and clarifying some of the archaeological sites in Jordan. This can be considered an acceptable interpretation method for small, local museums, in order to provide the local citizens, as well as visitors, with additional information about other sites they have not had the chance to visit yet.

Figure 2.30 Objects in the storing area. Photo by R. AlGhazawi

The objects not on display are stored in a storage area, adjacent to the museum curator's office. The storage area is a small room, which lacks the requirements and suitable conditions for storing artefacts; objects are stored in big plastic crates, which stand on metal shelves.

The interaction between the museum and the local community is very limited. Neither lectures and social activities, nor educational and training programmes are provided. To

achieve this interaction, technical workshops must be conducted to involve individuals with vocational industries and handicrafts such as the mosaics for which the city is famous. This can be achieved under the supervision of specialized technicians' envoys from the Department of Antiquities or from other local or foreign organizations.
The museum does not have the ability to do any conservation or restoration work, because of the lack of laboratories and expertise.

3.7.5 Environment visual assessment

The ventilation in the building is dependent on the windows. Neither central heating, nor temperature and humidity-control systems are available at this museum. Natural light enters the building through windows. In addition to natural light, there are artificial light sources such as lanterns and neon lamps on the ceiling. In general, the lighting is sufficient, but not appropriate.

3.7.6 Recommendations

Improving the museum's condition would require the following:

- Providing the museum with the required facilities, in order to improve the museum's performance, especially since it is located inside a city of historic and tourist importance.
- Installing an up-to-date electronic security system to protect the museum and its objects, not overlooking the human element.
- Organizing the displays following the chronological sequence to avoid confusion.
- Dependence on traditional means of explanation is one problem and the lack of identification cards on some shelves is another. Therefore, it is necessary to provide the objects with adequate, uniform size cards, placed on every shelf. These cards must provide more information for each object than is given presently. Furthermore, installing audio-visual devices will always enhance any display.
- The museum does not have any educational activities for the benefit of visitors or the local community. The museum's interaction with the local community should be increased by organizing training courses on handicrafts, especially mosaics. Also, disabled people and children must be provided with and involved in appropriate workshops and lectures.
- Installing up-to-date systems for controlling the various environmental conditions to safeguard all the exhibited and stored objects.
- It is necessary to provide the museum location signs at the city entrance, indicating the location of the museum in order to guide visitors to the museum's site. These signs should be placed at all entrances to Madaba city, because the museum is surrounding by other buildings and can be difficult to find.

3.8 Petra Archaeology Museum
3.8.1 Location and history

The Petra Archaeological Museum was first established in 1963 and a Nabataean cave dug in red rock was dedicated for this purpose (DoA 1994). The cave is at the

Figure 3.31 Petra museum
Photo by R. Alghzawi

western end of the ancient city of Petra and was only accessible by climbing a large number of rock-cut steps. It was therefore almost inaccessible to children, elderly people and handicapped people. In 1994, the Petra museum was moved to a new building, nearby, approximately 1500 m from the Siq, the long and narrow entrance of Petra (DoA 1994). The Petra Archaeological Museum is considered a site museum representing the worldwide famous archaeological site, which gives it an additional importance.

3.8.2 Building and interior

The Petra Archaeological Museum consists of one big room, the main display room, surrounded by two smaller rooms used for displaying objects, as shown in Figure 3.59.
The building lacks necessary utilities and services. The ceiling seems level and of medium height, about two meters. The walls are straight and painted white. They have some windows of different sizes, made of metal frames and glass panes, which are higher than the eye level of the visitors.
The halls have no interior doors. The only entrance is a metal door with glass boards (pull and swing type). The entrance is wide enough and of reasonable height and is unornamented. Its upper part is leveled and is always tightly closed. The floor is covered with ordinary tiles, which are a new addition and is level. Its colour is darker than that of the walls and this adds some coherence to the interior.

3.8.3 Management

The museum management system can be seen in the following chart:

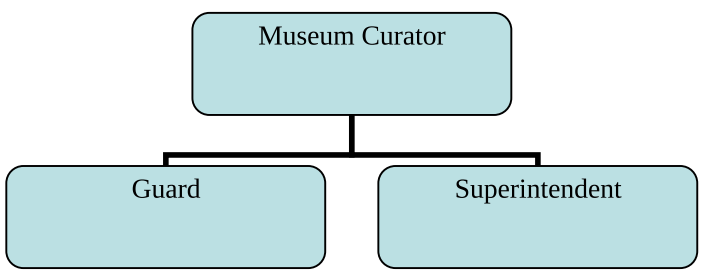

Figure 3.32 Petra Archaeology museum hierarchy chart

This system reflects the neglect of this museum by the Department of Antiquities although it is in a very important tourist site. At least this neglect affects the museum’s activities and participation in temporary exhibitions. The safety of the museum is entrusted to the guard. This does not conform to museum safety precautions. Emergency plans of most museums are limited to fire emergencies only. However, other types of emergencies, such as floods and hurricanes, electrical failure, sprinkler leakage, bomb threats, chemical contamination, medical emergencies, theft, etc, need also effective attention.
The excavations carried out in Petra either by the Department of Antiquities or by Jordanian local universities in cooperation with foreign missions are the main source of the museum contents (Marahleh 2009).

Museum records such as a guestbook and the records of the objects movements do exist, but without any additional copies in spite of the lack of security provisions (Marahleh 2009).

3.8.4 Exhibitions and collection

The museum exhibition is mainly displayed in showcases. These showcases are made of wooden bases and aluminium frames with big glass boards and they come in different shapes and sizes. The inside surface of these showcases is either covered with local sand or wrapped with velvet, which is not resistant to fire. Sometimes the artefacts are displayed outside the showcases on metal pillars or stone pedestals.

Figure 3.33 The wooden showcases.
Photo by: R. AlGhazawi

The method of display follows the geographical order, which is mainly used in site museums: each showcase is dedicated to the display of a specific excavated site, such as *Tawilan and Petra* In addition, a special showcase is dedicated to the display of Nabatean and Roman numismatics, which use the collection classification, a method often used in such museums (Marahleh 2009).

The historical periods represented in the museum start with the Hellenistic one (332-63 BC) and include the Nabataean (200 BC- AD 106), Roman (63-324 AD) and Byzantine (324-636 AD) periods (Milwright 2008; Marahleh 2009). Thus it is obvious that the objects on display represent only the finds from the extended site of Petra and still the lack of artefacts was clear, considering Petra's special role. Petra was chosen by UNESCO to be one of the new Ancient Seven Wonders of the World; the list of these new seven Ancient Wonders was announced on the 7th of July 2007. The number of tourists to the area has increased accordingly. It is therefore recommended that Petra should have a larger museum displaying more artefacts, in recognition of the significance of Petra and also to meet the expectations of visitors.

The explanations of the objects are primarily in the form of information labels, made of white cardboard, printed with black ink in Arabic and English. The information written on these cards are not sufficient for the visitor to gain the desired information about the displayed objects inside the showcases. Most of the cards only describe the objects and the date of the excavation. Despite the knowledge that the majority of the museum's visitors are foreigners, some of these labels are written in Arabic only and some do not have labels at all.

The first destination in this museum for excavated artefacts is the storage area, which is located in the basement of the museum in a small room. This storage area lacks all the required conditions. The museum does not have any educational activities. Educational activities are especially important for the local community, as they are directly related to the historical site of the city as it provides their main source of income.

3.8.5 Environment visual assessment

The museum's ventilation system depends mainly on the main door and windows, which are opened during the working hours of the museum. This disturbs the indoor environment of the museum because of the accumulation of dust inside the museum from the sandy environment of the historical site of Petra. The museum has neither an air-conditioning system nor a heating system and so the fluctuation of temperature and humidity is related directly to the outside climate. The lighting system in the museum depends mainly on daylight coming through windows. The windows in the museum do not have curtains. Curtains would reduce the amount of radiation emitted by the sunlight that enters the museum, especially in summer time.

Figure 3.34 an indoor general overview. Photo by R. Alghzawi

3.8.6 Recommendations

In order to improve this museum and make it worth its title as one of the most popular historical sites in the world, the following suggestions are given:

- The current museum is located in the middle of the historical site. In addition, the only official way to reach it is through the "Siq" which starts near the beginning of the Petra site. This pathway to the museum stretches some four km and usually takes visitors 50 minutes to walk. This is of course if they walk directly to the museum, non-stop. However, visitors often reach it after four hours of walking because of the frequent stops they make to see highlight along the journey. Therefore, it is recommended that the current museum be relocated to the entrance of Petra site so that visitors can visit the museum at any time without spending considerable time and effort to reach it.
- Provide the museum with qualified staff, especially tour guides, because Petra is considered the primary destination of tourists in Jordan.
- The museum is in desperate need of a ventilation system and climate control devices, in order to safeguard its vulnerable objects.
- The museum's collection must be enhanced, by borrowing or exchanging objects from other museums, or even from the main storage of the Department of Antiquities, which is saturated, with archaeological objects.
- The explanation labels, which contain limited information, should be changed and better information cards should be provided so that visitors are given sufficient clarification. In addition, audio-visual devices could be easily and cheaply installed in the museum, which would provide the visitor with more information in an exciting way. It may also lead visitors being willing to stay in Petra for one more extra day.
- If it is difficult to relocate the museum to another place, then it is necessary to provide the museum with a transportation system, taking the visitors to and from the museum without passing by the historical city.

3.9 Salt Archaeology Museum

3.9.1 Location and history

The city of Salt lies about 30km West of Amman with about 344,985 inhabiants (DOS 2004). It was of great importance in the 19^{th} and early 20^{th} century during the Turkish rule in Jordan, when it served as the chief administrative centre for the surrounding area. It was even considered as a candidate city for the capital of Trans-Jordan in the 1920s (Tanaka *et al*. 2005). However, this place was taken by Amman. Salt still retains the Ottoman architecture in classical style represented by long-arched windows, domed roof and yellow stone walls. The historical value of Salt's architecture is unique and the town is nominated as candidate to be a World Heritage Site.

Although the national Antiquities Law only targets remains from before 1750, Salt originally designated about ten later buildings to be preserved sites and placed a plate on the wall of these buildings (Tanaka *et al*. 2005).

Salt is also known as the final resting place of the Prophet Ayyoub, whose legendary patience and faith gave him strength to pursue hardships and was rewarded by being mentioned four times in the Quran. Along with its historical and religious characters, local handicraft work is also peculiar. It includes ceramics, weaving, silk screen printing, embroidery and dyeing (Tanaka *et al*. 2005).

Figure 3.35 The Salt Archaeology Museum.
Photo by: R. AlGhazawi

Salt's Archaeology Museum is considered as a regional museum for the Al-Balqa' governorate. It was established in 1981, in a building on *Al-Haman* Street, in Salt city. In 1986 it was relocated to its present location, a building owned by the Salt Municipality, to whom the museum pays an annual rent (DoA 1994). This could be seen as a disadvantage, because in the future additions or changes cannot be made to the building. At the same time, the building does not resemble the local architecture type. It is located in the city centre, close to governmental institutions and other private sector foundations. This makes it easily accessible for visitors by public transportation, but difficult by car, because it is difficult to find a parking space in the nearby area. Due to its location, the museum suffers from loud noise, over–crowding and air-pollution. Since the building was not designed to be a museum, it lacks some necessary utilities.

2.9.2 Building and interior

The museum consists of administration offices, display halls and other facilities, shown in Figure 3.60 and 3.61 and briefly described below:

The ground floor

- One can enter other rooms and halls through a long rectangular entrance. There are two small halls. One is used as an information office and the other is used as a hall for

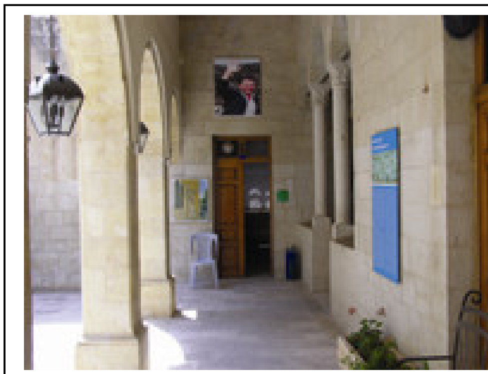

Figure 3.36 The display area and offices on the second floor.
Photo by: R. AlGhazawi

displaying stone objects, photos and maps painted on the walls.

- Display area

  The display area consists of two main halls. The first is a rectangular-shaped, wide hall. The display cases are in the middle of this room. The second is also rectangular-shaped hall, with showcases at the sides of the hall and a model of a *dolmen* field displayed in the middle.

The second floor

- Display area

  There are two main display halls of almost the same size and shape and both contain wooden showcases.
- Offices

  There are several rooms of different sizes used as offices, specifically for The governorate inspector of the Department of Antiquities Supervisor, the inspector's assistant's, the curator of the museum and other administrative personnel.
- Museum facilities

  It is clear that the museum lacks the necessary utilities for a museum. The kitchen and bathroom are also used by other departments in the same building, such as the Jordan Electricity Company. The museum has a storage room, located near the offices, which should be relocated from the offices, because the staff activities disturb the stability of the objects. Furthermore, the museum has no entrance to the courtyard and no wall to separate it from the street and other buildings.

The ceiling of the building is level and painted white. The the walls have different thicknesses and they are painted white. All the electrical connections are placed on walls and this distorts the museum's appearance and jeopardizes the lives of both visitors and employees.

The walls have rectangular windows, which are of different sizes and at different heights. Some doors are made of aluminium and some are made of wood.

The doors are of reasonable height but differ in width. They have no ornaments at all. The doors are quite levelled with the floor and can be closed tightly. Ordinary tiles have been used for paving the floors. The floors seem level and are of a darker colour than the ceiling and walls, which gives the interior some coherence. However, the tiles are slippery and thus not safe to walk on and can easily become dirty.

3.9.3 Management

The administrative hierarchy of this museum is illustrated in the following chart:

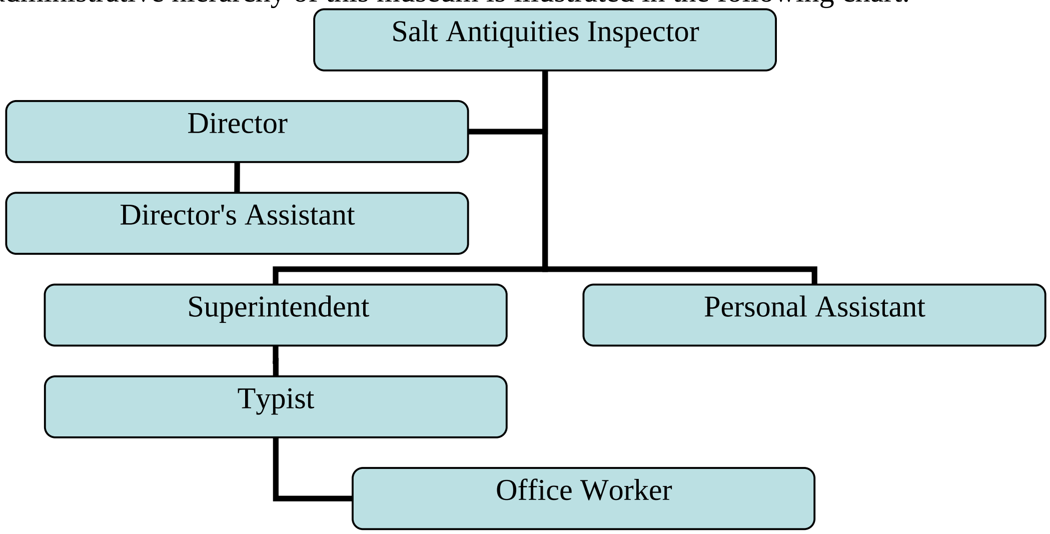

Figure 3.37 Salt Archaeology museum hierarchy chart

The inspector is the only specialized employee in the museum staff. The museum lacks specialists and qualified personnel that would have had a positive effect on the museum’s development.

In terms of safety precautions, the museum has a shortage in its provisions. It has iron bars attached to some windows and at the main entrance. Portable fire extinguishers are available, but there are no security guards.

Some of the objects in this museum have been excavated in the *al-Balqa* governorate by the Department of Antiquities. Some objects have been obtained from Jericho and *Kataret Al-Samra*, whereas others have been confiscated from local citizens.

The museum has a guest book and a record for exhibited and stored objects. No duplications of these records are available which makes them vulnerable to theft, loss or destruction (Bu'bu 2009).

3.9.4 Exhibition and collection

The objects are exhibited in display cases of different styles and sizes made of wood with glass fronts and with several shelves.

Figure 3.38 Stone objects displayed in the museum. Photo by: R. AlGhazawi

Some objects are exhibited on the floor, especially the stone ones. Metal stands are used in some showcases. The exhibition is arranged according to historical chronology, covering almost all the periods of the region, from the Stone Age to the Islamic periods. Within each period the objects are arranged according to site provenance. Explanation labels are printed clearly in black ink. They are written in Arabic and English, but with insufficient information. They are placed at the front of the exhibited objects. Some objects have no cards at all. Some interpretation cards are made of transparent paper and are pasted to the showcases in order to identify the historical period each objects belongs to. The cards are printed in black ink in two languages, Arabic and English. There are also maps, photographs and explanation labels at the main entrance about archaeological sites and excavations throughout Jordan. Due to frequent excavations, the number of objects has increased and as a result, some objects have been placed on the bare floor.

Figure 3.39 Sample of the showcases in the museum. Photo by: R. AlGhazawi

The museum director himself sometimes acts as a guide for visitors, missions or school groups. The number of visitors is not as great as had been expected and unfortunately the number is not increasing. The museum has no educational activities. The museum's interaction with the local community is limited. It appears to have overlooked people with mobility issues, as there are no special entrances. Several excavations in the *Al-Balqa'* governorate are represented such as *Deir Alla*, *Tel Nimreen in the Jordan Valley* excavations (Bu'bu 2009).

3.9.5 Environment visual assessment

Due to the lack of laboratories, conservation workshops and other equipment, the museum does not carry out conservation and restoration work. Its ventilation depends mainly on windows. Sometimes mobile electric fans are used and there is central heating in winter. Nevertheless, there are no humidity and temperature control devices. Lighting is provided either by means of the wide windows with curtains, or by fluorescent neon lights that are attached to the ceiling and other spotlights inside the showcases. Therefore, lighting is sufficient but it needs to be checked further in order to know if it is appropriate.

3.9.6 Recommendations

According to the conditions of this study, the following changes and enhancements are recommended:

- Moving the museum to one of the old houses in the city such as the *Abu Jaber* house or the *Al-Touqan* house, because they are compatible with the local style of architecture. Alternatively, a new museum could be built in a suitable location which fulfils all the requirements of a museum.
- Providing the museum with specialized, well-trained and qualified staff members so it may achieve the goals entrusted to it.
- The current safety provisions are mainly relying on the human intervention and on traditional means of security, which do not provide the necessary requirements of security and safety. Therefore, electronic security devices must be installed in the museum.
- Attention should be paid to the methods of explanation. The number of information cards must be increased and each shelf or even each object should be assigned a card. Moreover, providing the museum with modern audio-visual devices would provide visitors of all ages with sufficient information.

- Reorganizing the objects in a way, which creates coherence between the objects within the same shelf. Currently, some shelves are overcrowded, while other shelves are empty. The showcases containing coins must be provided with mirrors in order to show the other side of each coin.
- Increasing the museum's activities and interaction with local community. Special consideration should be given to groups such as visitors with special needs and children. This could be achieved through training courses, lectures, social events and special programs for children. The museum should also provide special entrances for the disabled.
- Taking care of the safety of exhibited and stored objects from any environmental aspects by providing the museum with ventilation, climate control and lighting control systems.

3.10 Museum of Archaeology / University of Jordan.
3.10.1 Location and history

The establishment of the Museum of Archaeology at the University of Jordan was synchronized with the establishment of the University in 1962. Originally, the museum consisted of a small room that later became insufficient for the vast number of discoveries that came out of various excavations. In 1986, the museum was transferred to its present site where it occupies a distinguished location within the university campus (Nahar 2009).


Figure 3.40 Museum of Archaeology and its courtyard.
Photo by: R. AlGhazawi

3.10.2 Building and interior

The museum was not designed to fit the university complex. It lacks some of the necessary requirements and conditions for a museum. It also does not represent any local architectural type. The plan in Figure 62 shows the building's plan and the interior is also described briefly below:

- The main entrance lies at the top of several steps that do not conform to the requirements of wheelchair users or people with mobility difficulties. Inside the building, the entrance opens into the other rooms and halls. The entrance has an information office.
- The display halls consist of three main halls with a side corridor alongside them. These rooms form around 50% of the museum's area.
- The administrative offices consist of the director's room and another room for the museum curator.


Figure 3.41 Display halls and the main entrance.
Photo by: R. AlGhazawi

- The museum has a number of necessary utilities, such as a studio, research and lecture halls, a drawing room and a very small library which has some specialized books for the benefit of students. Since the museum has an educational purpose for university students, a special hall, furniture and books must be provided for the benefit of researchers and students. There are two small storage rooms for storing furniture and equipment. In addition, there is a kitchen and a bathroom. It is worth mentioning that the museum has a maintenance and restoration laboratory in the basement of the building of the Faculty of Humanities.

The gardens and trees around the museum provide a natural surrounding. These gardens are used for displaying some stone objects. In addition, there are free areas around the museum which means that the building is far from other buildings and easily visible. Therefore, a wall around the museum is not necessary. The ceiling is of different heights and is painted white throughout. The walls are painted light colours such as white, yellow and pink and are sometimes used as a background for displays.

Figure 3.42 Side windows and transparent showcases.
Photo by: R. AlGhazawi

There are several kinds of windows of different sizes and at different heights, often lying diagonally under the ceiling. In other parts of the museum the whole outer wall is made up of windows. This greatly enhances the visitor's view of the outside displays and green areas and perhaps even improves the moods of the visitors. These windows have metal frames and transparent glass boards with curtains to control the amount of sunshine that enters the building.

The display halls lack doors and are connected to one another. The main entrance, made of aluminum and glass, is the only thing, which separates the display halls from the other parts of the museum. The entrance is wide and of middle height, approximately two meters, with no ornaments at all. The main entrance is wide and high enough for large objects to be brought into the museum. The floor is covered with brown ceramic tiles and considered being easy to clean, cheap, easy to repair, pleasant looking and comfortable. The colour of the flooring in the halls complements the ceiling and the walls. Some of the floors, for example in the offices and utility areas, are covered with carpets, whereas the floors of the kitchen and bathroom are paved with ordinary tiles.

3.10.3 Management

Since the museum is a direct part of the university, it follows the university roles and is directed by the President of the university and the Dean of the Faculty of Humanities. An administrative regulations guide, the Regulations of the Archaeology Museum in the University of Jordan, was set up in 1987 (Nahar 2009). These regulations stipulate that the museum with all its facilities is considered part of the faculty of Humanities. The regulations also require a council, called The Museum Council. This council is composed of six members who are appointed by the university President. This appointment lasts for 3 renewable years. The President of the university also appoints the curator of the museum. The curator is responsible for managing the museum’s affairs according to the university's regulations and disciplines (Nahar 2009). In particular, the curator must present an annual proposal of the museum’s program, provide the council with the annual budget and pay attention to any financial measures applied by the university. The museum’s council is responsible for issuing suggestions that may develop and for improving the museum work plan. It also discusses issues suggested by the curator related to the work of the museum, its objectives, its appointments and its programs. These decisions are submitted to the President of the university before being processed.

The museum aims to achieve the following tasks:

- Deepening knowledge of Jordanian cultural heritage and developing a national identity for the university's students and other visitors by illustrating Jordan’s historical importance through the ages.
- Establishing temporary, movable archaeological exhibitions inside and outside the university.
- Conducting the museum's work continuously in a way that corresponds with the scientific standards of the university.
- Establishing fruitful links with scientific departments and organizations of common interest, both locally and internationally.
- Applying a documentation system, starting with filling entry forms, accessioning, cataloging and movement control. In addition, if an object is in need of conservation the museum aims to restore it to its optimum condition.
- Keeping exact records and cards of the displayed and stored objects that have been photocopied just in case of loss or damage.
- Keeping a clear copy, for the records, of excavations carried out by the Department of Archaeology of the university. These records should include pictures, elucidative diagrams, necessary explanations and the original copy of the excavation diagrams that might serve as a reference for scientific researchers.
- Presenting lectures in the various archaeological and museum fields, especially those covering the results of archaeological excavations carried out by the Department of Archaeology in conjunction with the university.
- Facilitating the teaching process, especially in the applied science courses, such as photography, conservation and restoration of pottery, by supplying materials to the Department of Archaeology.
- Developing scientific research in archaeology through the museum's facilities such as the laboratory, the library, the photography studio and the drawing room for the benefit of the staff members, students and researchers. The museum should also provide the faculty excavation projects and archaeological surveys with the required equipment and tools.

The museum’s management hierarchy is shown in the chart below:

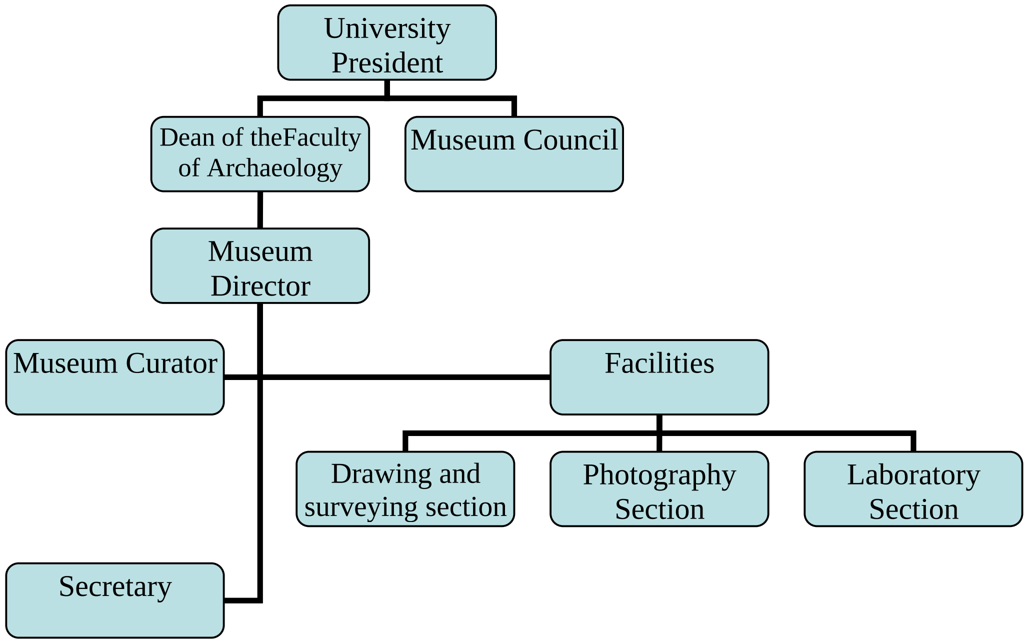

Figure 3.43 Museum of Archaeology hierarchy chart

The museum has a very specialized staff, including every specialist needed for the museum's work. This reflects positively on the museum's teaching message.
Safety precautions are applied by the university guards. Some windows have been strengthened with iron bars for more safety. Portable fire extinguishers are available. However, the museum lacks the electronic apparatus such as sprinkler and chemical contamination filter, which are indispensable for the museum. Archaeological excavations for scientific and training purposes are the main source of the museum's collection. There are two compulsory academic disciplines in archaeology at the University for Bachelor of Arts (B.A.) and Master of Arts (M.A.) degrees. Several excavations have been carried out by the Faculty of Archaeology in cooperation with foreign missions at different sites such as *Rujm Al-Kursi, Tell Nimreen and* others. Some objects have been obtained through exchange with other local museums and in cooperation with the Department of Archaeology (Nahar 2009).
The museum has a guest book and also a record of objects, whether they are displayed or stored. The record of objects contains pictures as well as explanations. Copies of the records of the excavations carried out by the faculty are provided along with pictures and drawings and necessary elucidation. The museum has the original copies of diagrams of excavations, to which a person could easily refer for the purpose of scientific research.
In addition, records are kept documenting the museum's work, for example lending objects, conservation and restoration. These records are kept in tightly closed cupboards in the Director’s office. The diversity of records shows the staff's awareness of the importance of keeping and documenting archaeological objects. This reflects the museum's active role towards the teaching process.

3.10.4 Exhibition and collection

The method of display at this museum is based on chronological order. Consequently, visitors can follow the displays from prehistoric periods to the Islamic periods. The displaying of the objects is diverse. Some objects are inside wood and glass cases of different sizes and shapes. Others are displayed on glass shelves, plexiglas stands, or on small marble pedestals. The surface of the cases is sometimes mirror, in order to reflect the other side of objects, especially coins. It is noted that some objects are hung by thin threads inside showcases, especially pottery lanterns. The surfaces of the cases are always used for display and are covered with velvet, which is not fire resistant, of different colours. Some displays are outside the cases on metal, wooden or stone stands or directly on the ground, or hang on walls or directly over showcases. Other objects that are resistant to erosion and degradation and cannot be easily stolen, such as stone sarcophagi and *dolmen* graves, are displayed outside. The displays seem diverse and comprehensive and cover all historical periods. The display halls have areas covered with ornamental plants, which complement the display area.

Figure 3.44 The display method at the museum. Photo by: R. AlGhazawi

With regard to means of explanation, traditional means are mainly used. Transparent labels written in Arabic and English are pasted on the cases to show their contents. They are of coherent shapes and dimensions and are placed on the glass shelves and on the surface of the cases. They can be easily seen and have adequate information. However, some of the displayed objects and shelves do not have any cards.

Explanation maps and drawings are hung on the walls. These are insufficient in representing a geographical background for Jordan and the region. Models and replicas of some objects such as the *Mesha* stele are available. Since it is considered an educational museum, it is necessary that larger explanation boards with more information about the displayed objects be placed within the cases or at their side or even to be hung on the wall, in order to provide visitors with more comprehensive and specialized information.

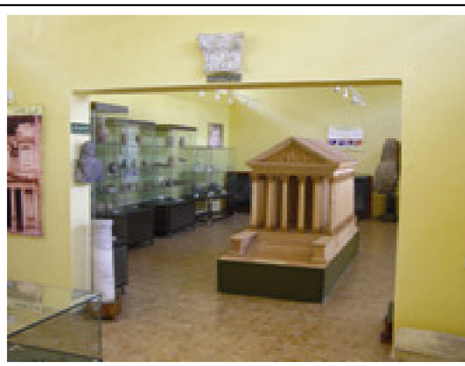

Figure 3.45 Sample of displayed models. Photo by: R. AlGhazawi

This museum, as well as the other museums described in this essay, lack audio-visual means of explanation.

Objects which are not on display are stored in the basement of the Faculty of Humanities building. This basement lacks proper ventilation and has no means for controlling the indoor environment.

The museum performs many teaching activities. It is open for students and visitors as well. The objects in the museum are used to explain and clarify some scientific courses in the Department of Archaeology, such as analyzing and dating pottery. Sometimes, specialists in the field of archaeology are asked to give lectures for students. These activities positively affect the interaction and relationship with the local community. The museum also interacts with the local community through coordination and cooperation with schools, educational and social organizations.

3.10.5 Environment visual assessment

The availability of services and utilities, especially conservation and restoration laboratories, enable the staff to apply some protective treatment procedures to the archaeological objects. The ventilation of the building is natural and is achieved through wide windows. There is also a central heating system installed in the museum, hidden behind the showcases and curtains. Electronic devices are not used to control temperature and humidity. The museum is lit naturally through the high, wide windows, while at the same time there are electric neon lights fixed to the ceiling and directed toward cases and objects. Curtains are used to lessen the amount of light penetrating through the windows.

3.10.6 Recommendations

To develop this museum further as an educational museum, the following recommendations are given:

- A specialized library should be provided for students, researchers and other interested individuals. A study hall must be reserved for this purpose.
- The main entrance has a number of steps which are not accessible to disabled people. A special path should be provided for them.
- As the museum lies in the university's campus, its working hours are restricted to the university regulations. This prevents a great number of people from visiting it and this problem cannot be easily solved with the museum in its present location.
- The museum's security depends mainly on human intervention. However, in order to have more safety measures, it must be supplied with safety electronic apparatus.
- Means of explanation are traditional, which is considered insufficient. This necessitates installing an up-to-date audio-visual system, which will be of great benefit for visitors and tourists of different nationalities and educational levels. It would be especially beneficial for school students.
- The displays must contain additional information and explanation and so more information on the display cards must be provided. Most visitors to the museum are students and educated people and they would benefit from additional information.
- The museum must have an up-to-date means of controlling environmental conditions (temperature, humidity, ventilation and lighting). This is necessary in order to safeguard the objects from deterioration and destruction.

3.11 Museum of Jordanian Heritage
3.11.1 Location and history

The Museum of Jordanian Heritage was established in 1988 and managed by the Faculty of Archaeology and Anthropology of Yarmouk University (Anthropology 1988). It has one main purpose: to embody the overall historical developments specific to Jordan. The building was designed to replicate Islamic buildings in the Ottoman period and has a specific style of architecture. In this way, this museum is distinct from other local museums.

As a place of academic achievement and civilization, the museum was the result of a cooperative German-Jordanian effort, the government of Germany having already provided much assistance at the initiation of the project (Anthropology 1988).

Being located on-campus, the Jordan Heritage Museum has the advantages of being able to serve both students within the institute and the local community in general, while having the availability of financial support and being staffed by competent staff members. The disadvantages of its on-campus location are the restrictions of the university as well as the restrictive working hours according to that of the university. As a result, the museum would benefit from being partially separated from the campus, possibly by opening up a new entrance on the *Irbid-Edoun* Main Street. This entrance exists but had been precluded.

3.11.2 Building and interior

In addition to its distinctive style of architecture, the museum comprises many features, such as cosmetic and folklore exhibits that represent the modern local environment. This indicates a deliberate design in order to attract as many visitors as possible, to service the academic specializations in the Faculty of Archaeology and Anthropology at the Yarmouk University.

Figures 3.63 and 3.64 show the layout of the museum and it is also briefly described below:

- *Entrance Hall*:
  The first and then later the final view for the visitor is a central space, which leads to rooms, halls and various facilities and includes a reception and information desk.
- *Display Aria*:
  The display area takes up a large portion of the total area of the museum, with four halls on the ground floor. There is also a mezzanine floor, which is accessed by rising stairs, making it very difficult for disable persons, aged people and children to reach. The solution to this problem would be an elevator or escalator.

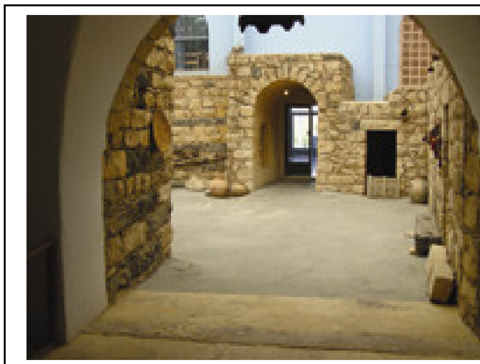

Figure 3.46 The open courtyard.
Photo by: R. AlGhazawi

- *Open courtyard*:
  The open courtyard has a rebuilt example of a rural house in northern Jordan. It shows the essential components of domestic architectural style, such as crossed-vault rooms. The courtyard also comprises many rooms such as an external arena,

completely furnished rooms, stables and a small traditional oven. Local stone was used in the building.

- *Administration offices*:
  The administrative offices are in the building of the Faculty of Archaeology. These offices are not only for the museum staff members, but also for the teaching staff. In spite of it being separated from the museum, these offices are quite easy to reach.
- *Facilities*:
  In terms of facilities, the museum has an information desk in the entrance hall, publications and bulletins, a small video-room, which is sometimes used for overhead projections and a multipurpose hall used for temporary displays, lecturing or other purposes.

If the museum was to be made separately accessible for the general public from outside the campus, there would be a need for a fence or a wall around the museum building, in order to allow local citizens to visiting the museum through a special entrance. This special entrance would serve the museum building only.

The ceiling of the museum varies in height. Sometimes it is very high, especially the courtyard (approximately eight meters) and normal in the second floor about three meters. Both the walls and the ceiling are painted white. The walls are sometimes used as a background for the display cases. there are many windows at various heights, some of which are located near the ceiling and others are at a vision level. The windows have metal frames and transparent panes of glass. There are no doors between exhibition halls, but the lintels are of adequate height, giving easy access both for the visitors and for moving large objects. The main gate is a metal door of moderate height and width that is enough for entering groups and different museum objects, with panes of glass and above it there is a big glass window with an arch shape. The windows, although wide and high, lack protective iron bars. The Information Office provides directives and instructions related to rules and prohibitions, without any signs to clarify them.

Figure 3.47 Part of the ceiling in the museum. Photo by R. AlGhzawi

The main gate is only accessible by several steps leading to the museum, which makes it impossible for disabled people to be reached. It is thus important for the museum to provide special access ramps. Additional metal doors have been installed to separate the museum's main halls from the courtyard in the middle of the museum. The museum does not have an emergency exit, essential in a museum nowadays. Almost all of the Jordanian museums lack an emergency exit. The floor is plain in the showroom halls and covered with ordinary tiles, with a lighter colour than the ceiling. This design does not fit with display requirements or make for easy cleaning. Moreover, in the second floor, tiles are not used and the floor is covered with pure cement, which is irritating to walk on.

Figure 3.48 The main gate and the stairs. Photo by R. AlGhzawi

3.11.3 Management

As an educational institution, this museum plays a significant educational role as it provides extracurricular activities based on determined goals and objectives. The museum also offers children's workshops aiming at introducing the objects, antiquities and acquisitions to children in a way that goes beyond simply walking around the museum.

The museum, in general, reflects the studies, research and field excavations that are done by either the Archaeology Faculty staff members independently, or in collaboration with national institutions such as the Department of Archaeology, local universities or with specialized academic institutions abroad. Another critical role played by the museum is that of interactivity with local communities through organizing workshops for children on weaving, ceramics, flint instruments, etc. Further examples of organized activities would be lecturing and publishing bulletins aiming at alerting people's national awareness and appreciation of antiquities in order to motivate them towards the maintenance of antiquities and heritage.

Another role assumed by the museum is organizing travelling fairs. In collaboration with the German Cultural and Information Centre, a lorry-travelling fair was organized in 1990 and this experience promoted collaboration between local museums and the Ministry of Education, involving regular visits by school students, introducing teachers and supervisors to the museum programs and services. Temporary exhibitions have also been held in order to make visitors aware of monuments of civilization of the country.

Most significantly, the museum produces many publications such as Museum guide, cards, catalogues, posters and booklets particularly on children-related issues. The Jordan-Germany relationship has been strong because of long-term scientific projects such as the *Umm Qeis* project, the *Bastah* Excavation project and the exhibition of Jordan-Palestine Heritage in Cologne in 1987. Cooperation with foreign missions is well established. For example, there has been collaboration with missions from the Netherlands in the *Deir Alla* Excavations, with the USA in *Ain Ghazal* and with France in *Abu Hamed* (Anthropology 1988).

The museum's location on-campus and more specifically its connection with the Faculty of Archaeology and Anthropology has resulted in the availability of many utilities and service facilities which are necessary for the achievement of the museum's education mission and goals. Most significant of these facilities are the laboratories and the restoration and conservation workshops. The German government has donated equipment and necessary materials to the museum and the Linden Museum Stuttgart has installed them (Anthropology 1988). A number of staff members have been sent to European Universities in order to attend training courses and gain specialized academic certifications in museology and conservation.

The museum management hierarchy is shown in the following chart:

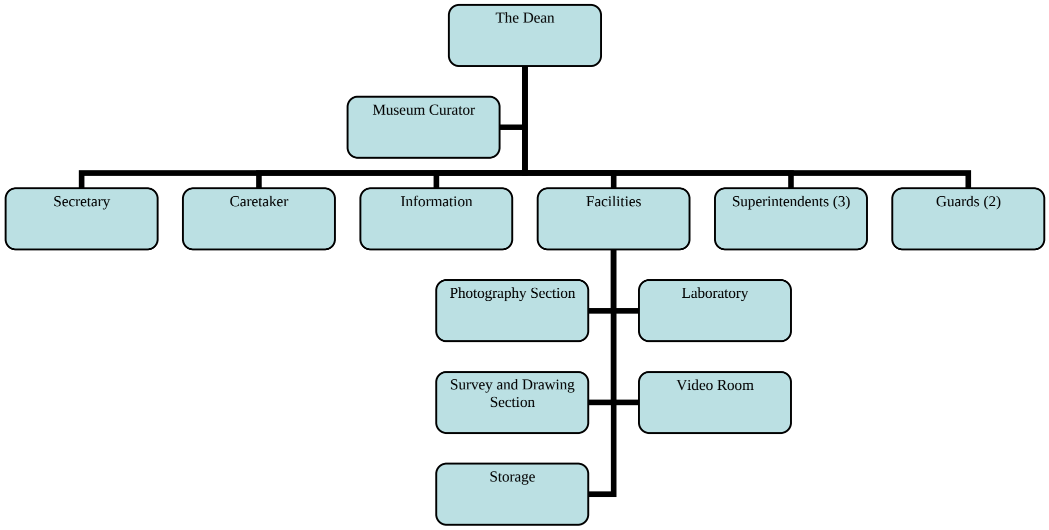

Figure 3.49 Museum of Jordanian heritage hierarchy chart

The benefit from the Faculty of Archaeology and Anthropology also includes photographic laboratory, drawing studio and the library (till recently).

Because the museum is located on-campus, security provisions depend heavily on the security personnel of the university. There are no electronic devices such as warning sirens or cameras.

3.11.4 Exhibition and collection

Great efforts had been made to acquire artefacts for the collection and the Department of Antiquities has been very active in this respect. The Department, for example, provided the opportunity for the museum to borrow significant objects freely from collections owned by the Department of Antiquities, displayed at the museums of Amman, *Irbid*, *Jarash*, *Madaba*, *Karak* and *Petra*. Furthermore, excavations carried out by the Faculty of Archaeology or its staff members have produced a large quantity of objects from a variety of sites such as *Sahab*, *Queen Alia Airport*, *Ain Ghazal*, *Abu Hamed*, *Bastah*, *Al Kharraneh and Deir Alla*. Other archaeological objects and ethnographic items have been taken from other sites and regions such as *the eastern Badia of Jordan*, *Tuleilat Al-Ghassoul*, *Bab Al-Dhra', Jericho, Kattaret Alsamra*, *Abu Aland, Tabaqat Fahl, Al-Numeirah, Tall Irbid, Petra, Madaba, Jarash, Umm Qeis, Quailbeh, Karak, Alqastal, Ajloun and archaeological sites in the desert* (Anthropology 1988).


Figure 3.50 The oldest objects in the museum, excavated at the Ain Ghazal site.
Photo by: R. AlGhazawi

In addition, there are ethnographic materials, which have been collected and documented by museum staff. These emphasize selected aspects of social and economic life, such as production strategies, the history of the stability of different ethnics in the region, settlements and Bedouin lifestyles. On a collaboration basis, the museum collects its own objects by donations, grants and gifts and long-term borrowing from other institutions or establishments and private-owned collections.

Three sets of records are found in the museum. There is one of visitors, one of official missions and one record of objects, whether displayed or stored. The records are easily accessible for researchers, students and staff members to retrieve necessary and relevant data. Nevertheless, copies that may serve as documentation or reference to be used in case of loss are non-existent.

Figure 3.51 Flooring within showcases.
Photo by: R. AlGhazawi

The showcases used for exhibitions vary in size, form and material. The showcases are made from either metal frames with panes of glass, or from a combination of glass and wood. The glass is actually Perspex, characterized by strength and transparency at the same time and it has no effect on objects environmentally.

Built-in showcases with pyramid-shaped peaks over wooden pedestals were designed, manufactured and donated by Germany and are used especially on the upper floor in the centre of halls. Individual objects are displayed on wood and metal stands and pedestals, or exhibited outdoors in the garden. The flooring used in the display cases varies in nature, ranging from baked brick-paved floors, stone chips, basalt, or with sand or wood. All the flooring types are consistent and suit the objects displayed on them. The disadvantages of the exhibition cases are that they are relatively low, disproportionate with the variety of ages and heights of visitor groups. As a result, viewing the objects may be difficult and eyestrain may occur. The cases lack any glass shelves and exhibits are generally laid out on the floor of the cases.

The objects are generally exhibited according to period, depending on socio-economic development and their provenance, but also according to type of artefacts and their production method. The ground floor exhibition format is based upon as follows:

First Hall:

Periods of hunting, food gathering, food production in peasant communities and early village life, representing Pre-historic periods in Jordan.

Second Hall:

Objects from early historical periods “Bronze and Iron Age”.

Third Hall:

Objects formatted under the title 'Relationships between East and West', where the role of local populations, especially of Nabataean and other tribes of Arabs during Roman and Byzantine periods, is salient. “Biculturalism and ethnicity in Jordan during the classical period” and “From Decapolis to Military-Sector of Jordan”.

Fourth Hall:

Jordan as 'Part of the Islamic World'. 'Jordan under the Caliphate', 'Jordan in the *Mamlouk* and *Ottoman* Era' , 'Land Confiscation and Allotment by the late 19th Century' and 'Jordan: Present and future'.

Figure 3.52 Sample of objects used locally.
Photo by: R. AlGhazawi

The ground floor also includes instruments and equipment used locally, pastoral and farm machinery, transport and commerce vehicles and means such as saddles and supply wagons, tools and materials representing craftsmanship and industry, including smith craft tools, as well as fashions, cosmetics and amulets common used materials. Special attention has been paid to the collection related to the Ottoman rule in Jordan.

There are other collections of certain significance including handmade pottery from northern Jordan and another collection lists medicines and magical potions used by traditional herbalists.

Stairs lead from the Entrance Hall up to the balcony on the upper floor, which contains objects relating to technological advances in Jordan, such as stone quarrying, rock engraving, mining, inscription and seal- making arts.

Exhibitions are numerous: temporary exhibitions in special halls, travelling exhibitions and open-air exhibitions in the garden.

In conclusion, it is clear that this museum portrays the historical developments of the region with specific emphasis placed on physical, environmental, socio-economic population and cultural interrelated connections. No definite borderlines could be seen concerning the transition between archaeological and ethnographic objects. Objects are consistently and harmoniously ordered and have inclusive coverage of historical periods. Furthermore, the exhibition pays attention to both archaeological and ethnographic aspects, in order to clarify domestic life patterns.

Information cards are white pasteboards glued inside the showcases and inscribed in clear-to-read bold writing, giving full data written in both Arabic and English. Other illustrative aids include pictures, maps, sketches and charts on the walls either inside or outside showcases These are also bilingual and presented in a clear manner. For further information, staff members are fully competent and able to help visitors of various levels and classes of education. However, the museum lacks audio aids. Because of the fact that most visitors are from the elite class of society or are undergraduates or school students, the traditional illustrative aids are highly fulfilling.

The stored objects are found in the storeroom, which consists of three divisions for antiquities, anthropology and inscriptions. Each division has its own metal shelves in which objects are stored. Because of its high capacity, it is furnished with tables, chairs and other equipment for conducting studies on a variety of samples. Objects may be stored by either name of excavation or by geographic basis. Also included in the storeroom is a chamber devoted for storing objects that are of special importance, or those on which work has been completed.

3.11.5 Environmental visual assessment

The ventilation in the building depends throughout on large windows and doors, including in the warehouse. Heating, on the other hand, is central and hidden in order to fit into the general layout of the halls. A modern environment-control system is required to deal with temperature and humidity, since even simple humidity control means such as silica gel are not used. Artificial lighting is provided by fluorescent lamps fixed on the ceiling and focused on showcases and on individual freestanding exhibits.

3.11.6 Recommendations

Solutions to problems faced by this museum could be summarized as follow:

- As this museum is located on a university campus, the number of local community visitors has been severely limited. Consequently, it must be separated from the university. The solution visualized is to open an entrance from the west directly to

Shafiq Irshedat Street, to offer outsiders the opportunity to come in freely, even on days on which the university is closed. The opening hours of the museum should, therefore, be separate from those of the university.

- Attention should be paid to disabled people by offering them special access ramps to enter the museum and an elevator should be installed inside the museum to allow access to the second floor.
- Although museum security is heavily dependent on university security manpower, electronic devices should be installed for more safety and security.
- Display cases should be raised to a height which is suitable for the wide range of ages and heights of visitors. At present, the objects displayed cannot be seen clearly and the information cards cannot be read easily at this angle, causing physical discomfort and eye strain.
- The museum depends on traditional and environmental explanation means, which are insufficient for modern museums. Therefore, audio explanations should be available in order to make data accessible to visitors and tourists of all nationalities.
- Up-to-date temperature and relative humidity measurement and control and a ventilation system are essential to ensure the safety and preservation of artefacts, whether on exhibition or in storage.
- Displaying more than one type of material in one showcase should be avoided.
- Displaying sensitive collections like textiles without any protection should also be avoided.

3.12 Summary and conclusion

The number of museums in Jordan is increasing. They are fast becoming one of the main tourist destinations for the local and global, community. Despite this, an evaluation of the current status of Jordanian museums remains far from any specialized researcher's interests, either locally or at an international level. This present research aims to illustrate the current situation of Jordanian museums, to descriptively evaluate their conditions and to conclude with suggestions to enhance the selected museums' functions.

The ten selected museums were visited periodically, interviews were made with staff members and the museums were photographed. Brochures and leaflets issued by the museums were reviewed as an additional source of information. The standards to which I refer in this chapter were the book by Garry Thomson *The Museum Environment* (1986) and the International Council of Museums (ICOM) Ethics.

With the exceptions of the Jordan Archaeology Museum and the Museum of Jordanian Heritage, none of the other Jordanian museums in this study is purposely designed as a museum. With the exception of the Karak Archaeology Museum, which is located within a historical castle, the museums in this research are built from cement and natural stone types. The indoor environment was not isolated from the outside environment because of the side openings the museums have. These side openings are usually open during the working hours. Therefore, generally speaking, these museums do not conform to the international standards and guidelines for museum environment and air purifications (ICCROM 1998; ICOM 1974), (Ambrose and Paine 1993), in terms of planning, architectural criteria or interior environment control. It would be possible to upgrade these museums with expert supervision and consultants' advice concerning conservation, preservation and museology, in order to fulfil the museums' missions in an efficient and effective operative manner. The kind of locations of the museums vary from one to another.

The Aqaba Archaeology Museum is located near the city centre, directly by the beach. This location on the one hand provides an easy access to visitors. On the other hand it provides the ambient atmosphere with a high relative humidity (RH), thus the museum needs to install a humidistat to keep the atmosphere in the museum display halls within a constant level of humidity within its exhibition halls. The museum building is a historical house built from concrete and stones. The museum does not have qualified personnel among its employees. The curator and the director have an archaeology background, but the other employees do not have any university degree. The safety precautions are the presence of the tourist police, the metal frames on the windows and the presence of mobile fire extinguishers. The exhibited objects are in cases which are made from a variety of materials. Most of the cases are old, made of wood and glass. Some of the showcases are locally made. The showcases do not provide a microclimate for objects and are not airtight. The explanation labels for the collection are in Arabic and English, but the information was not sufficient. In addition, other explanation means such as audio-visual are not utilized at this museum.

The Irbid Archaeology Museum is located in an adequate location for a museum, in a quite neighbourhood, with limited traffic. The museum shares its entrance with the rest of the building's residents. The main gate is accessible only by stairs, which makes access difficult for elderly and handicapped people. The side walls of this museum have big windows which are mainly open during the working hours. This leads to an interaction between the indoor and outside environment. The building comprises other governmental institutions and civil flats. The museum, together with the Department of

Antiquities occupies the ground floor. The museum has limited staff members. The curator and his assistant both have an archaeology background. The museum lacks all kind of safety provisions. Objects at this museum are randomly exhibited, either clustered in the same showcase or on the bare ground. Explanation means are limited to descriptive panels.

The Jarash Archaeology Museum is a site museum, located within a Roman Decapolis city “Jarash Archaeological site”. Reaching the museum is quite difficult because of the bumpy roads within the Decapolis city. The museum’s indoor environment is not isolated from the outside, as the side walls have windows at all façades. Despite the fact that the museum building is located adjacent to a main street, one cannot visit the museum separately from the Jarash archaeological site, which presents an obstacle for museum visitors. The museum management depends on the museum director, who has an archaeological background and the superintendent. Security provisions depend mainly on the archaeological site guards and the metal bars on the side windows. Some objects are displayed in wooden showcases with panes of glass of various size and shapes and others are displayed on metal pillars or wooden stands or even directly on the floor. Concerning information cards, white pasteboards are placed inside the showcases to concisely describe the objects behind them.

The Jordan Archaeology Museum was originally built as a museum, but unfortunately the building does not comply with the museum’s mission. The offices of the staff members are located within the same building and are only accessible through the main halls. Smoking is prohibited in the main display halls, but it is allowed in the offices. The interactions between the two environments will provide neither a suitable nor safe environment for the collection. In addition, the main entrance gate is always open and this will lead to interaction between the indoor and outside environments. The staffs consist of a number of officers and employees of different specialities, but which are unfortunately not related to the museum’s missions. Safety provisions depend mainly on a number of guards and a securely locked metal safe in the director office, as well as the presence of manual fire extinguishers. Objects are exhibited in cases of varied shapes and sizes, made from a variety of materials. In addition, there are exhibits on wooden pedestals or directly on the ground. The use of modern technology for explanation was missing at this museum.

The Karak Archaeology Museum is part of a historical castle. The museum was recently renovated and another showroom was added to the museum. The museum has small side openings, which are always open. This leads to an interaction with the outside environment. The castle can easily be reached, unlike the museum. Visitors have to walk quite a distance on a bumpy road and up several stairs. A curator and three superintendents are responsible for managing the museum. Electronic apparatus necessary for protection and safety are unavailable in the museum. Objects are displayed either in showcases of different sizes and shapes or outside of them. The only means of explanation used is description labels.

The Madaba Archaeology Museum has a unique location in the centre of Madaba city, far from traffic. This location may mean that there is not too much air pollution inside the museum, in spite of the open widows during working hours. The main problem that may face visitors is accessibility. The route between the showrooms consists of different types of steps. The museum is run by a sufficient but not qualified staff. Only the curator has an archaeological background. Security provisions are represented by the assignment of guards, iron bars on some windows and the availability of manual fire extinguishers. The display showcases are locally made, with glass and frames made of metal. Some of the objects are displayed on the bare floor. Transparent information cards have been pasted on the front side of showcases, printed in Arabic and English.

The Petra museum is located in the middle of the Petra archaeological city in a desert environment the museum is approximately three kilometres from the main entrance to the city and is accessible only by walking. This is by itself considered to be one of the main obstacles for visitors. Despite the fact that the museum was recently built, the building has only big windows in two of its façades. The opening of the windows and main entrance door is the main reason for the accumulating dust in the museum, especially in the first two rooms. The museum management consists of the museum curator and one superintendent. The safety of the museum is entrusted to the guard. The exhibition inside the museum is mainly displayed within showcases, which are made of a wooden base and aluminium frame with big glass boards. The explanation method is information labels, which are made of white cardboard, printed in Arabic and English.

The Salt Archaeology Museum is located on a main road in the Salt city centre which is always crowded with traffic. Air pollution and noise make this location unsuitable for a museum. Moreover, the museum has windows on the street side, which are occasionally open. The museum building includes administration offices, which visitor may confuse with the display halls, especially on the first floor. The museum depends mainly on the museum curator and his assistant and in a minor way on the superintendent. The museum lacks adequate safety precautions as it mainly depends on iron bars at the windows and some portable fire extinguishers. When the museum was renovated it was provided with new showcases in different sizes and shapes, made of wood with glass fronts. However, some objects are still displayed on the bare floor. Explanation labels, printed on white cardboards in Arabic and English, are the only means of information on the objects.

The Museum of Archaeology is located within the campus of Jordan University. On the one hand, this location limits the type of visitors, because the university allows only students carrying valid student identification to enter the campus. On the other hand, this location provides the museum with a good environment, since it is located far from any traffic and is surrounded with trees. The western side of the building is a complete glass façade, which makes the interior vulnerable to the strong rays of the sun during the day. A museum director and a museum curator who both have an archaeology background direct the museum affairs. The safety precautions in this museum are the same as are applied in the university that is security guards and there are also portable fire extinguishers. The collection is displayed in metal showcases with a glass shelves. The means of explanation are labels attached to each showcase and maps and drawings which are hung on the walls.

The Museum of Jordanian Heritage is also located within a university campus- Yarmouk University- and thus its visitors are limited to students of the university. This museum is one of the only museums researched for this essay which was built e as a museum. Accordingly, it may be considered as the best museum in Jordan. The Faculty of Archaeology at Yarmouk University is responsible for this museum and therefore the museum benefits from the expertise of the faculty staff and staff from other facilities such as the conservation laboratories. The security provisions of this museum depend heavily on the security personnel of the university and security electronic devices are not available.

In general, museums are advised to display objects which are not in excess of 10% of their assets (Ambrose and Paine 1993). However, in the Jordanian situation, the selected museums seem to display most of their possessions in permanent exhibitions. The displayed collections at the Jordanian museums, which are deteriorating continuously, are not undergoing any conservation treatments or assessment procedures. The storage areas of the selected museums are used to maintain objects that are damaged or not relevant to display. Furthermore, the selected museums are completely void of modern electronic devices used for safety and security purposes and above all they lack any kind of insurance for their objects.

Objects that are not currently exhibited are generally stored on metal shelves in warehouses. As excavations and discoveries have increased, the accumulated objects have by and large been packed in boxes or arranged on bare floor. Generally speaking, the conditions inside the warehouses are incompatible with those required for the safety and security of the objects and these inappropriate conditions actually hinder the work of scholars and researchers.

The successive visits to these museums show that the collections in these museums suffer from fluctuations in temperature and relative humidity, in correlation with the outside environmental conditions. Furthermore, this study has noted the deterioration and damage that the collections on display at these museums suffer from on a daily basis. In particular, objects, which are vulnerable to RH and temperature fluctuation, seem to be at risk of damage .This damage would ruin the chances of any later intervention for conservation. Therefore, the current priority should be to address the stabilization of the museums' environmental conditions, thereby preventing further deterioration.

As a result of the research presented in this essay, it is safe to assume that the cost of making the necessary improvements to the selected museums would be high in monetary terms, but would be a small price to pay for the proper preservation of Jordanian national heritage. Time is of the essence in implementing a comprehensive programme of improvements in these museums to meet international standards of museums. Staff training programs are of prime importance, in order to educate all those, who work in museums, in terms of respect for historical legacy and pride in responsibility for preservation. Given the importance of environmental control, control systems should be installed throughout the museums, including in storage areas. Climate studies should also be updated periodically.

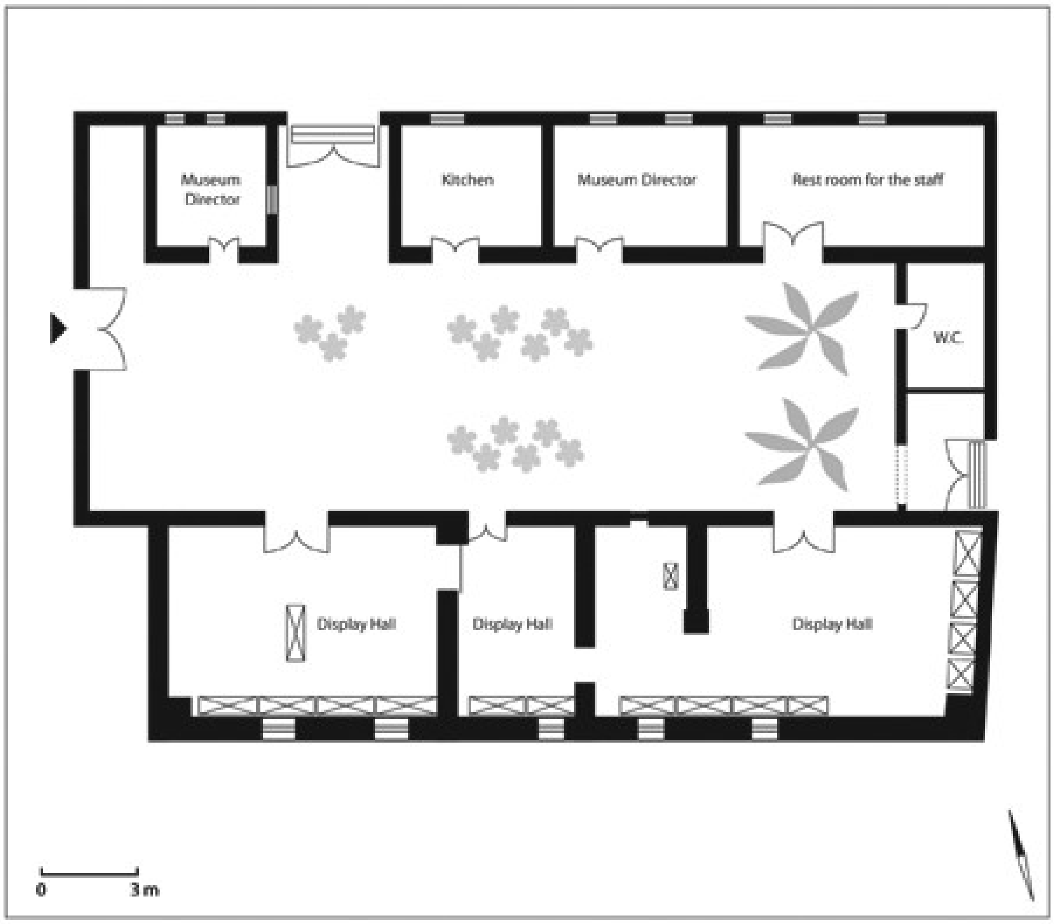

Figure 3.53 Aqaba Archaeology museum sketch plan

Figure 3.54 Irbid Archaeology museum sketch plan

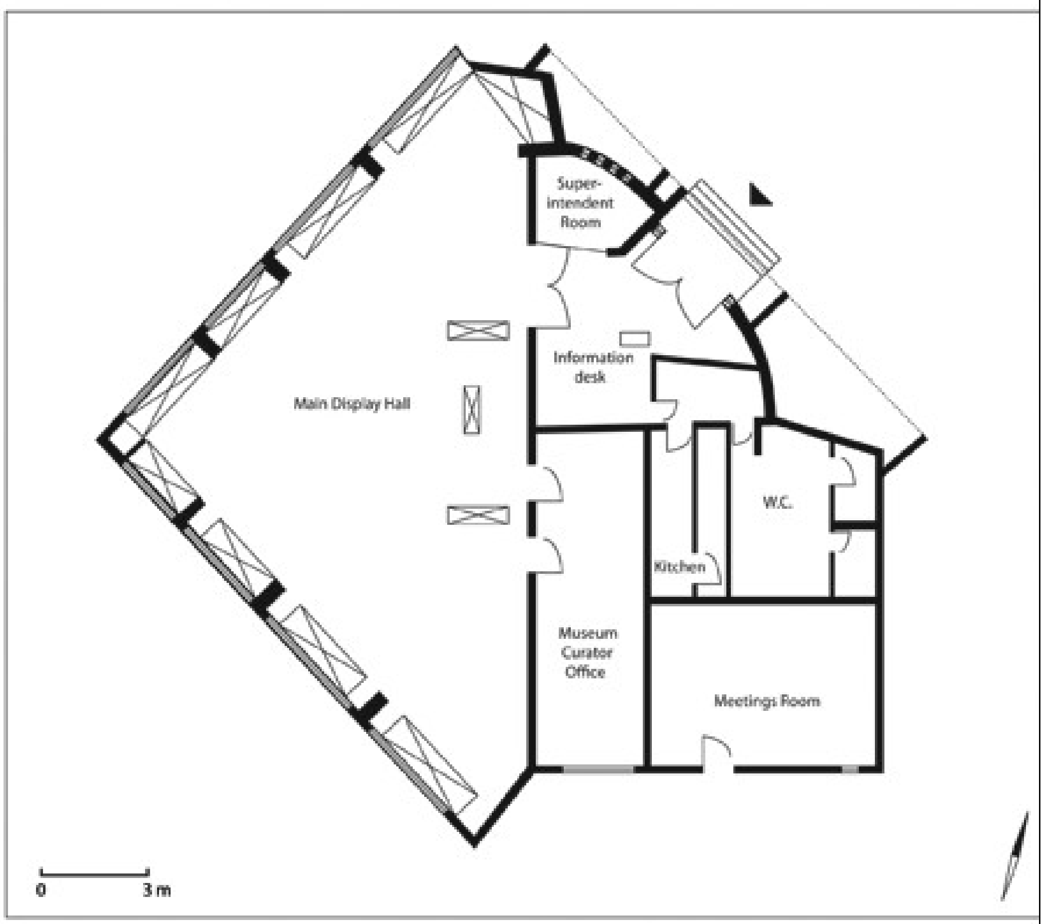

Figure 3.55 Jarash Archaeology museum sketch plan

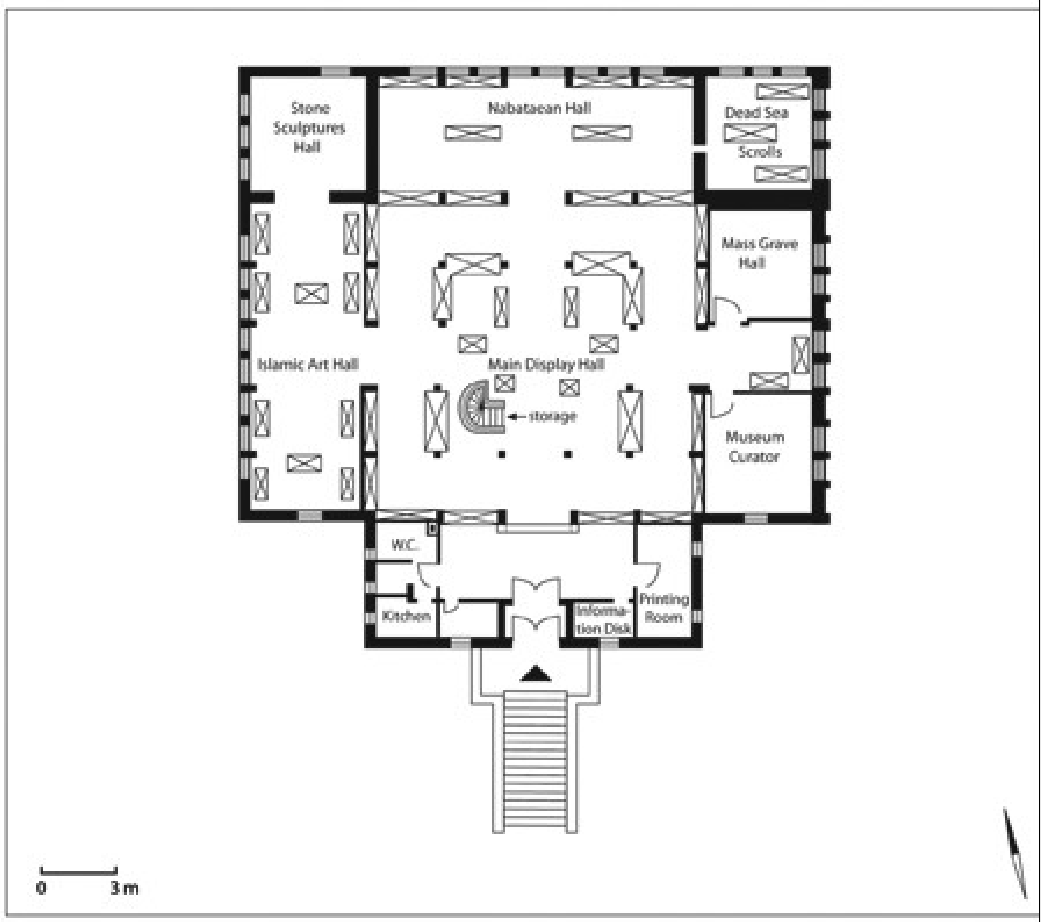

Figure 3.56 Jordan Archaeology museum sketch plan

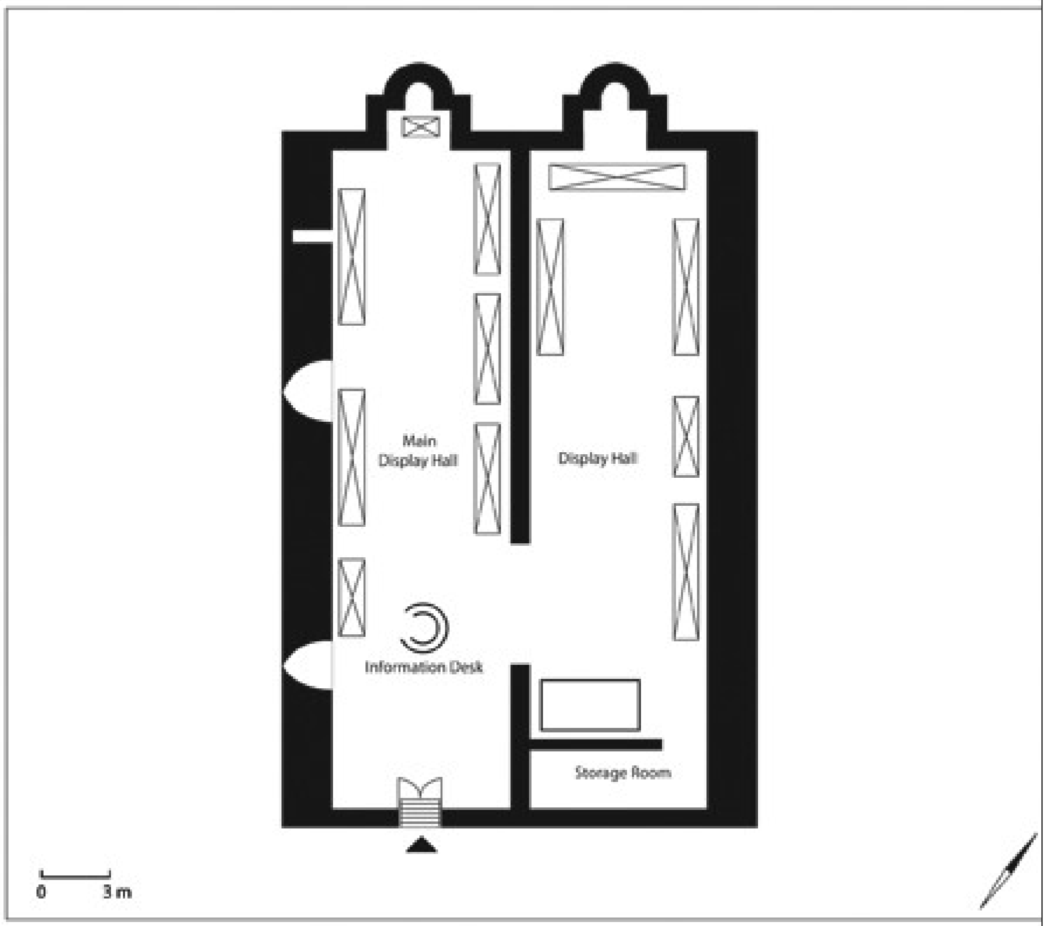

Figure 3.57 Karak Archaeology museum sketch plan

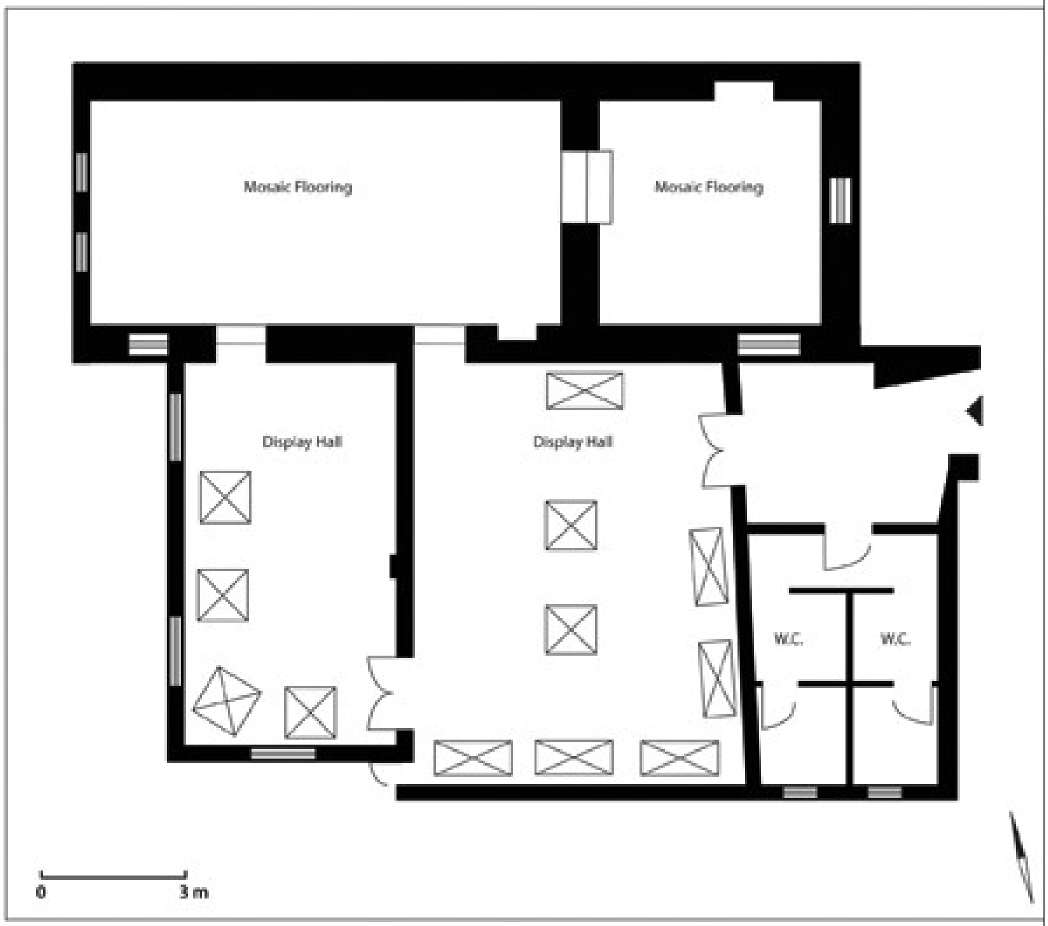

Figure 3.58 Madaba Archaeology museum sketch plan

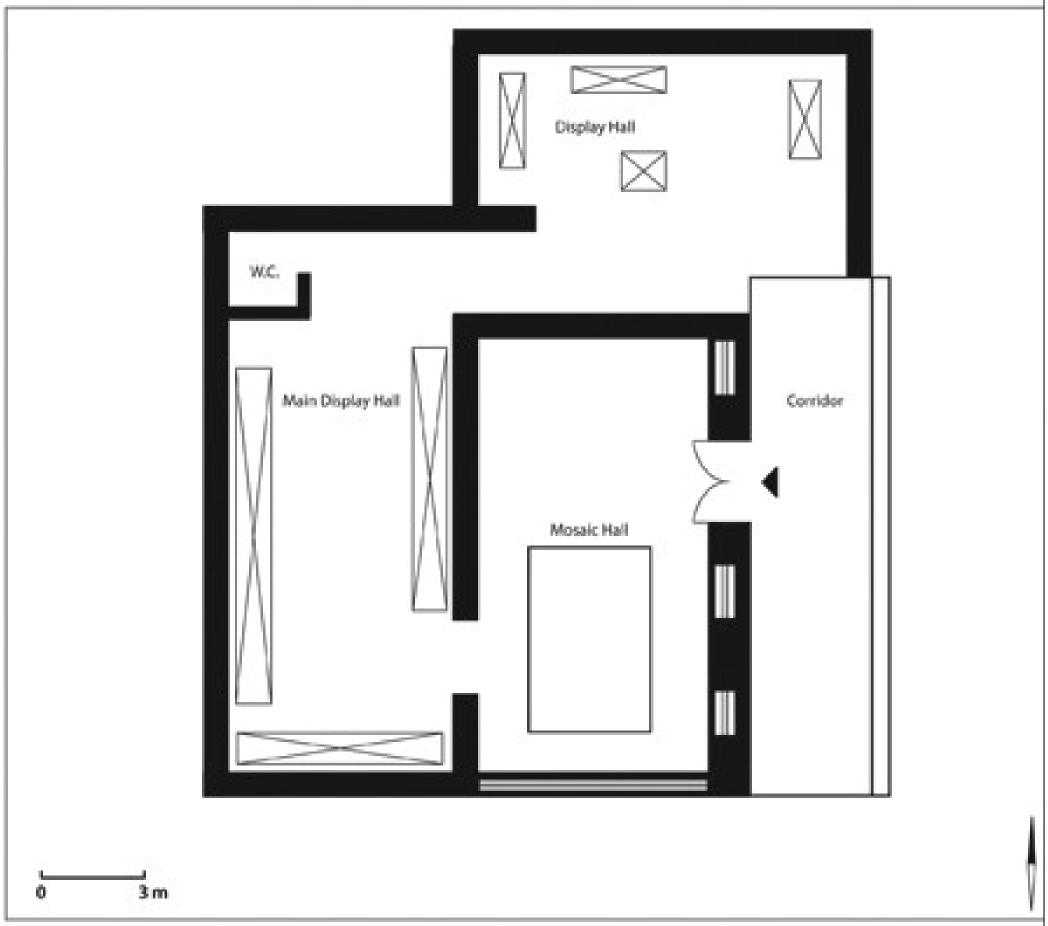

Figure 3.59 Petra Archaeology museum sketch plan

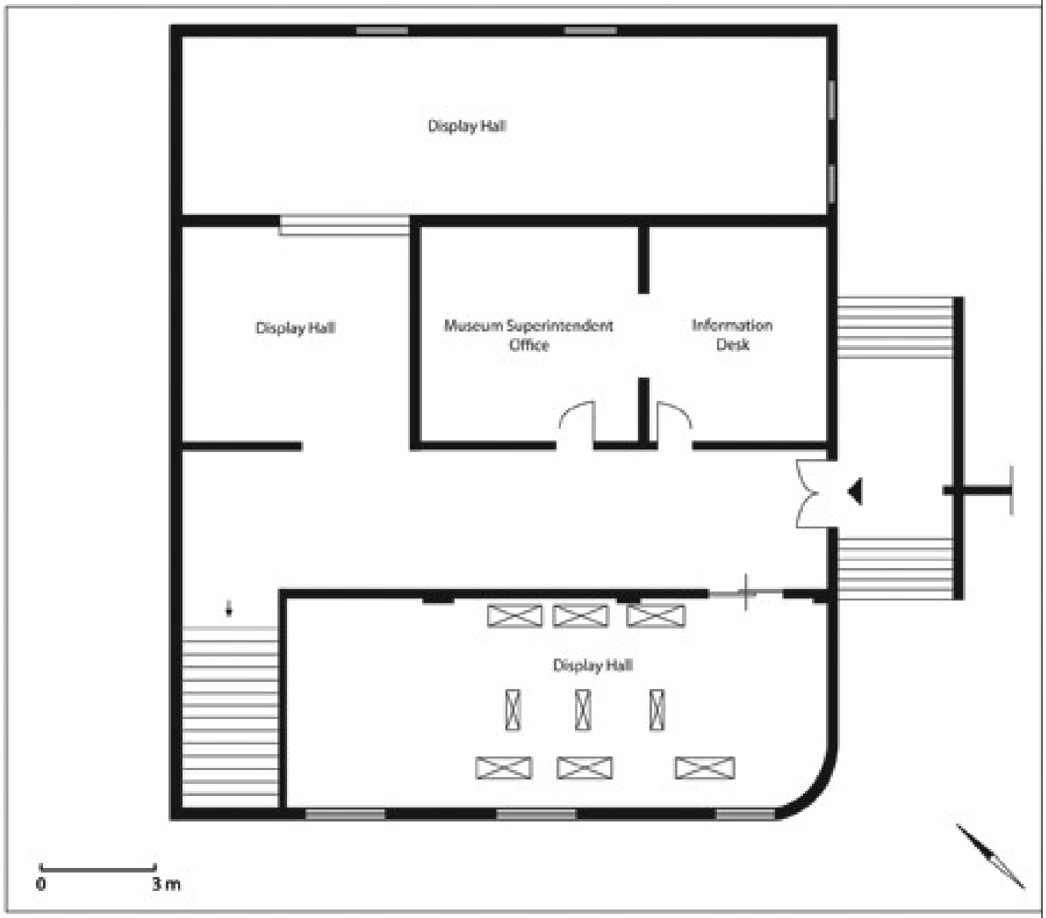

Figure 3.60 Salt Archaeology museum sketch plan (Ground Floor)

Figure 3.61 Salt Archaeology museum sketch plan (First Floor)

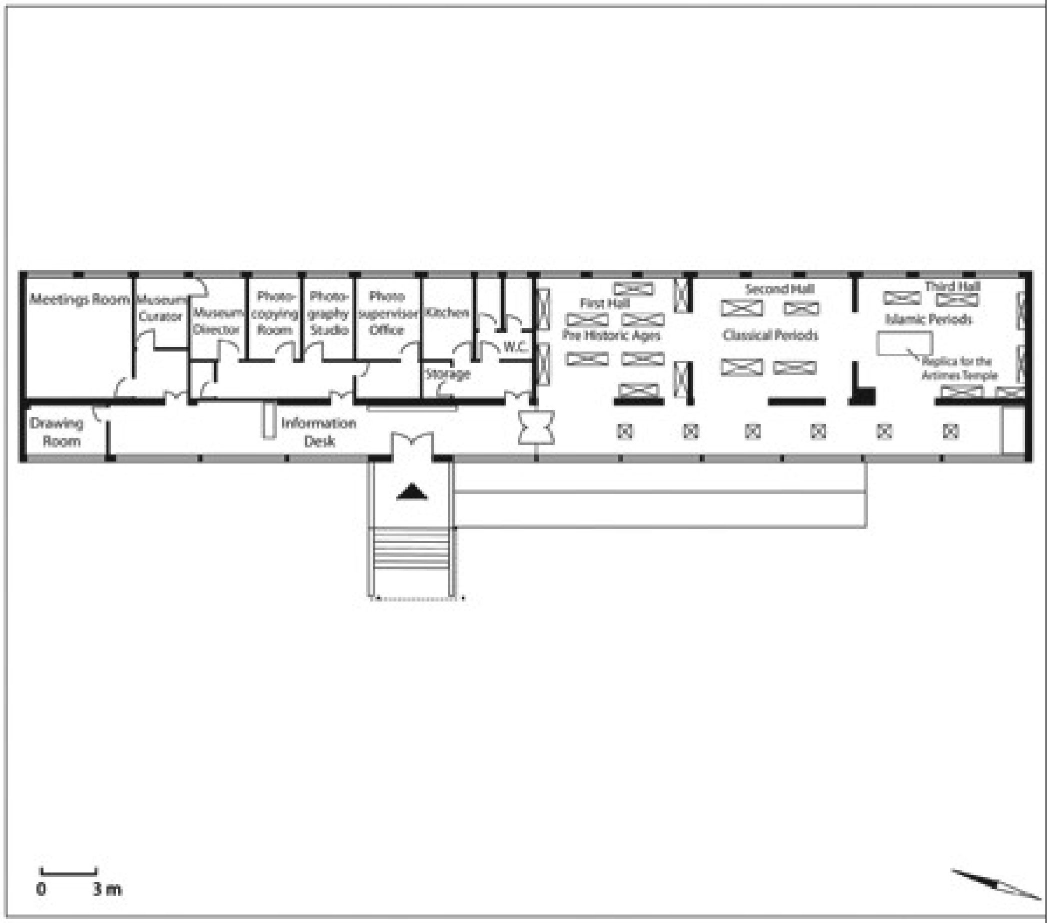

Figure 3.62 Museum of Archaeology / Jordan University sketch plan

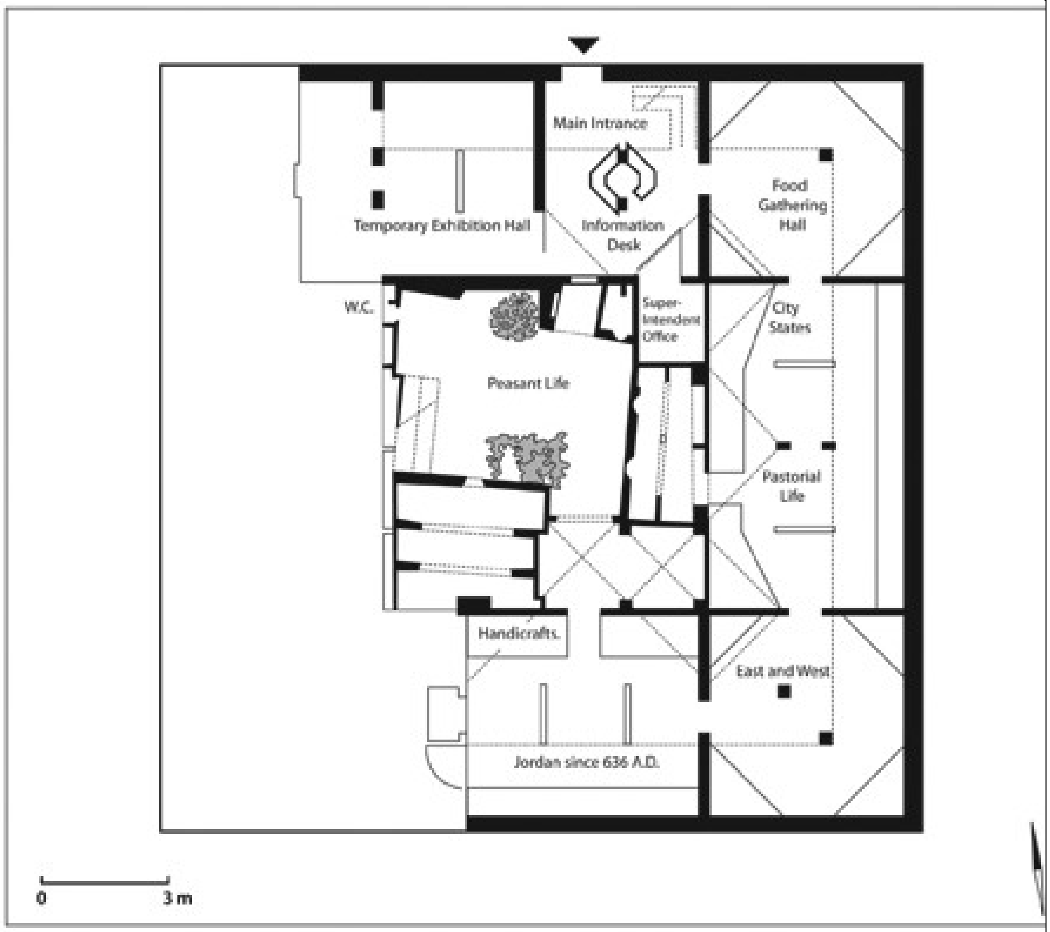

Figure 3.63 Museum of Jordanian heritage sketch plan (Ground Floor)

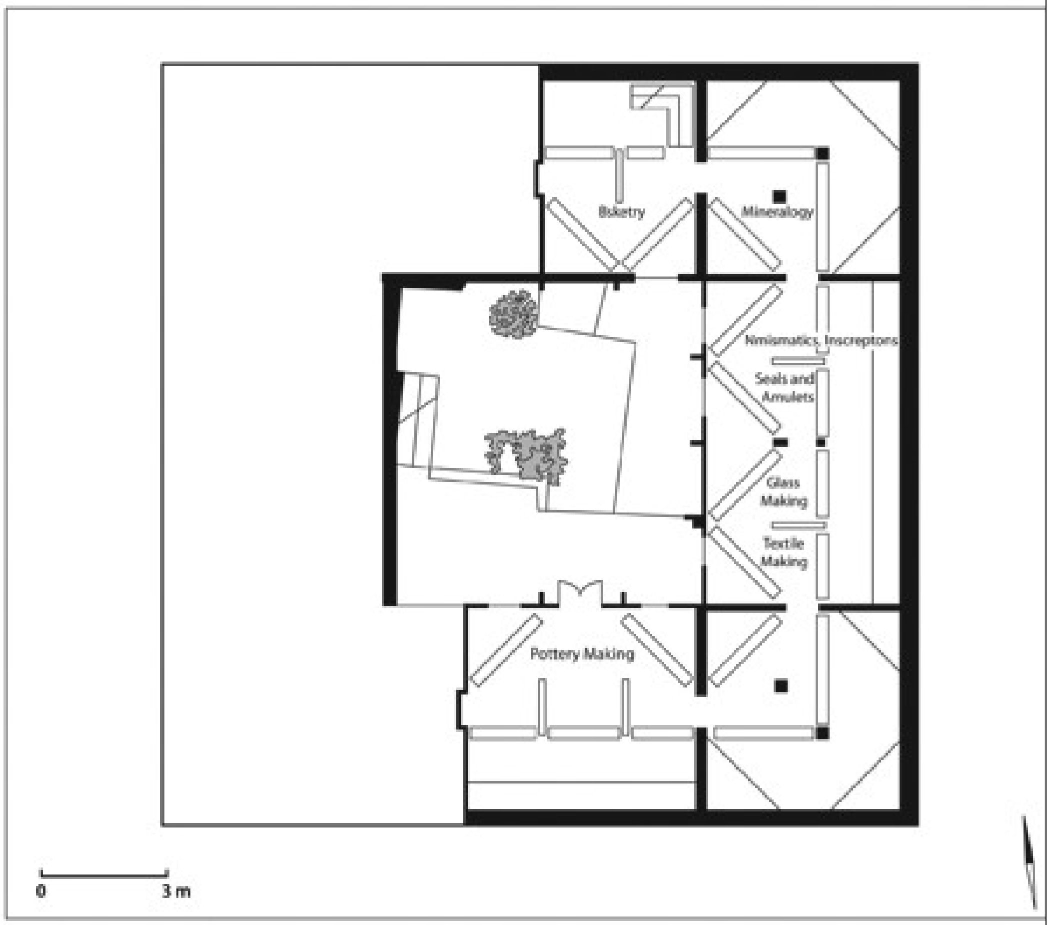

Figure 3.64 Museum of Jordanian heritage sketch plan (First Floor)

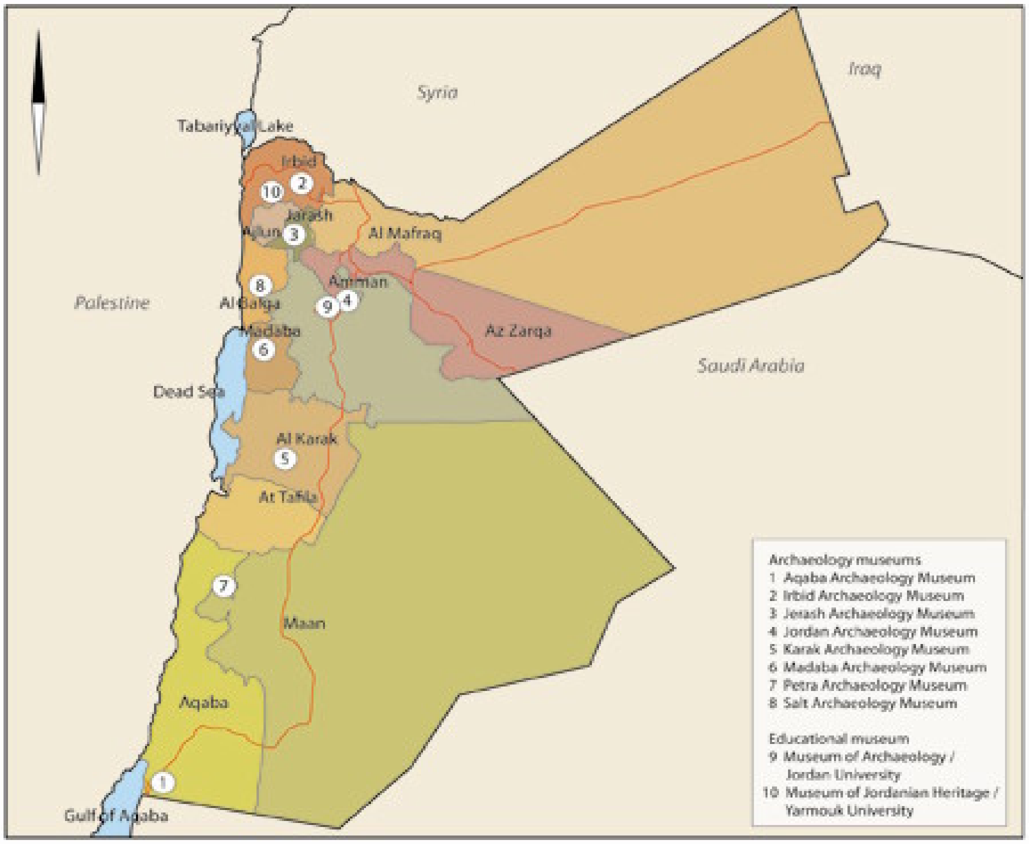

Figure 3.65 Jordan political map indicating the museum locations within their province

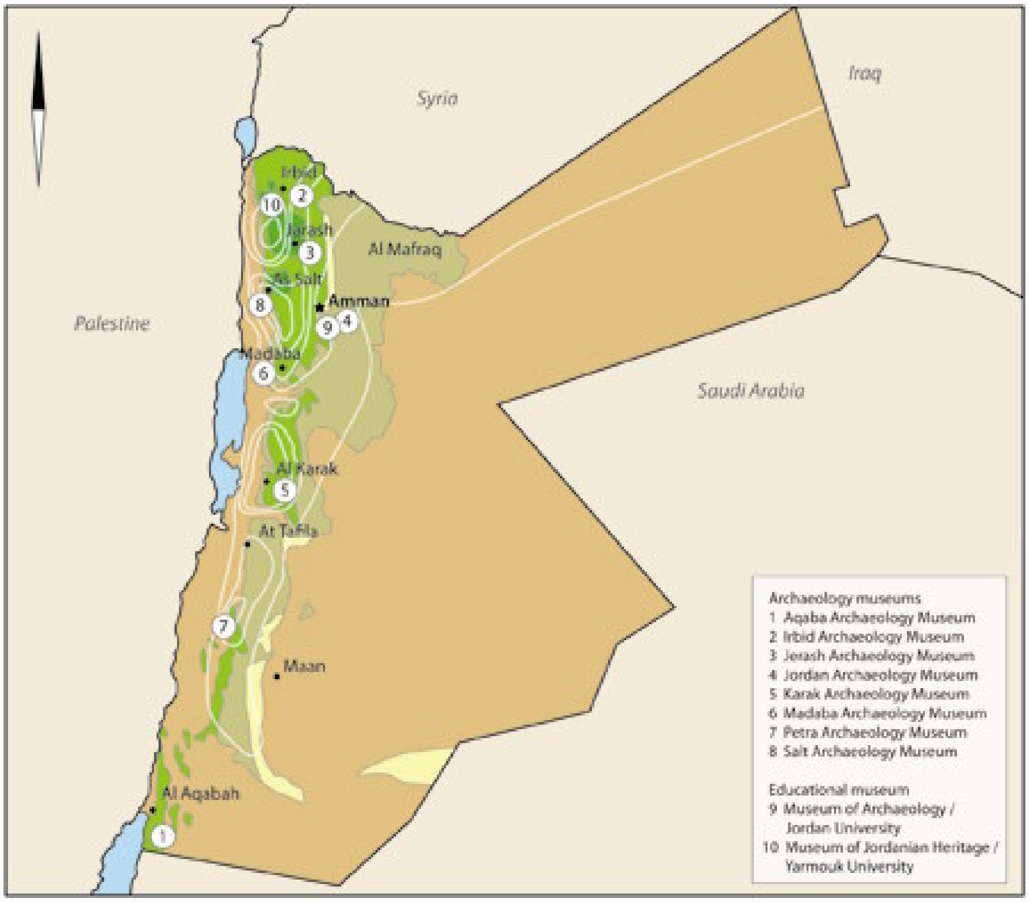

Figure 3.66 Jordan topographical map indicating the museum location in their geographical region

A HOLISTIC APPRAISAL OF THE LIGHTING SYSTEM AT JORDANIAN MUSEUMS AND GALLERIES

A holistic appraisal of the lighting system at Jordanian museums and galleries

4.1 Introduction

Light is an agent of long-term deterioration to exhibition objects. The major effect of light is damage to the surface of materials and organic and inorganic all materials are at risk when exposed to light. Light and heat are forms of energy and it is the energy, which is held in molecules, that causes deterioration. In museums, activation energy may be brought to an object by heating or illuminating it (Cronyn 1990). Energy is defined as being conserved, which means that the total amount of energy in a closed system always remains unchanged (Thomson 1986). A large portion of light energy is infrared, which mainly cause an increase in temperature. Here we do not presume that visible light are heating energy free. Conversely, visible light contains heating energy but with less amount than the Infrared radiations (Thomson 1986). Moreover, light causes many different types of deterioration in museum objects other than simply the damage caused by increasing temperature. The most common deteriorations caused by light are the fading of dyes, the weakening of textile fabrics and the discoloration and embrittlement of organic-based materials (Thomson 1986).

The first widely-read recommendations for museum light intensity appeared in the July 1930 issue of the Burlington Magazine. (D.G.C 1930) presented thirteen sets of recommendations for low, medium and high illumination levels, published throughout the 1930s and 1950s in various journals and books (Druzik and Eshoj 2007).

A museum audience expects to be able to see the exhibited objects of a collection clearly. Therefore, it is the dual role of the museum administration to meet the visitor's expectations and at the same time protect the objects from any deterioration, which might occur from unsuitable lighting. The significance of light cannot be neglected; it plays a role as a major element in any museum. In other words, museums require light in order to spotlight magnificent displays and attract visitors and yet this must be done in a manner, which does not harm the exhibited collection.

4.1.1 Aim of the study

This chapter aims to evaluate the current situation of the lighting systems within selected Jordanian museums, in order to estimate the total exposure of the objects to both natural and artificial light. Through identifying and measuring all sources of light that may reach the objects of the monitored museums, the damage that might occur to these valuable pieces in the future may be estimated. The data on daylight variation, combined with measurements of light intensity, will be compared with the recommended international standard levels of light intensity. The ultimate aim of this study is to reduce as much as possible the deterioration caused by unsuitable illumination at these museums. This research covers as well the evaluation of day-lighting and artificial lighting performance by using the Desktop ELSEC 764 scale model. The selected museums are located in different climatic zones and geographic locations, distributed all over Jordan. This study will discuss museums, which are situated on the plains, in the mountains, in desert areas and in coastal regions.

4.1.2 The Dilemma

The problem of light in museums revolves around the idea that exhibition of objects increases the risk of damage. The more visible and more accessible an artifact is, the higher the risk of damage by light. The damage could be either photochemical damage (fading) or photomechanical damage (structural damage). Therefore, the safest place for museum objects is in a vault, where no light is allowed. However, this would not be compatible with the general mission of museums, which alongside safeguarding and conserving, is to interpret and exhibit its collection for the benefit of the public.
When light reaches any object, the rays either will be absorbed or will reflect. The reflected rays hit the human eye and become ‘vision’. The absorbed rays, or energy, can cause chemical changes in the material either on its surface or in its structure (Miller and Miller 1994).

4.1.3 Spectral composition of light

The spectrum of radiation from museum light sources can be divided into three regions by wave length: ultraviolet radiation (300-400 nm), light or visible radiation (400-760 nm) and infrared radiation (beyond 760 nm) (Kuhn 1986). Infrared is the region of the electromagnetic spectrum that extends from the visible region to about one millimetre in wavelength and infrared (IR) waves include thermal radiation. Ultraviolet radiation (UV) has a range of wavelengths from 400 billionths of a meter to about 10 billionths of a meter (Figure 1). Both visible and ultraviolet light (UV) are forms of energy, since the amount of energy is inversely proportional to wavelength of the light. UV light and the blue end of the visible spectrum, being of short wavelength, have the most energy. Visible light is measured in lumens per square meter (Lux). In museums, UV and visible radiation must be measured and controlled (Cronyn 1990). Visible light contributes to both vision and damage, whereas IR and UV energy, which are not visible, contribute only to damage. Unless all artefacts in a display area are totally insensitive to exposure, UV and IR should be controlled, usually with filters (IESNA 2000). The most hazardous radiations are those with spectral distributions which are dominant in the shorter wavelengths. The relative damage factor increases logarithmically in inverse ratio to wavelength. Thus, ultraviolet is far more hazardous than visible light (IESNA 2000). Illumination value, also known as level of illumination or simply illumination, is measured internationally in Lux where one Lux equals one lumen/m^2. Exposure over a period of time may be expressed in Lux-hour. For example: exposure at 100 Lux for 12 hours = 1200 Lux-hours (Thomson 1967). This implies that what really matters is the total exposure time. In our study, the basic unit expressing visible light will be Lux and the unit expressing UV will be µW/lm.
Hermann Kuhn (1982) also determined the light levels in museums that are recommended for different materials. His recommendations are based on international expert researchers and experiences. Kuhn also mentions that the ideal Lux measurement light for sensitive objects like paintings, textiles and painted objects should not exceed 50 Lux. For other museum objects like painted sculptures, leather, horn, bone, ivory, etc, he recommends no more than 150 Lux. As an example, he mentions for general information that a 100-watt bulb results in a one meter measuring distance in light intensity of approximately 120 Lux. As a result of subsequent experience, the recommended 150 Lux has been revised upwards to 200 Lux, while it is recommended that UV radiation should not exceed 75 µW/lm (Thomson 1986).

Table 4.1 The efficacy of the spectrum of radiation upon its wavelength

The spectrum	UV light	Visible light	IR light
Wave length	300-400 nm	400-760 nm	Beyond 760 nm
Effect	Damage	Vision & Damage	Damage

4.1.4 Light effects on museum objects

Light is radiant energy and exposure to light causes permanent damage to most museum objects. The expected damage can be divided into two main groups depending on the wavelength: the UV region mainly causes surface damage such as fading or degradation of organic materials, while the long-wave Infrared (IR) region brings about heating of the entire indoor environment, causing dehydration and shrinkage of all organic materials (Huber 2007). When there is radiant energy on the surface of a material, some portion of that energy is absorbed. This can promote two distinctly different processes, which can cause the degradation of museum objects. The first is radiant heating which leads in a later stage to the second process, photochemical action. There is a much higher proportion of UV energy in daylight radiation through glass than in tungsten radiation, characteristically about six times as much (Thomson 1986). Fluorescent lamps emit more UV than a tungsten lamp and therefore daylight has the highest proportion of UV radiation, next is fluorescent light, which has less UV than daylight but requires filtering and finally tungsten light, which does not need to be filtered (Thomson 1986).

Since both UV and visible radiation cause colour change, fading and surface deterioration, it is not sufficient to only remove UV radiation, but also visible radiation must be limited. Therefore, we have to accept that displaying museum collections causes a certain amount of damage. Precious objects have often been known to deteriorate under conditions of ill-considered illumination and so, reducing the illumination levels in museums is recommended.

Radiant heating produces a rise in temperature on the surface of the material exposed to the source of energy. The surface expands relative to the body of the object and moisture is driven from the surface material. The symptoms include surface cracking, the lifting of surface layers and loss of colour. Although the symptoms of photochemical action is similar, the process is quite different and often more serious. A chemical change occurs when a molecule irreversibly changes its structure. Photochemical action may include fading; darkening of colours; yellowing; loss of strength; fraying of fabrics and even dramatic colour change in some pigments (IESNA 2000).

Table 4.2 The impact of light on objects displayed at Jordanian museums

Object type	Visible light	IR	UV	Type of Damage
Stone	N	N	N	No damage
Ceramics	N	N	N	No damage
Metal	Y	Y	N	Expansion and contraction
Glass	N	N	N	No damage
Mosaics	N	N	N	No damage
Frescoes	N	Y	N	Embrittlement
Accessories	N	N	N	No damage
Bone	Y	Y	Y	Embrittlement & Expansion
Ivory	Y	Y	Y	Embrittlement & Expansion
Stuffed animals	Y	Y	Y	Biological activity
Leather	Y	Y	Y	Expansion
Wood	Y	Y	Y	Swelling & Expansion
Furniture	Y	Y	Y	Embrittlement
Textiles	Y	Y	Y	Embrittlement
Basketry	Y	Y	Y	Embrittlement
Paintings	Y	Y	Y	Embrittlement & Colour fading
Pictures	Y	Y	Y	Embrittlement & Colour fading
Maps	Y	Y	Y	Embrittlement & Colour fading
N: indicates that light is not harmful to the object. Y: indicates that light is harmful to the object.				

4.1.5 Daylight in museums

I must admit that I had assumed that in most museum buildings, bioclimatic, environmental-friendly and energy-conscious design has been completely ignored. There are good reasons to support my assumption, as, as far as can be seen from the available literature, museums seem to be lit, heated and ventilated by artificial means. In other words, this means a dependency on mechanical equipment. The sensitivity of the objects exhibited is the main argument to justify this dependency. The exhibits are considered being better preserved when light, temperature etc., are fully controllable and adjustable according to the special requirements of the exhibits
(Tombazis and Preuss 2001). In terms of the lighting issue, the use of daylight in museums is somewhat controversial for two reasons. First, the ultraviolet component of natural light has a deteriorating effect on museum objects and second, daylight is difficult to control because of the variability of sky conditions in a day and throughout the seasons (ROM 1976). Moreover, the sun emits a wide spectrum of electromagnetic radiation and causes thermal effects on the indoor climate of any building. These concerns have tended to curtail the use of daylight in museum buildings.

4.1.6 Benefits of daylight in museums

The most important criterion for museum lighting is spectral distribution. In this respect, daylight is considered as the best choice. Some museum curators even claim that daylight, because of its superior colour properties, has no substitute in art galleries during the daytime. No electric light source can exactly simulate the colour composition of daylight (Neeman n.d.). Daylight, whether bright or dim, always offers a continuous spectral curve, meaning that it can reveal all the colours in works of art (Darragh and Snyder 1993). In addition, daylight also gives a natural feeling to the museum visitors. By using daylight in museums, electric lighting usage is decreased during the daytime.

4.2 Hypothesis

Jordanian museums face greater problems concerning lighting control than those in non-Mediterranean Europe for the following reasons:

- Illumination values are higher and therefore require firmer control.
- There is a greater contrast between interior and exterior brightness.
- Taking advantage from natural daylight, since the working hours for museums in Jordan 'in general' are from nine a.m. until three p.m. which are generally sunny hours.
- Due to lack of knowledge, expertise and strict regulation, non-suitable lamps and artificial lighting tend to be used instead of more costly UV filtered and unfiltered lamps.

4.3 Methodology

This study aims to discuss the light efficiency at Jordanian museums. Therefore, fourteen museums were examined. The selected museums varied in their locations, collections and in their building type.

The ELSEC 764 Environmental monitor, borrowed from the Cultural Heritage Inspectorate (Erfgoedinspectie) in the Netherlands, was used to monitor visible light and ultraviolet radiation at the selected Jordanian museums.

Figure 4.1 ELSEC 764 Environmental monitor.
Photo by R.AlGhzawi

The data from the ELSEC 764 device was compared with the current recommended international guidelines for museum lighting. Furthermore, another comparison was made between the different monitored museums, depending on the susceptibility of their collections to exposure to unsuitable illumination. Finally, the available light sources in each museum were investigated, in order to determine the best lighting possibility, depending on the availability of the light types on the Jordanian local market and the museum's budget.

The ELSEC 764 also measures humidity as a percentage of the relative humidity and temperature as degrees Celsius or degrees Fahrenheit. Using the ELSEC 764, measurements can be taken of the proportion of UV present as microwatts per lumen (μW/lumen), the total amount of UV as milliwatts per square meter (mW/m^2) and the amount of visible light present as Lux (Engineering 2002).

The ELSEC 764 can be left for extended periods to log the above-mentioned parameters at a user set interval ranging from 10 seconds to one hour. The saved data can then be transferred to a computer for display, graphing etc (Engineering 2002).

4.4 Research area

Throughout human history, Jordan has witnessed successive ancient states; significant developments have occurred and thus a critical role had been played through numerous ages. Thus the significance of remains and monuments found indicate permanent importance. In recent years, increasing interest in archaeology has resulted in more excavations and explorations of archaeological sites and consequently an increase in the number of monuments and antiquities revealed. In response, it was necessary and urgent to establish museums in which to display such remains aesthetically and historically and this had to be achieved over a short period.
The fourteen museums of this study include The Ajloun Museum; The Aqaba Museum; The Archaeology Museum / Jordan University; The Dar Alsaraya Museum; The Folklore Museum; The Jarash Museum; The Jordan Museum of Popular Traditions; The Jordan National Gallery of Fine Arts; The Museum of Jordanian Heritage / Yarmouk University; The National Heritage Museum / University of Jordan; The Natural History Museum / Yarmouk University; The Salt Museum; The Petra Museum and The Umm Qeis Museum.

4.4.1 The Ajloun Museum

The Ajloun Museum was established in 1993, as part of Ajloun Castle (*Qal'at ar-Rabad*). In 1184-5 Iss ad-din Usama, "one of Saladin ablest amirs" was transferred to Ajloun from Bairut and the building of the castle began (Johns 1931). It arose loftily placed on the escarpment on the eastern side of the Jordan Valley. The position was well chosen. Not only does it command an uninterrupted view of the whole length of the Jordan Valley between the two lakes and of the Palestine ridge from Jerusalem to Tabor, Kawkab and Safad, it also dominates one of three valleys, which lead straight up to the high lands on the Trans-Jordan side. Unlike the majority of the mountain castles, Ajloun is accessible by an easy slope on all sides. Elsewhere a rock promontory was almost invariably chosen, protected by cliffs on three sides and cut off from the mountain on the fourth by a short rock-hewn fosse (Johns 1931). The museum is located on the ground floor of the castle and consists of two main halls, the second hall being accessible only through the first hall. The exhibition does not represent its objects in any particular order, so a visitor can easily become lost along the display route.

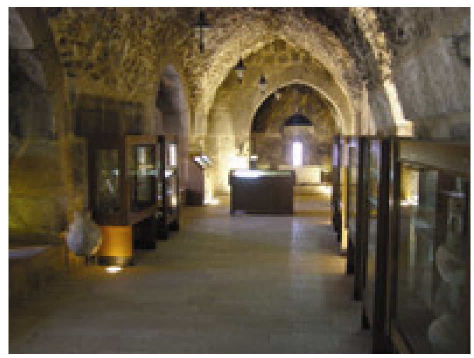

Figure 4.2 Main display hall (Ajloun museum)
Photo by R. AlGhzawi

The museum is not considered being a site museum (a museum which is located at an archaeological site); hence, the objects on display are collected from different archaeological sites and belong to various eras. They consist of pottery objects, glass wares, accessories, metallic objects and coins.
The museum was monitored on October 4, 2009, from 10 a.m. until 2 p.m. The light intensity for both visible and ultra violet light upon a random walk within the museum was measured five times, once every hour, in the mentioned period. Six locations were examined within the two museum halls. These locations were selected because of the diversity of the illumination source, that the objects are lit by. Later, an average of these

readings was given. The museum has different light sources. Daylight enters the museum directly and indirectly through the opened doors and by means of non-UV filtering windows. Moreover, there are fluorescent lamps and incandescent light bulbs.

4.4.2 The Aqaba Museum

The Aqaba Museum was built within the old house of Sharief Hussin Bin Ali (the first king of modern Jordan) in 1991. This museum is located right on the coast of the Red Sea. The museum consists of three main halls, which are not separated from each other. The museum hosts a semi-comprehensive site collection, *i.e.* pottery, metallic, accessories, numismatics, photos and posters. The museum depends mainly on the discoveries of the Aila (Ailana) archaeological site. This archaeological site is located at the Aqaba-Eilat border and was founded after the 8th century BC and served commercial and industrial purposes such as smelting copper and offering a resting place for caravans.

Figure 4.3 Side of a lighting system at the Aqaba Museum. Photo by R. AlGhzawi

During the early part of the 20th century, European and American scholars in the regions of Syro-Palestine and Trans-Jordan conducted the first extensive archaeological research. The results of these investigations yielded a great deal of information about the history and monuments of the Levant and provided a solid basis for all future research in the area. During the 1980s and 1990s, archaeological surveys of the modern city of Aqaba were conducted, revealing evidence for Nabataean occupation of the site and providing the impetus for the archaeological excavations conducted by the Roman Aqaba Project (Dolinka 2003). Excavations of the site in 1994 by a team from North Carolina State University located the Nabataean-Roman town of Aila two kilometres from Tell Al-Khalifeh, in the circular area of modern Aqaba (Dolinka 2003). The collection of the museum contains pottery objects, Quran verse inscriptions (*ayat alkorsi*) and coins (golden, silver, bronze) and also some posters showing the city of Aqaba. However, the museum's most important object is an Arabic inscription, which originally was placed above the eastern city gate (Egypt gate).

The museum was monitored on October 7, 2009, from 10 a.m. until 2 p.m., in order to cover both a part of the morning and a part of the noon of a day. Within this period, a random walk was carried out and a measurement was done at special locations. In total nine locations have been examined. Each location was chosen to be near a light source illuminating an object. Besides the light intensity inside a showcase was examined.

In total, each location was examined five times over this period on light intensity. Both visible and ultra violet light intensities were included and the average of these readings was applied for the interpretation. This museum has different light sources. Daylight enters the area directly and indirectly by means of non-UV filtering windows. Furthermore, there are fluorescent lamps, incandescent light bulbs and spotlights present.

4.4.3 The Archaeology Museum/ Jordan University

The Archaeology Museum was established in 1962, the year in which the University of Jordan was founded. As part of the Department of Archaeology, but formally inaugurated in 1986, the educational mission of the Archaeology Museum is to spread archaeological awareness among future generations of Jordanians.

At first the museum consisted of merely a small room that later became insufficient for the amount of discoveries arriving from various excavations. It was then transferred to its present location where it occupies a distinguished area in the centre of the University campus. The museum area contains two parts: an archaeological outdoor plaza and an indoor exhibition gallery. Despite its prestigious place, the museum was not designed to fit the area of the campus in which it is now located. It also lacks many of the necessary requirements and conditions of a museum. The building itself does not represent any specific local architectural type.

Figure 4.4 Side windows and incandescent lamps at the Archaeology museum/Jordan university.
Photo by R. AlGhzawi

The Archaeological Museum started with a limited number of archaeological objects, but recognizing the value of such a museum the University encouraged the renewal, development and expansion of its existing collection. The museum now represents most prehistoric and historic phases of Jordan’s past. Many of its objects were discovered through the field school excavations sponsored by the Department of Archaeology at the University of Jordan.

A number of archaeological objects are displayed in the outdoor plaza to attract students and visitors’ attention and strengthen their feelings of connection to the importance of a shared historical and national heritage.

The indoor gallery displays numerous archaeological pieces and information about the different historical periods. It displays various objects representing periods extending from the Palaeolithic to the end of the Islamic periods, ordered chronologically.

The museum was monitored on September 6, 2009, from 10 a.m. until 2 p.m. The light intensity for both visible and ultra violet light was measured five times, once every hour, in the mentioned period. Each location was chosen to be near a different light source. In total seven locations have been examined. In total, each location was examined five times over the monitoring period on light intensity. Both visible and ultra violet light intensity were included, later, an average of these readings was given. The museum has different light sources, such as daylight, fluorescent lamps, incandescent light bulbs and spotlights.

4.4.4 The Dar Alsaraya Museum

The Saraya Castle was built in 1886 in Irbid as a residence for the Utman governor in North Jordan (Altamimi 2001). Later it was used as a local prison by the Jordanian police until 1994. After that date, the Saraya Castle was taken over by the Jordanian Department of Antiquities (DoA) to be

Figure 4.5 Irbid hall at the Dar Alsaraya Museum. Photo by R. AlGhzawi

restored and used as The Dar Alsaraya Museum (Antiquities 1994).
The museum consists of two stories. The ground floor has the museum halls and the second floor the administration offices. The museum contains three main display halls and four small halls. The objects in the museum are displayed in chronological order in each hall. The first main display hall, the Irbid hall, displays archaeological artefacts and gives a historical introduction to Irbid City. This hall leads to the other halls of the museum. The second display hall, the Ancient Period hall, displays archaeological objects belonging to the period 1600-1200 BC. The last main hall, the Metallurgy room, displays in its showcases metallic objects belonging to the period 4500-2200 BC. The other halls display mosaics and Islamic pottery.
The museum was monitored on September 2, 2009, for the period of four hours, from 10 a.m. until 2 p.m., in order to monitor light intensity in the morning and in the noon periods of the day. A random walk in the museum was carried out and measurements were done at specific locations. In total seven different locations have been examined. Each location was chosen to be near a specific light source that is illuminating an object.
The light intensity for both visible and ultra violet light was examined five times, once every hour, in the mentioned period. Both visible and ultra violet light intensities were included and the average of these readings applied for the interpretation. The museum has different light sources, such as daylight, fluorescent lamps, incandescent light bulbs and spotlights and so the ELSEC 764 light monitoring device was installed in several places at the museum, to monitor all available light sources in the museum halls and inside the showcases.

4.4.5 The Folklore Museum

The Folklore Museum, which is located on the ground floor of the Roman Theatre in Amman, was established in 1975. The museum is in the city centre of the capital Amman and lies within a significant Roman archaeological site. The museum was established through the continuous work and supervision of the Department of Antiquities.
The museum consists of four main halls. The entrance hall is reached by climbing several steps, without disabled access and exhibits mannequins wearing traditional Jordanian cloth representing some of the handcraft of the past few decades. It also exhibits some traditional swords and guns. The second hall takes the form of a traditional Jordanian guest room. Guest rooms in traditional Jordanian houses are dedicated to receiving guests and are not for the daily use of the owners of the house. The third hall, which is only accessible through the second hall, represents a typical Jordanian living room, furnished with the type of traditional furniture that was used in the middle of the last century. The last hall, the largest of the museum halls, is dedicated to large traditional objects and exhibits for example an Arabic traditional tent, a camel saddle, a mannequin of a woman milking a sheep and traditional metal cooking pots.

Figure 4.6 Traditional guest-room at the Folklore Museum. Photo by R. AlGhzawi

The museum was monitored on September 7, 2009, from 10 a.m. until 2 p.m.. The light intensity for both visible and ultra violet light was measured five times, once every hour, in the mentioned period and later an average of these readings was given. Within this period, a random walk was carried out and measurements were done at special locations. In total seven locations have been examined, each location was chosen to be illuminated by a different light source. The museum has different light sources, such as daylight, which penetrates through non-UV filtering side openings, fluorescent lamps and incandescent light bulbs.

4.4.6 The Jarash Museum

Ancient Jarash has a unique, gentle, seductive beauty in which the clear mountain light plays an important part. The lie of the land over which it is spread means that it does not disclose everything at once; there is a constant change of view, a slow unfolding, so that one is kept enthralled in a sequence of delights. Jarash is one of the three great classical cities of the Near East (Kennedy 2007). It is, however, altogether different from Petra and Palmyra. Set in a wide, fertile valley high in the hills of "Gilead", Jarash is also the best preserved of the cities of the Decapolis. The word 'Decapolis' means 'ten cities' and that these were of Hellenistic origin (Browning 1982). Jarash was on of the leading cities of the Decapolis (Weber 1990). The Jarash Museum was first established in 1962, inside ancient Jarash. It was at this time housed in the basement of a building near the Artimis temple. In 1985, the museum was moved to another building, its present place and got the name 'Jordan Through History'. This was done under the supervision of Yarmouk University and the Ministry of Tourism and Antiquities. The building had formerly been used as a rest house. The museum now has a prominent and distinguished position on the eastern hill of the archaeological site, overlooking the old city forum as well as modern and old Jarash.

Figure 4.7 Jarash Museum.
Photo by R. AlGhzawi

Like the Karak, Petra and Umm Qeis museums, the Jarash Museum is a site museum, as it is related to a specific archaeological site. Site museums are built in the same area in which archaeological objects have been excavated, so that visitors can see the artefacts close to their original environment. This enables visitors to experience the origins of the objects and perhaps discover how these objects were used. Jarash museum has no buildings nearby and its flexible boundaries mean that the museum could easily be expanded in the future with no legal or technical difficulties.

Notably, some difficulties might arise; especially those revolve the trees surrounding the museum building. Other problems may arise facing the museum in the future. These problems could be illustrated as recruiting visitors to the museum and the route to the museum, which must be well-paved within the archaeological site to enable pedestrians reaching the museum.

The collection of the museum mainly consists of the findings of the excavations of the archaeological site of Jarash. The objects displayed in the museum include pottery objects, glassware, metallic objects, coins, accessories, gemstones, stone artefacts and sculptures.

The light measurements were taken in this museum throughout a random walk. Six vital spots within the main hall of the museum were investigated. These readings were taken in different illumination sources upon the museum objects. The museum was monitored on October 4, 2009, from 10 a.m. until 2 p.m. The light intensity for both visible and ultra violet light was measured five times, once every hour, in the mentioned period. In each monitored spot readings were taken five times and later an average of these readings was given. The museum has different light sources, such as daylight, fluorescent lamps and incandescent light bulbs.

4.4.7 The Jordan Museum of Popular Traditions

The Jordan Museum of Popular Traditions was established in 1971 and located on the ground floor of the Roman Theatre in Amman, opposite the Folklore Museum.

The museum consists of three main halls. The first hall is the entrance hall, which exhibits traditional women's dress representing the local traditional dress of each tribe or area in different locations in Jordan. In the second hall, women's accessories, such as anklets, bracelets and necklaces, are displayed. The third hall displays pictorial epigraphy and mosaics.

Figure 4.8 Spot lights near textile objects, at the Jordan Museum of Popular Traditions. Photo by R. AlGhzawi

The museum was monitored on September 7, 2009, from 10 a.m. until 2 p.m. in order to cover both a part of the morning and a part of the noon of a day. Within this period a random walk was done inside the museum halls and the measurements were taken at vital spots depending on their illumination source. In total seven locations were examined in this museum. The light intensity for both visible and ultra violet light was measured five times, once every hour, in the mentioned period. Later, an average of these readings was given. The museum has different light sources, such as daylight, fluorescent lamps, incandescent light bulbs and spotlights.

4.4.8 The Jordan National Gallery of Fine Arts

The Royal Society of Fine Arts is a cultural, non-governmental, non-profit organization, founded in Amman, Jordan in 1979. Its goal is to encourage cultural diversity, disseminate artistic knowledge and promote contemporary art from the Islamic and developing worlds. The compound of the Jordan National Gallery of Fine Arts comprises two buildings flanking a sculpture park that is also a model garden for water conservation, with a children's playground, an open-air stage, a Japanese garden, an Andalusian fountain and an art lounge and restaurant.

The Jordan National Gallery of Fine Arts is one of the major art museums in the Middle East and houses a unique permanent collection of contemporary art from the developing world.

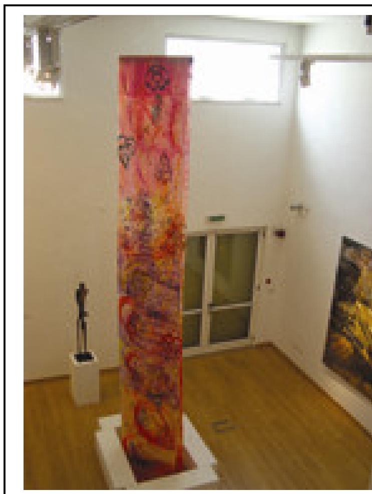

Figure 4.9 Natural and artificial light at the Jordan National Gallery of Fine Arts**.** Photo by R. AlGhzawi

The collection comprises over 2000 works including paintings, prints, sculptures, photographs, installations,

weavings and ceramics, by more than 900 artists from 60 countries, mainly in Asia and Africa.
It was decided to take two readings a day, in order to cover both working day periods, the morning and the afternoon. Therefore, the museum was monitored five times a day, once every hour. Later, an average of these readings was given. This museum was monitored on September 10, 2009, from 10 a.m. until 2 p.m. The light intensity was examined in different illuminating locations, for both artificial and natural lighting, in the mentioned period. The museum has different light sources, such as daylight, incandescent light bulbs and filtered spotlights and so the ELSEC 764 light monitoring device was installed in several places at the museum, to monitor all available light sources in the museum halls and inside the showcases.

4.4.9 The Museum of Jordanian Heritage / Yarmouk University

The Museum of Jordanian Heritage, part of the Faculty of Archaeology and Anthropology at Yarmouk University, is a dynamic facility in a growing organization. The museum recounts the story of humankind from its earliest stages until today. The museum reflects the research and field projects conducted by the faculty, researchers and technicians of the faculty, whether independently or in cooperation with other local and foreign institutes. The museum was established in 1988 and was opened to the public in the same year.

Figure 4.10 Fluorescent and incandescent lamps, at the Museum of Jordanian Heritage/ Yarmouk University.
Photo by R. AlGhzawi

The museum of Jordanian heritage was monitored on August 31, 2009, from 10 a.m. until 2 p.m. That is to investigate light intensity in the morning and in the noon, to determine whether there was a contrast between these two periods of day. The light intensity for both visible and ultra violet light was measured five times, once every hour, in the mentioned period. A random selection for the monitored locations within the museum halls were determined, depending on their illumination source. Besides, the light intensity in a showcase was examined. Later, an average of the five readings was given. In total nine vital illuminating spots were examined. The museum is lit throughout different light sources, such as daylight, fluorescent lamps, incandescent light bulbs and spotlights.

4.4.10 The National Heritage Museum / University of Jordan

The National Heritage Museum at the University of Jordan is located near the Archaeological Museum at the centre of the campus. The museum opening was in 1986. The museum consists of one main hall and all the exhibition materials are on the display in this single room. The museum presents various models of Jordan's traditional social and economic structures, highlighting the reliance on the family as a self-sufficient unit for

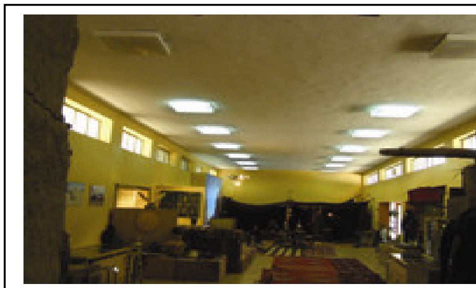

Figure 4.11 Different light sources at The National Heritage Museum.
Photo by R. AlGhzawi

the protection of most of its basic needs. Village areas and peasant life are represented in the museum by a village house made of mud. Because the ethnographic collection does not fall under the Jordanian antiquities law, prohibiting trade of archaeological objects, most of the museum collection was assembled either through purchase or by gifts.

The collection of the National Heritage Museum is arranged thematically according to economic and environmental styles. The museum includes a number of sections such as the bedouin tent area (*beit al-shaar*) and the city area, the museum also includes a number of corners such as the public coffee shop corner, a handmade items corner, a herbal medicine corner and ornament and clothing corners. Moreover, the museum includes a number of sections such as those for agriculture instruments, domestic tools, coffee tools and weapons.

The museum was monitored on September 6, 2009, from 10 a.m. until 2 p.m. to cover all the working periods of the day when the objects are exposed to light. The light intensity for both visible and ultra violet light was measured five times, once every hour, in the mentioned period. Later, an average of these readings was given. The different light areas naturally and artificially lit were examined, in total five different locations were monitored. These locations were selected to cover all types of available light sources in the museum halls. The museum has different light sources, such as daylight, fluorescent lamps and incandescent light bulbs.

4.4.11 The Natural History Museum / Yarmouk University

The Natural History Museum, part of the Faculty of Science at Yarmouk University, was established in 1981. In 2008, the museum was under conservation and restoration works, which included paving the floor with ordinary tiles, painting the walls, renewing the lighting system, adding aquaria and providing all showcases with interpretation labels.

The museum started its collection by gathering botanical, geological and zoological species on a daily basis from different locations in Jordan. This procedure continued until the early 1990s. After that, field trip tasks have been decreased to a minimum, as a result of the existing large quantity of collected species.

Figure 4.12 Fluorescent lamps, at the Natural History Museum/Yarmouk University.
Photo by R. AlGhzawi

The museum collection is divided into three main departments:

- Zoological species:
    - Vertebrates (mammals, birds, reptiles, amphibians and fish)
    - Invertebrates (insects, molluscs and scorpions)
- Botanical species, including medical herbs, poisonous plants and fruit plants.
- Geological and fossil samples.

The museum consists of two main halls. The first hall displays zoological species and the second hall, which is only accessed through the first hall, exhibits botanical species and geological remains.

The museum was monitored on September 1, 2009; from 10 a.m. until 2 p.m. This period of the day is sufficient to cover the variation in the illumination level during the exposure time for the museum objects. Readings were taken in different places in the museum in order to cover all the museum-displayed collection as well. These places were selected randomly, in total five locations were examined. The light intensity for both visible and ultra violet light was measured five times, once every hour, in the mentioned period. Later, an average of these readings was given. The museum has different light sources, such as daylight and fluorescent lamps.

4.4.12 The Petra Museum

Petra is one of the Seven New Ancient Wonders of the World and is also one of the UNESCO World Heritage sites. The Petra museum is located in the western end of the ancient city of Petra, approximately 1500m from the Siq, the entrance of Petra. It was established in 1994 and consists of two main halls and an entrance hall.

Figure 4.13 Natural light and fluorescent lamps at the Petra Museum.
Photo by R. AlGhzawi

The entrance hall presents an introduction to the Nabataean kingdom and the geological facts about Petra. The second hall hosts excavated objects from Petra, displayed in chronological order. It also deals with the historical earthquakes that occurred in Petra. The third hall contains a pottery collection, bronze statues, ceramic wares, jewellery and a numismatic collection.

The museum was monitored on October 5, 2009, from 10 a.m. until 2 p.m. The light intensity for both visible and ultra violet light was measured five times, once every hour, in the mentioned period. Later, an average of these readings was given. The time of measuring was chosen in order to cover both morning and noon periods. A random walk was made through the museum halls and measuring spots were chosen, representing the diversity of illumination sources in the museum. In total nine locations were examined in this museum, which

has different light sources, such as daylight, fluorescent lamps and incandescent light bulbs.

4.4.13 The Salt Museum

The city of Salt city lies about 30km North West of Amman with about 35,000 inhabitants. It was of great importance in the 19th and early 20th century during Ottoman rule in Jordan, when it served as the chief administrative centre for the surrounding area. It was even considered as a candidate for the capital of Trans-Jordan in 1920s. However, this position was taken by Amman. Salt still retains the Ottoman architecture in the classical style represented by long-arched windows, domed roof and yellow stonewalls. The historical value of Salt's architecture is unique and a reason to

Figure 4.14 Windows with curtains and incandescent lamps at the Salt Museum.
Photo by R. AlGhzawi

be nominated as candidate of the World Heritage Site nominations (Tanaka *et al*. 2005). Although, the national Antiquities Law only concerns the remains from before 1750, the city designated about ten buildings for preservation and placed a plate on the front wall of each of them as an indication for that purpose. Salt is also known as the final resting place of the Prophet Ayyoub, whose legendary patience and faith gave him strength to pursue hardships, for which he was rewarded by being mentioned four times in the Quran. Along with its historical and religious characters, local handicraft work is peculiar. It includes ceramics, weaving, silkscreen printing, embroidery and dyeing (Tanaka *et al*. 2005). The Archaeological Museum is a regional museum, dedicated particularly to the Balqa' area. This area is a varied geographical landscape, which has been adapted and used by people throughout the centuries. The displays are arranged chronologically under the general theme of 'Archaeology in the Landscape'.
The museum was established in 1986 and it is located in the middle of the new city centre of Salt. The museum consists of two storeys, each with two main halls. One of the halls on the first floor contains a pottery collection, excavated in *Tlelat Alghasool* and belonging to the period 4500-3300 BC (Kennedy and Bewley 2004). The other hall on the same floor hosts a collection of Bronze Age (3300-2200 BC) pottery. Most of these objects were excavated in the Alsalalem area. This hall also includes pottery objects belonging to the period 2200-539 BC, excavated in *Tell Deir Alla*. The first hall on the second floor displays Byzantine period (324-636/640 AD) (Kennedy and Bewley 2004) objects in its showcases. These objects include pottery, bronze objects, including bracelets and a collection of numismatics. The other hall on the second floor, which is the smallest in the museum, contains a glass collection excavated in Balqa' and a mosaic brought to the museum from Southern Shouna.
The museum was monitored on September 8, 2009, from 10 a.m. until 2 p.m. The timing for this was chosen to cover all periods that represent the exposition time of objects to light. Moreover, a random selectivity of locations to be examined was determined in order to cover all illumination sources in the museum. The light intensity for both visible and ultra violet light was measured five times, once every one hour, in the mentioned period. Later, an average of these readings was given. The light intensity was measured in fourteen locations comprising all illumination sources in this museum. The museum has different light sources, such as daylight, incandescent light bulbs and spotlights.

4.4.14 The Umm Qeis Museum

The Department of Antiquities in Jordan renovated one of the houses from the Ottoman period at the archaeological site of Umm Qeis (ancient Gadara) in 1987 and it has been used as a museum ever since. The museum consists of two separate halls, the first of which has three showcases. One displays the pottery collection belonging to different historical eras, beginning with the Hellenistic period till the Islamic periods. Another showcase displays what has been excavated at the site of Umm Qeis. The last showcase in that room displays stone and flint tools. The second hall displays statues and stone sculptures, which belong to the Roman–

Figure 4.15 Fluorescent and incandescent lamps at the Umm Qeis Museum. Photo by R. AlGhzawi

Byzantine period.
The museum has its own courtyard, in which basalt sarcophagi, tombstones and mosaics are exposed. Gadara is one of the Decapolis league (the "ten cities" in Greek) that first appears in the historical records shortly after the conquest of the region by the forces of Alexander the Great in 333 BC (Weber 1990). The ruins of Gadara cover the east side of a triangular plateau, whose highest point is 378 metres above m.s.l. in a bountiful environment. The surrounding splendid environment includes the perennial Yarmouk River to the north, the forested hills of the Ajloun range to the south, the fertile lands of the Irbid plateau to the east and the Jordan Valley to the west, with several therapeutic thermal mineral springs in the Yarmouk gorge. Gadara developed into a major town because of the combination of the rich natural environment and its strategic location at the junction of several ancient routes. It often served as a key frontier post alongside the natural border formed by the Yarmouk River and it also derived commercial income from the trade route, which linked the Palestinian Mediterranean ports with Bostra and the Hawran region of southern Syria. No firm evidence has been uncovered of human exploitation or settlement of the Umm Qeis plateau before the Hellenistic period (Weber 1990).
Although most of the old city of Umm Qeis was occupied by the houses of local citizens, the Jordanian Department of Antiquities managed to obtain the entire archaeological site of Umm Qeis. From that day onward, there has been a continuous process of conservation and restoration work on the entire site, as well as an annual excavation. Objects yielded from these excavations are placed in the Umm Qeis museum.
The museum was monitored on September 3, 2009, from 10 a.m. until 2 p.m. The timing of this light intensity investigation was chosen to cover all periods that comprise the exposition time for objects to light. In addition, a random selectivity of locations to be examined was determined in order to cover all illumination sources in the museum. The light intensity for both visible and ultra violet light was measured five times, once every hour, in the mentioned period. Later, an average of these readings was given. The light intensity was measured in fourteen locations covering all illumination sources in the Umm Qeis museum. The museum has different light sources, such as daylight, fluorescent lamps and incandescent light bulbs.

4.5 Results

Light causes many different kinds of degradation in museum objects, the most common being the fading of dyes, the weakening of textile fabrics and the discoloration and embrittlement of paper. Heat and humidity may also cause great damage but here it is intended to focus only on the effects of light, though light, heat and humidity are all acting together (Thomson 1961). The light sources at the investigated museum in Jordan, differs from one museum to another. Some of the Jordanian museums depend more on natural day light, while others depend more on artificial light lamps. Furthermore, the artificial lamps installed in the museum and even inside the showcases are varying from one museum to another. There were no specifications for the artificial light lamp type to install in the Jordanian museum. Therefore, the results of each investigated museum will be presented separately as follows:

4.5.1 Ajloun Museum

Based on a short assessment on the current lighting system at the Ajloun museum, it was found that the light luminance in the Ajloun museum could not be managed. Light can be switched on and off manually. Furthermore, two types of light sources were found:

- Daylight coming through unfiltered side openings.
- Tungsten incandescent lamp.

Although, two types of illumination were used in the museum, it was found that all light sourced were overlapping each other. Table 4.3 gives a summary of the method of illuminating the museum. The six locations where measurements were taken can be found in Table 4.4. The result of the measurements in this museum as it is shown in Figure 4.16 reveals that the visible light was within the required standards, but the UV measurements were far in excess of the accepted standards that is 75 µW/lm (Thomson 1986) up to 1100 µW/lm at some investigated spots.

The collection of this museum contains coins, glass in both shapes transparent and painted, accessories (silver, gold, bronze and beads); pottery (unpainted) and mosaics.

The maximum rate for visible light investigation in this museum ranges between 23-158 lux and for the investigation of the UV results differ from 0- 1197 µW/lm.

Figure 4.16 shows the average of the readings of the six locations. In this graph, the irradiance of visible light and UV light can be found. In addition, the correlation between visible light and UV with their maximum allowable rates according to international guidelines (Thomson 1986) in the Ajloun museum is also indicated.

Table 4.3 The Ajloun Museum

Museum type	Archaeological site museum
Light sources	Tungsten lamps & natural light
Daylight vs. artificial light	50% natural, 50% artificial
Type of collection	Numismatics, glass, accessories, pottery, mosaics

Table 4.4 Delineate the locations of the ELSEC 764 devices in the Ajloun Museum

Location number	Description of location
1	First hall, facing ceiling
2	First hall, against light
3	First hall, opposite window
4	Second hall, facing ceiling
5	Second hall, opposite window
6	Second hall, inside showcase

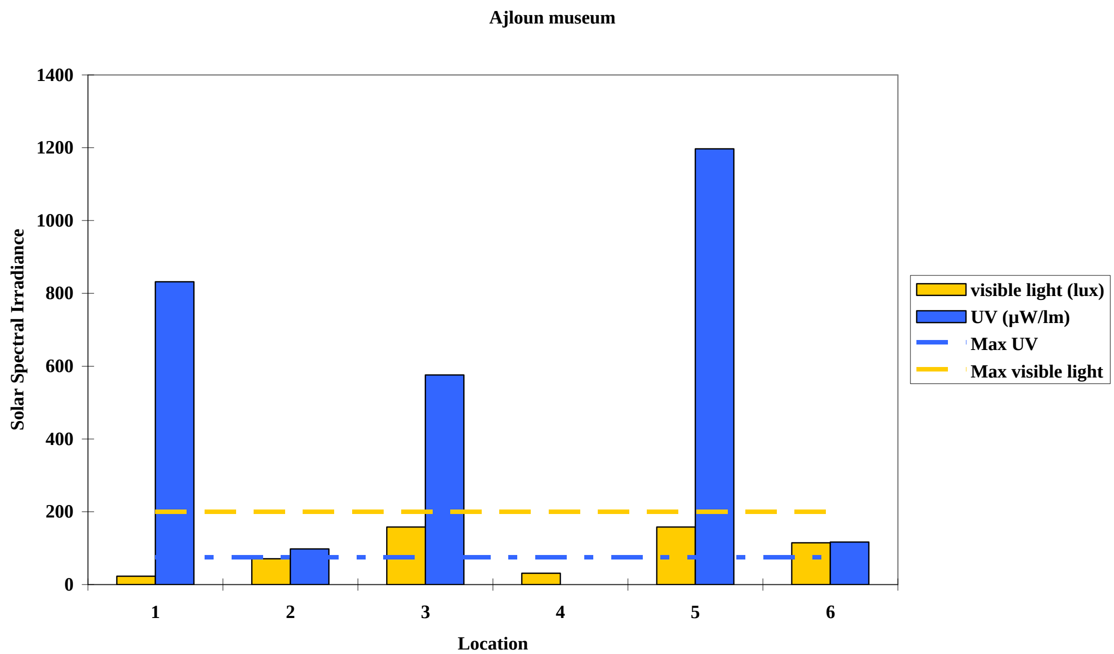

Figure 4.16 The average of the solar spectral irradiance readings at the Ajloun Museum within specific locations mentioned in Table 4.4.

Discussion

The results of the light examination at the Ajloun museum revealed that the intensity of the visible light was within the recommended levels. That can be explained by the fact that the museum is located within a historical castle (Ajloun castle) which was built in 1184. The castle has extremely thick walls, which provide the castle with high humidity levels. Furthermore, there are small side openings in walls of the castle, which in the past were used for shooting arrows to defend the castle. These openings do not provide the halls in the castle and the museum, with sufficient illumination. Therefore, the amount of visible light was under 200 Lux in all investigated locations. As has been mentioned, the Ajloun museum depends on natural daylight for 50% of its lighting. Keeping the hall relatively unlit makes it difficult for visitors to read the interpretation labels. However, three of the six examined locations exceeded the recommended 75 µW/lm. Therefore, it is recommended that a non-UV artificial lighting system be installed in the museum, so that the museum would depend on these filtered artificial lights for at least 90% of its light.

4.5.2 Aqaba Museum

Based on a short assessment of the lighting system at the Aqaba Museum, it was found that the light luminance in the museum could not be managed. Three types of light sources were found:

- Natural light coming through open windows and doors.
- Incandescent light.
- A few filtered spotlights. The type of the spotlights could not be discovered, as the staff present was unable to provide any further information on the types of light used.

Although several types of illumination were used, it was found that all light sources were overlapping each other.

Table 4.5 gives a summary of the lighting system in the museum. The nine locations where measurements were taken can be found in Table 4.6.

Materials displayed in this museum were mainly transparent and coloured glass objects, accessories made of silver or bronze, or beads and monochrome and coloured pottery and ceramics.

At some locations, it was noticed that the visible light intensity exceeded the recommended level for sensitive objects. For items such as paintings and textiles, the light intensity should not be higher than 50 Lux and for other museum objects, the light intensity should be at a maximum of 200 Lux. For UV, similar results were obtained but less frequently. The light in the museum contains a high portion of UV light and in most investigated locations, the UV exceeded 200. However, guidelines recommend that UV radiation should not exceed 75 µW/lm (Thomson 1986).

Figure 4.17 shows the averages of the readings at the nine locations. Here the irradiance of visible light and UV light can also be found. The recommended maximum levels (Thomson 1986) are also presented in the graph.

Table 4.5 The Aqaba Museum

Museum type	Archaeology museum
Light sources	Natural light & tungsten lamps
Day light vs. artificial light	70% natural, 30% artificial
Type of collection	Ceramics, glass, accessories, wood and parchment

Table 4.6 Delineate the locations of the ELSEC 764 devices in the Aqaba Museum

Location number	Description of location
1	First hall, facing ceiling
2	First hall, opposite window
3	First hall, opposite door
4	Second hall, against tungsten light lamp
5	Second hall, directed to display area
6	Third hall, opposite window
7	Third hall, facing ceiling
8	Fourth hall, against spot light lamp
9	Fourth hall, opposite wall

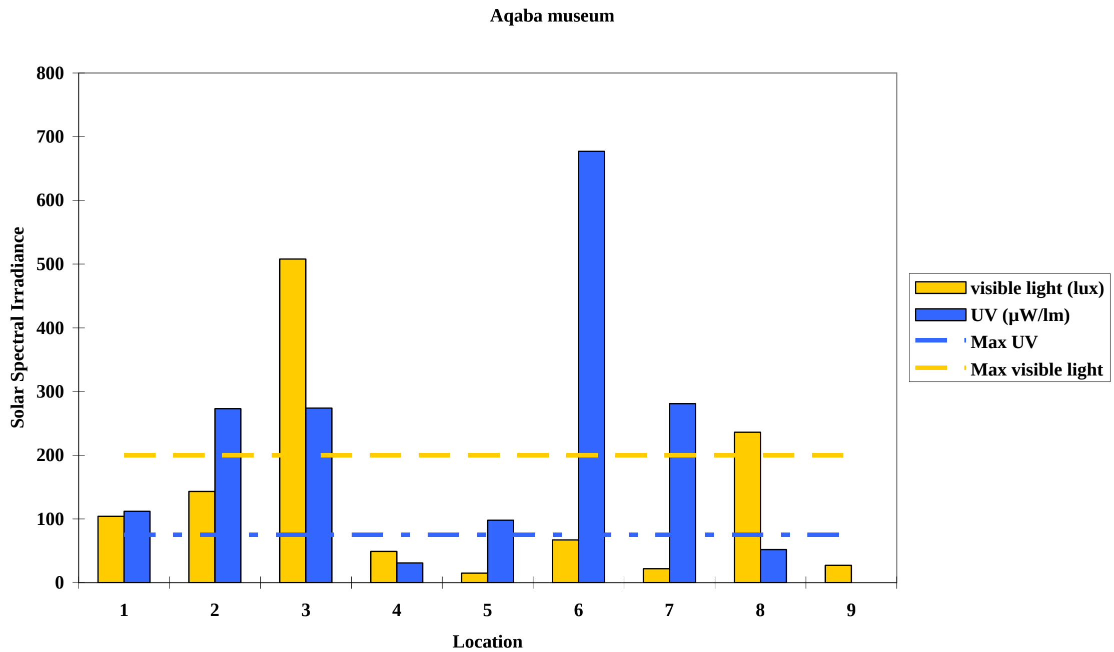

Figure 4.17 The average of the solar spectral irradiance readings at the Aqaba Museum within specific locations mentioned in Table 4.6.

Discussion

Based on the results it was found that for six of the nine locations the recommended levels for UV light were exceeded. For visible light, the recommended levels were only exceeded in two of the nine locations. The museum hosts a diversity of collection and has some coloured surface objects within its exhibition. Therefore, it is important to gain more knowledge on the coloured surfaces of the objects; hence, organic dyes are more sensitive to discoloration than inorganic dyes. This requires further study in the near future. Furthermore, it was found that the museum staff were not aware of the effects of UV light on the possible accelerated deterioration of especially organic materials. Although this museum holds a high number of inorganic materials, the number of organic artefacts cannot be ignored. Therefore, the found levels of UV light indoors have to be reduced. Both outdoor light and the types of light bulbs and spotlights used in this museum contain UV and have to be changed.

As the results for this museum show that only two out of the nine locations exceeded the recommended levels for visible light, it has to be questioned if the light management system is really functioning. In cases where low levels of visible light were found, the objects could hardly be seen. Improvement of the whole light management system is therefore recommended.

4.5.3 Archaeology Museum / University of Jordan

Based on the evaluation of the current lighting conditions at the Archaeology Museum the results were even worse than at the Ajloun museum. The Archaeology Museum depends mainly on two types of lighting:

- Natural daylight, which comes in through large windows, especially at the western façade of the museum.
- Tungsten lamps, which vary in intensity from 75 to 100 Watt. These are installed in all museum halls.

The light intensity measurements revealed that most of the tested light spots in this museum exceeded the UV radiations and visible light intensity recommended levels and in addition, all of the examined spotlights contained a high proportion of UV radiation. Although artificial lighting was used in this museum, it can be assumed that it depends mainly on natural light coming in from the large windows on the western sides of the façade for its light. In other words, the artificial lights were not in use at the time of measuring. Despite this, artificial lights were installed in the museum, either fixed on the ceiling or hung on the walls.

The results reveal that the museum does not provide adequate lighting intensity for its collection. In six of the seven investigated locations, visible light exceeded 200 Lux and in five of the seven locations, UV light intensity exceeded the recommended 75 µW/lm.

Table 4.7 gives a summary of the illumination in the museum. The seven locations where measurements were taken can be found in Table 4.8. This museum hosts in its custody various collections of glass, painted and transparent, silver, bronze and bead accessories, pottery, metallic objects, painted and unpainted bones and stone objects.

Figure 4.18 shows the averages of the UV radiations and visible light intensity readings at the six locations at the Archaeology Museum at the University of Jordan. The correlation between visible light and UV with their maximum allowable rates according to international guidelines (Thomson 1986) is also shown in this graph.

Table 4.7 The Archaeology Museum / University of Jordan

Museum type	Educational museum
Light sources	Natural light & tungsten lamps
Day light vs. artificial light	90% natural, 10% artificial
Type of collection	Bones, glass, accessories, pottery, stone

Table 4.8 Delineate the locations of the ELSEC 764 devices in the Archaeology Museum / University of Jordan

Location number	Description of location
1	First hall, towards the glass façade.
2	First hall, facing ceiling.
3	Second hall, opposite window.
4	Interior hall, facing ceiling.
5	Corridor, directed to the exhibition halls.
6	Corridor, entrance directed to the ceiling.
7	Corridor, opposite window.

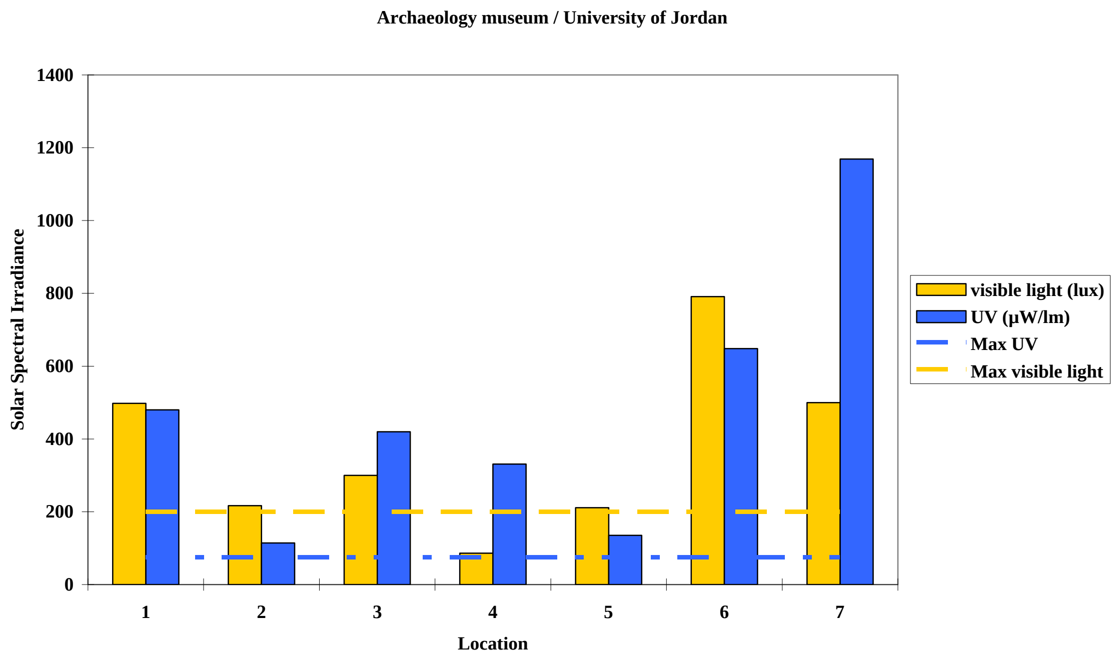

Figure 4.18 The average of the solar spectral irradiance readings at the Archaeology Museum within specific locations mentioned in Table 4.8.

Discussion

Measurements in all examined locations at the Archaeology Museum appear to have a proportion of UV light higher than the recommended 75 µW/lm. Moreover, it was the same case for the visible light at all but one monitored location, which was the interior hall. This museum depends mainly on daylight; it has a complete glass façade. In addition, the glass used in the windows is not UV-filtering and there are no curtains at the windows. Therefore, it was obvious that the results would have a high portion of both UV and visible light. According to the museum curator, who was in charge of renovating the museum in 2007, windows were not installed because of aesthetical purposes. Here we can state that in museum renovations aesthetical issues should not have priority. Priority should be given to the safety of the collection. This safety is only achievable though the provision of suitable environmental parameters, which do not lead to the degradation of the exhibited materials. Therefore, it is recommended that curtains be hung at all of the museum windows, in order to block the sunlight coming through. UV-free lamps are also recommended instead of the current ones.

4.5.4 Dar Alsaraya Museum

The Dar Alsaraya Museum was recently renovated, but surprisingly the museum installed unsuitable artificial lights. These lights comprised all types of light sources available in Jordan at the time. Based on the assessment of the illumination system, the results show that visible light was within the required range except in one location, where the measurement was taken under the effect of two light sources (natural light and incandescent lamps). As for UV radiation, however, the measurements reveal that the lights contained a high portion of UV light except for one case, where the measurement was taken at the end of a long hall far from any windows or artificial light.

Table 4.9 gives a summary of the lighting in the museum. The seven locations where measurements were taken can be found in Table 4.10. The objects at this museum include frescoes, ivory, painted pottery, painted and transparent glass, coins and other metallic objects.
The visible light readings show that the illumination levels exceeded the recommended levels inside the Ancient Periods Hall. The readings for UV light exceeded the recommended levels in five of the seven investigated spots. The highest proportion of UV light intensity was found in the Classical Periods Hall.
Figure 4.19 Presents the averages of the five readings of each of the investigated locations. The graph also demonstrates the correlation between visible light and UV with their maximum allowable rates according to international guidelines (Thomson 1986).

Table 4.9 The Dar Alsaraya Museum

Museum type	Archaeology museum
Light sources	Natural light, tungsten lamps & fluorescent lamps
Day light vs. artificial light	20% natural, 80% artificial
Type of collection	Numismatics, glass, accessories, pottery, fresco, ivory, bone

Table 4.10 Delineate the locations of the ELSEC 764 devices in the Dar Alsaraya Museum

Location number	Description of location
1	Ancient periods hall towards a wall
2	Ancient periods hall facing the ceiling
3	Inside showcase against a fluorescent lamp
4	Ancient periods hall against tungsten lamp
5	Classical periods hall towards the hall
6	Classical periods hall facing ceiling
7	Inside showcase

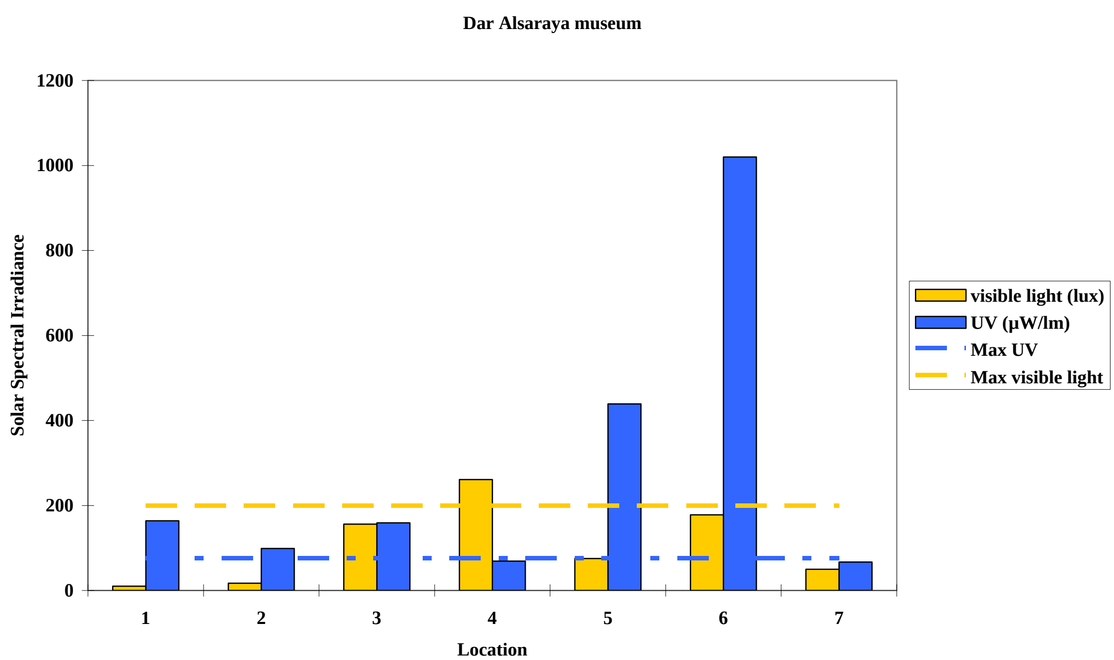

Figure 4.19 The average of the solar spectral irradiance readings at the Dar Alsaraya Museum within specific locations mentioned in Table 4.10.

Discussion

The main lighting problem at the Dar Alsaraya museum is the presence of high UV light intensity. It was found that in six of the seven monitored locations the levels of UV light exceeded the recommended 75 µW/lm. The museum building is an old historical castle, constructed from thick walls with a few small windows. This makes the museum dependent on artificial light for 80% of its illumination. The artificial lights installed in the museum are not adequate, because they provide the museum with high UV light intensity. Supplying the museum with UV filtered lamps can lessen the proportion of UV in the museum. Organic-based materials are at risk of degradation from exposure to high levels of UV (Thomson 1986) and although a high proportion of the objects in this museum are organic-based, the museum curator was not aware of this danger. If the management of the Dar Alsaraya Museum is willing to enhance the lighting in the museum, installing UV-free lamps in the museum halls and inside the showcases is recommended.

4.5.5 Folklore Museum

While evaluating the current lighting situation at the Folklore Museum, it became evident that, even though the displayed objects in this museum are susceptible to damage through unsuitable illumination, the lighting in this museum was difficult to manage. Two kinds of light sources were found at this museum:

- Natural daylight
- Incandescent lamps

As the results demonstrate, the UV radiation exceeded the recommended levels in most of the locations at the museum. Two sources of light were unfortunately unable to provide the museum with appropriate lighting. In the case of visible light, however, most of the readings were within a suitable range, except for one measurement, which was taken directly under an unfiltered tungsten spotlight. Table 4.11 gives a summary of the lighting system at the Folklore museum. In addition, the seven locations where measurements were taken can be found in Table 4.12. The objects at this museum are mainly organic-based materials such as textiles and furniture, which are very susceptible to damage through exposure to light.

Figure 4.20 is an interpretation of the data of the averages of the readings for all seven locations. The graph also shows the correlation between visible light and UV, with their maximum allowable rates according to international guidelines (Thomson 1986).

Table 4.11 The Folklore Museum

Museum type	History museum
Light sources	Natural light & tungsten lamps
Day light vs. artificial light	40% natural, 60% artificial
Type of collection	Textile, furniture, tent

Table 4.12 Delineate the locations of the ELSEC 764 devices in the Folklore Museum

Location number	Description of location
1	First hall, opposite door
2	First hall, facing ceiling
3	First hall, opposite window
4	First hall, against spot light
5	Second hall, facing ceiling
6	Second hall, opposite door
7	Third hall, facing ceiling

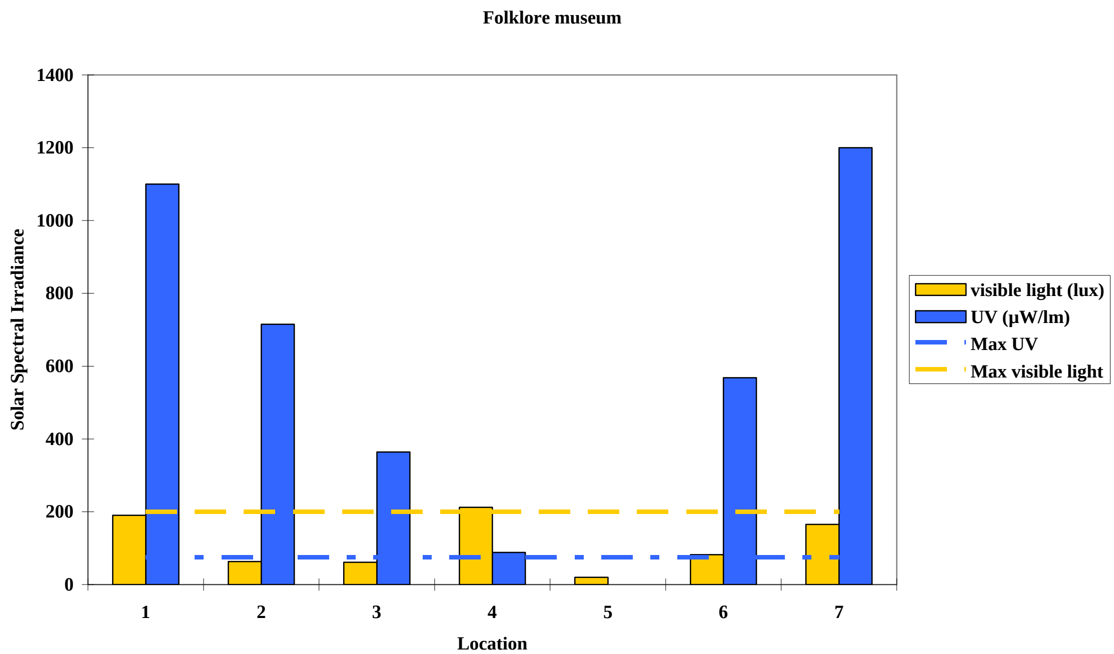

Figure 4.20 The average of the solar spectral irradiance readings at the Folklore Museum within specific locations mentioned in Table 4.12.

Discussion

The Folklore Museum depends on natural daylight coming through the main door and a few windows and on unfiltered tungsten lamps. Surprisingly, the results of the visible light intensity show that the 200 recommended Lux was not exceeded. In contrast, UV light surpassed the recommended 75 µW/lm (Thomson 1986) in all examined locations. The contrast between the UV and visible light results requires a further study in the near future. Extra attention should be paid to the lighting system, as the collection at this museum contains extremely fragile organic materials.

4.5.6 Jarash Museum

The results of the Jarash museum light intensity investigation confirm that natural daylight contributes a high proportion of the lighting in the museum. Moreover, the lighting system at the Jarash museum can be turned on and off manually. Therefore, levels of illumination are difficult to control. Three different light sources were found:

- Natural daylight coming through side openings.
- Incandescent lamps installed inside showcases and hung on the ceiling.
- Unfiltered tungsten-halogen spotlights hung on the ceiling and on the sidewalls.

The museum has different types of light sources, but these light sources overlap each other. Although the museum has large windows at the northern and western façades, which provide daylight sufficient for displaying objects, the artificial lights in the museum were left on continuously throughout the working hours. Table 4.13 indicates the lighting system in the museum. The six examined locations where measurements were taken can be found in Table 4.14.

The results of this study reveal that there was a high intensity of visible light in one spot located in the main hall. On the contrary, for UV light intensity it appears that five of the six examined locations were suffering from a high intensity of UV radiation. These

readings were taken in different lighting spots, which represent the natural and artificial lighting that is available in the museum.
The artefacts at this museum are mainly objects excavated from the site, such as gold, silver and bronze coins. Unpainted pottery, bones and some glass wares.
Figure 4.21 shows the averages of the readings, which were taken in six locations at the museum. The correlation between visible light and UV with their maximum allowable rates according to international guidelines (Thomson 1986) is also indicated in the same graph.

Table 4.13 The Jarash Museum

Museum type	Archaeology site museum
Light sources	Natural light, unfiltered tungsten-halogen spot lights and tungsten lamps
Day light vs. artificial light	70% natural, 30% artificial
Type of collection	Numismatics, glass, pottery, bones

Table 4.14 Delineate the locations of the ELSEC 764 devices in the Jarash Museum

Location number	Description of location
1	Main hall, facing ceiling
2	Main hall, inside show case
3	Main hall, opposite northern window
4	Main hall, opposite western window
5	Main hall facing ceiling
6	Opposite the entrance

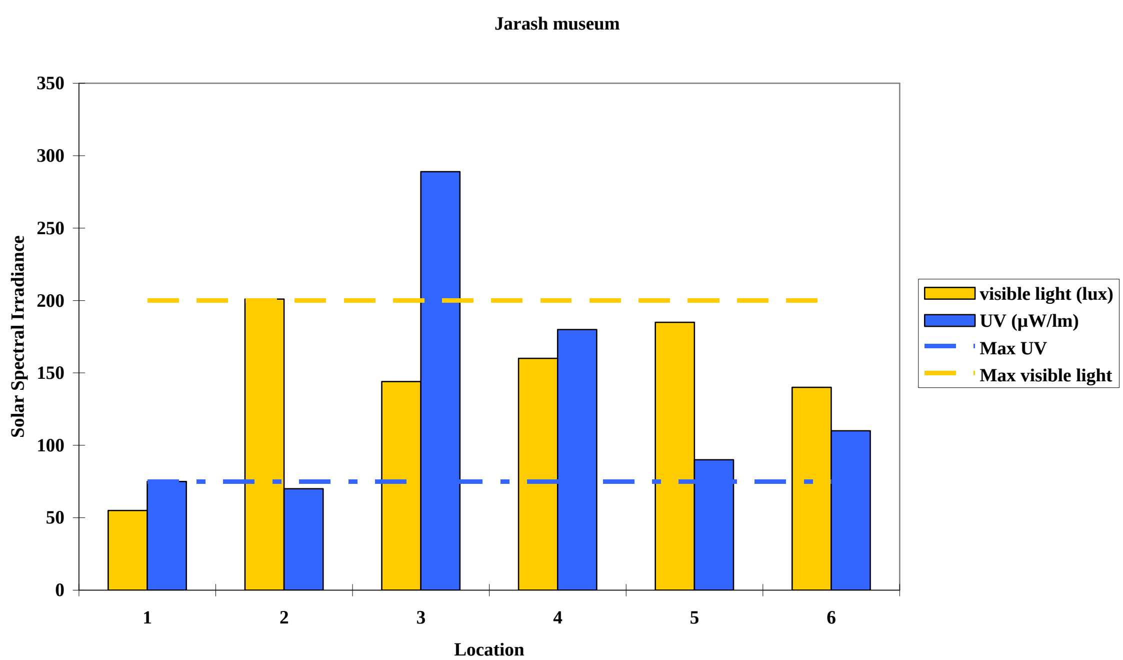

Figure 4.21 The average of the solar spectral irradiance readings at the Jarash Museum within specific locations mentioned in Table 4.14.

Discussion
The Jarash Museum has different types of artificial light lamps installed in its halls and showcases. However, the museum depends on natural daylight coming though the main door and windows for 70% of its lighting system. The main display hall at this museum has many windows in the upper part of the walls. Nevertheless, the visible light at the measured locations did not exceed 200 Lux. On the contrary, the results for UV light measurements reflect the high quantity of UV radiation, which exceeded 75 µW/lm in four of the six locations. The Jarash museum is an archaeological site museum and therefore most of the displayed objects are excavated from the same site. These excavated objects are usually immune to light destruction. However, the museum has some objects, which are sensitive to light, for example bones (Kuhn 1986). Since the main lighting source for the museum is the side windows, it is vital that these be fitted with curtains. In addition, the tungsten lamps should be changed to UV-free lamps.

4.5.7 Jordan Museum of Popular Traditions

After measurements were taken at the Jordan Museum of Popular Traditions, the light intensity was evaluated. This evaluation shows that the light in this museum was not controlled. Three types of light sources were found:

- Natural daylight
- Fluorescent lamps
- Incandescent lamps

These three sources overlapped each other. Although UV-free fluorescent lamps accelerate the degradation of most organic-based materials, surprisingly fluorescent lamps were used inside the showcases. This type of light has a high level of visible light and a large proportion of UV (Thomson 1986). The intensity of the fluorescent lamps installed inside the showcases could not be discovered, as the staff present was unable to provide any further information on the types or intensities of the lights used. The results of the measurements at this museum reveal that there was high intensity of visible light in two of the measured spots. These locations are in the fist display hall, one inside a showcase and another facing an incandescent lamp. The results also show a high level of UV in three locations, which all had different types of lights. However, some measurements for the same light source in different locations gave different light intensities. This may prove that the museum used different types of incandescent lamps without determining which are the most suitable. Table 4.15 gives a summary of the lighting system at the Jordan Museum of Popular Traditions. The seven locations where measurements were taken can be found in Table 4.16. In this museum, most objects on display are physically vulnerable to light, for instance textiles, cloth, accessories and wooden objects.
Figure 4.22 gives the averages of all the readings on the same day in all seven locations. The correlation between visible light and UV with their maximum allowable rates according to international guidelines (Thomson 1986) can also be found in the same graph.

Table 4.15 The Jordan Museum of Popular Traditions

Museum type	Ethnography museum
Light sources	Natural light, tungsten lamps & fluorescent lamps
Day light vs. artificial light	80% natural, 20% artificial
Type of collection	Textile, cloth, accessories, wood

Table 4.16 Delineate the locations of the ELSEC 764 devices in the Jordan Museum of Popular Traditions

Location number	Description of location
1	First hall, inside showcase
2	First hall, facing ceiling
3	First hall, against incandescent light lamp
4	Second hall, facing ceiling
5	Second hall, opposite door
6	Third hall, against spot light
7	Third hall, facing ceiling

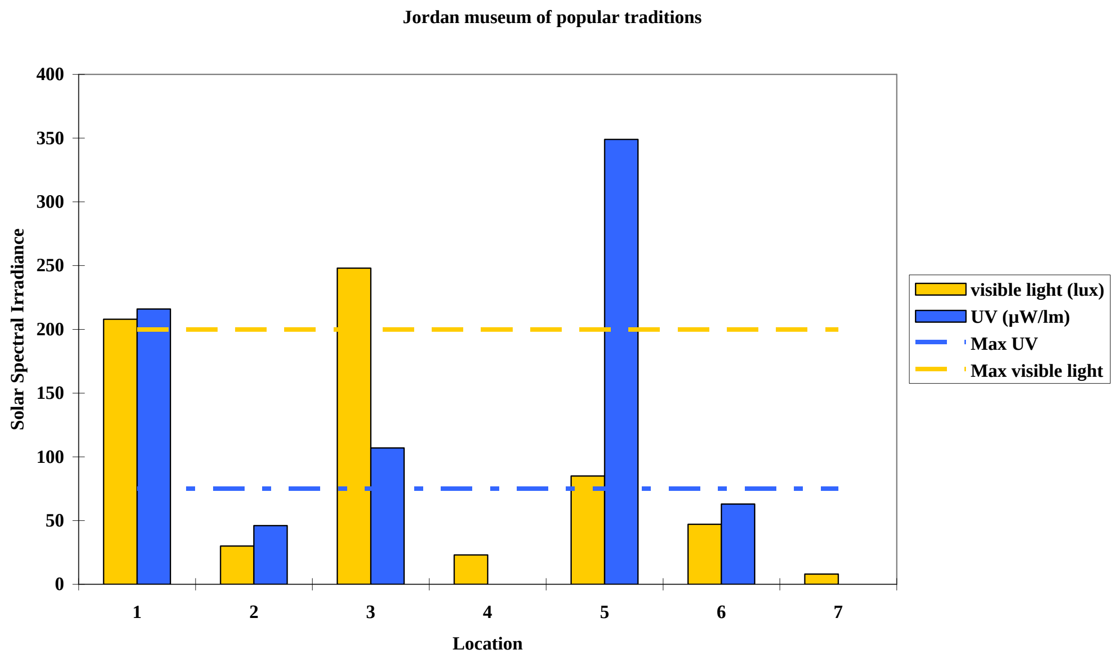

Figure 4.22 The average of the solar spectral irradiance readings at the Jordan Museum of Popular Traditions within specific locations mentioned in Table 4.16.

Discussion

Based on the results it was found that UV light at three of the seven examined spots exceeded the recommended levels according to Thomson (1986) and Kuhn (1986). The case is similar regarding visible light radiation, as this exceeded the recommended level in two of the seven examined locations. The museum displays many organic-based objects and therefore light is an important element to be controlled if the museum is willing to safeguard its collection. The museum curator seems unwilling to make any changes at the moment. The Jordan Museum of Popular Traditions at least needs to install curtains, before a full improvement of the whole light management system is considered.

4.5.8 Jordan National Gallery of Fine Arts

Based on the evaluated results of the illumination at the Jordan National Gallery of Fine Arts, it appears that this museum is the best-lit museum in Jordan, regarding light intensity measurements. The museum depends mainly on filtered spotlights in the display halls and often on natural daylight, which is available through a few side openings. The results reveal that the light intensity slightly exceeds 200 Lux in several

places in both display floors. As for the UV measurements, results were non-existent except for a few instances, where the measurements were taken in the entrance hall of the museum and near the window on the first floor.
Table 4.17 gives a summary of the lighting system at the museum. The 16 locations where measurements were taken can be found in Table 4.18. This museum mainly displays artistic objects such as paintings, drawings and some ceramics, many of them with highly vulnerable materials.
Figure 4.23 shows the averages of the readings at the examined locations. The correlation between visible light and UV with their maximum allowable rates according to international guidelines (Thomson 1986) is also shown in the same graph.

Table 4.17 The Jordan National Gallery of Fine Arts

Museum type	Art museum
Light sources	Natural light & tungsten lamps
Day light vs. artificial light	10% natural, 90% artificial
Type of collection	Paintings

Table 4.18 Delineate the locations of the ELSEC 764 devices in the Jordan National Gallery of Fine Art

Location number	Description of location
1	Ground floor/first hall, against spot light
2	Ground floor/first hall, facing ceiling
3	Entrance hall opposite main door
4	First floor, against spot light
5	First floor, far corner, facing ceiling
6	Entrance hall, opposite main door
7	First hall, facing window
8	First hall, facing ceiling
9	First hall, against spot light
10	Second hall, facing ceiling
11	First floor, facing ceiling
12	First floor, beside window facing ceiling
13	First floor, opposite window
14	Middle hall, facing ceiling
15	First floor/middle hall, facing ceiling
16	First floor/interior hall, facing ceiling

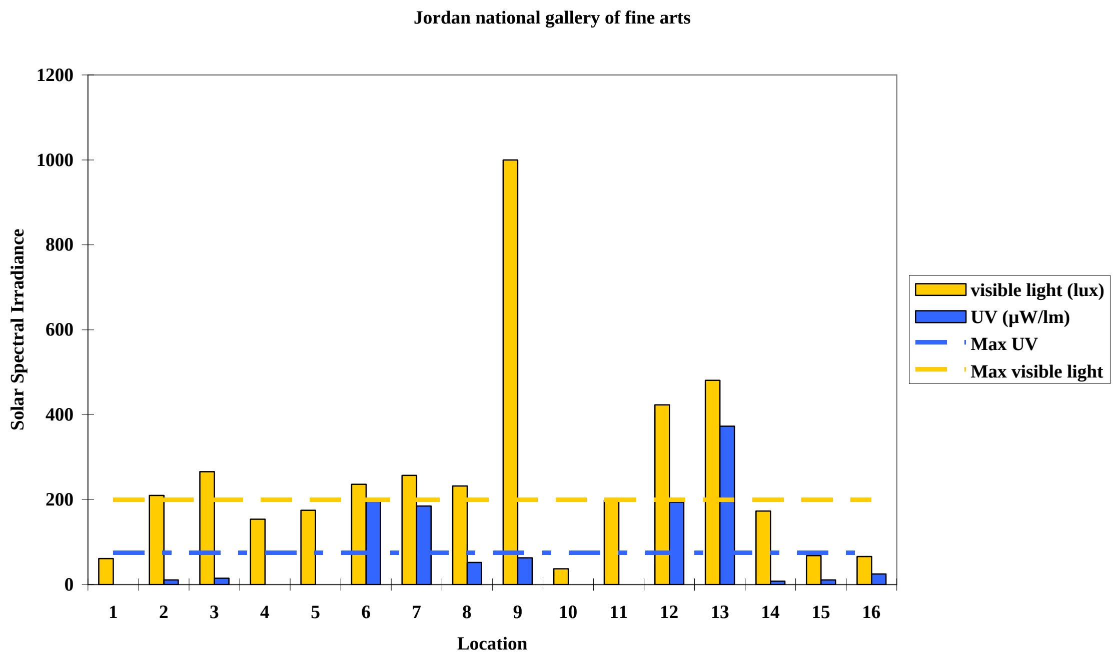

Figure 4.23 The average of the solar spectral irradiance readings at the Jordan National Gallery of Fine Arts within specific locations mentioned in Table 4.18.

Discussion

Except for the main entrance door on the ground floor and one window on the first floor, the Jordan National Gallery of Fine Arts does not have any side openings. Therefore, it can be assumed that the museum depends on artificial lighting for at least 90% of its light. The results of the examination of light intensity confirm that the installed tungsten spotlights are UV-filtered, albeit in differing amounts. The results also reveal that these spotlights are of different intensities. Although they are UV-free, the spotlights provide the museum with a high intensity of visible light. This was confirmed at eight of the 14 examined locations. However, four of the eight locations were measuring natural daylight. In other words, at the four locations where artificial light was measured, the intensity exceeded 200 Lux. This can be explained, as either there are two different types of spotlights installed in the museum, or natural daylight and artificial light overlap at some spots. The Jordan National Gallery of Fine Arts is an art museum and it exhibits paintings and drawings, which are highly susceptible to damage through unsuitable lighting. Some of the staff at the museum is aware of this danger. The results show that the museum's only window allows a high intensity of both UV and visible light into the building. It is therefore recommended that this window be closed permanently. As a remedial procedure, hanging thick curtains would lessen the light intensity. It is also recommended that all the spotlights be checked to ascertain whether they are of the same type and whether they provide the same filtration capability.

4.5.9 Museum of Jordanian Heritage / Yarmouk University

The light sources at the Museum of Jordanian Heritage were not vastly different to those at the other museums. The museum has three types of light sources:

- Natural daylight

- Incandescent light
- Fluorescent light which has been added recently

The results of the measurements at this museum reveal that in some display halls, the light luminance was within the recommended levels, but in other places, the levels were too high. The UV radiation was too high at most of the museum locations. Alarmingly, a high proportion of visible light was recorded in the hall of the Peasant House, which displays materials most vulnerable to light. UV light exceeded the recommended levels in three places in the first and second halls.

Table 4.19 shows a summary of the lighting system in the Museum of Jordanian Heritage, while the eight locations where measurements were taken can be found in Table 4.20. The Museum of Jordanian Heritage owns a semi-comprehensive collection, which includes textiles, cloth, furniture, metal, glass, bone, pottery, maps, pictorials and wooden objects.

Figure 4.24 shows the averages of the readings at the eight examined locations. The amounts of visible light and UV can also be found here. The maximum allowable rates according to international guidelines (Thomson 1986) are also shown in this graph.

Table 4.19 The Museum of Jordanian Heritage / Yarmouk University

Museum type	Educational museum
Light sources	Natural light, tungsten lamps & fluorescent lamps
Day light vs. artificial light	40% natural, 60% artificial
Type of collection	Numismatics, glass, accessories, pottery, mosaics, maps, pictures, lead, wood, basketry, furniture

Table 4.20 Delineate the locations of the ELSEC 764 devices in the Museum of Jordanian Heritage / Yarmouk University

Location number	Description of location
1	First hall, inside showcase
2	First hall, inside showcase
3	Entrance, facing ceiling
4	Middle Hall facing ceiling
5	Peasant house, opposite incandescent lamp
6	Second hall facing ceiling
7	Court yard facing day-light roof
8	Peasant house facing ceiling

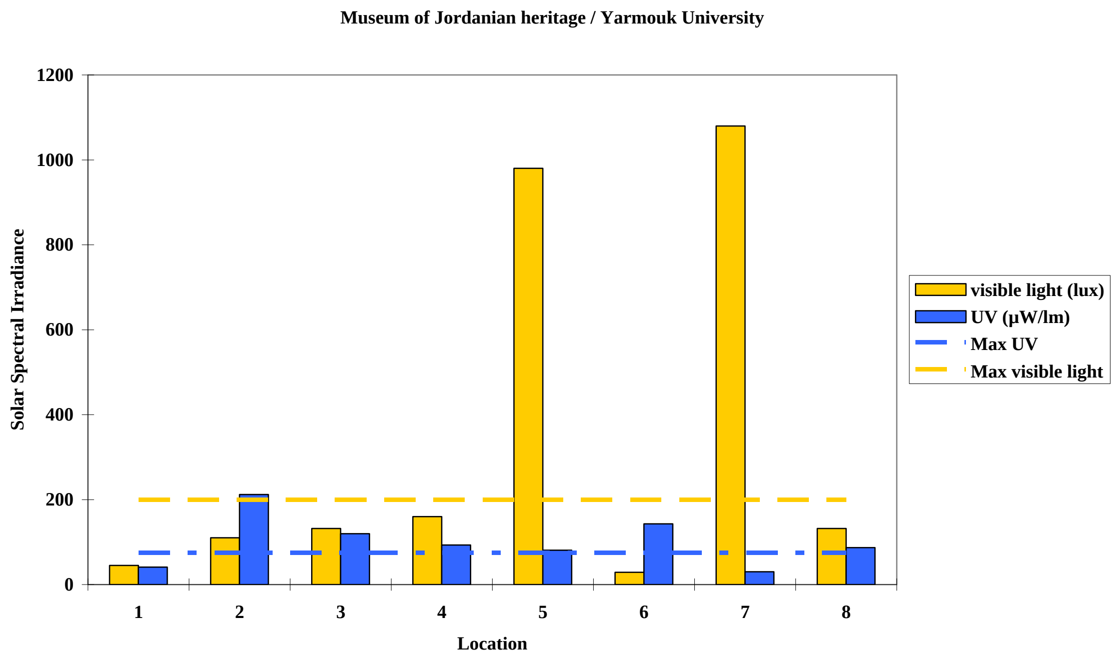

Figure 4.24 The average of the solar spectral irradiance readings at the Museum of Jordanian Heritage within specific locations mentioned in Table 4.20.

Discussion

The lighting system at the Museum of Jordanian Heritage was updated in 2007. However, the changes were limited to installing fluorescent lamps on the walls of the halls and inside showcases. The installation of fluorescent lamps not only causesaesthetical disturbance , but also lighting quality. On the one hand, visitors can see the exhibited objects more clearly now, but was the safety of the objects considered? The management team at the time examinations were made, had none of the necessary knowledge required to protect the collection from deterioration[1]. Because the museum exhibits a semi-comprehensive collection, materials, which are susceptible to damage through high light intensity, cannot be ignored. The results reveal that the fluorescent lamps installed provide the museum with high levels of UV and visible light. Therefore replacing the existing lamps with UV-free bulbs is necessary. In addition, the courtyard, which is located in the middle of the museum, has the highest intensity level of all examined locations. The courtyard has a sky-light roof. The radiation through the translucent insulation glass into the roof is absorbed by the indoor walls and floors. The heat flows directly into the solid construction of the building, where it is stored by the mass of the bricks. In other words, besides fitting new fluorescent lamps, the ceiling of the courtyard is another unsuitable source of light, which should be dealt with.

4.5.10 The National Heritage Museum / University of Jordan

The National Heritage Museum consists of one large hall which has windows along the eastern side and which is additionally lit by:

- Fluorescent lamps
- Incandescent lamps

[1] The museum curator was so naive as when I discussed with him about the damage caused by light, he remarked in a cynical tone: “What kind of damage can light cause to displayed objects?”.

Based on the assessment results of the lighting methods and equipment at this museum, it appears that light in the National Heritage Museum exceeds the recommended levels in a few of the examined locations. In addition, the results of the measurements at this museum show that where the ELSEC 764 devices were oriented towards a direct light source, high amounts of light intensity and UV were recorded, whereas where devices were oriented towards a non-lit location, adequate results were found.
Table 4.21 summarizes the lighting system in this museum. The four locations where measurements were taken can be found in Table 4.22. The collection of the Museum of National Heritage includes cloth, textiles, basketry and furniture, which are all of high vulnerability to damage through high amounts of illumination and UV light.
Figure 4.25 gives the averages of the readings at the four locations. The correlation between visible light and UV with their maximum allowable rates according to international guidelines (Thomson 1986) is also represented in the same graph.

Table 4.21 The National Heritage Museum / University of Jordan

Museum type	Educational museum
Light sources	Natural light, tungsten lamps & fluorescent lamps
Day light vs. artificial light	60% natural, 40% artificial
Type of collection	Textile, basketry, furniture, cloth

Table 4.22 Delineate the locations of the ELSEC 764 devices in the National Heritage Museum

Location number	**Description of location**
1	Main hall, against incandescent light lamp
2	Main hall, facing ceiling
3	Towards display hall
4	Main hall, opposite window
5	Main hall, against incandescent lamp

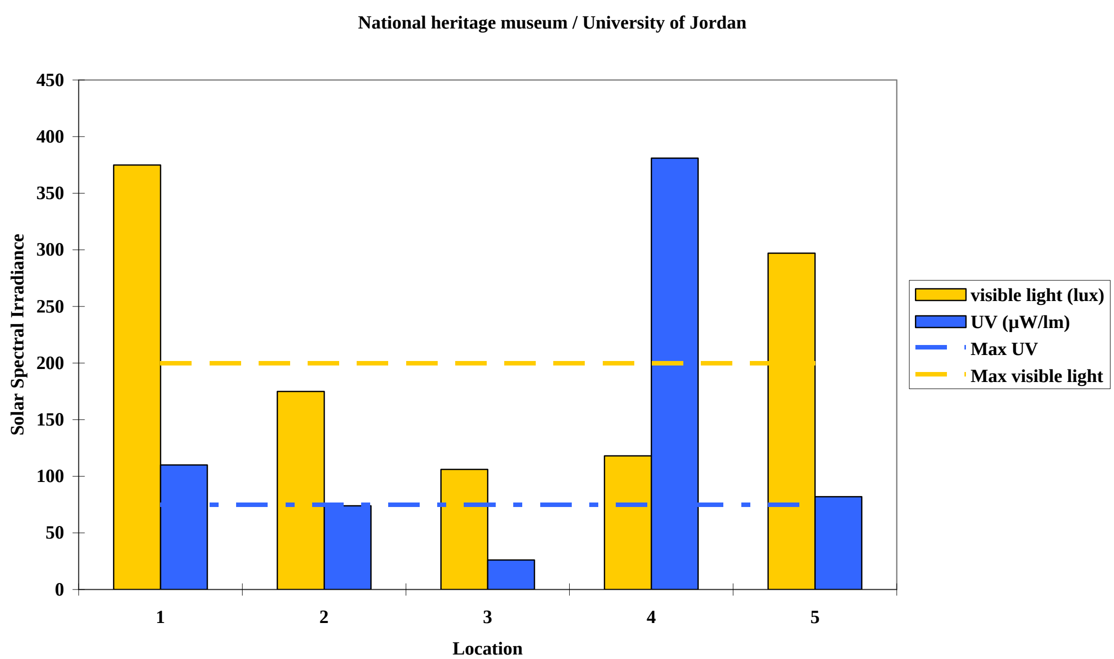

Figure 4.25 The average of the solar spectral irradiance readings at the National Heritage Museum within specific locations mentioned in Table 4.22.

Discussion

While investigating the lighting system at the National Heritage Museum, it was evident that the museum depends on different illumination sources. Moreover, it was clear that these sources overlap. Despite this, an attempt was made to investigate the light sources separately. The museum is rectangular in shape. It has many windows along the top of the eastern and western walls. These windows do not have any curtains or blinds. Therefore, daylight streams through the windows into the museum all day long. Furthermore, the museum has artificial lights, which are switched on during working hours. The type of artificial light installed in the museum varied; some were fluorescent and others were tungsten. When the ELSEC 764 device was directed towards the windows, the results show a high intensity of UV light and an average intensity of visible light. When the device was directed towards an artificial light, tungsten, or fluorescent, the results show an intensity of visible light higher than the recommended 200 Lux and intensity in UV light slightly higher than the recommended 75 µW/lm (Thomson 1986). Although the light sources overlapped, the museum has inadequate illumination in most of the investigated spots, which were directly at one of the light sources in the museum. The collection at this museum mostly consists of organic-based material and these are most susceptible to damage through high levels of light intensity. Improvement of the entire light management system is therefore recommended.

4.5.11 Natural History Museum / Yarmouk University

At the Natural History Museum, light was measured in several locations. The light sources at this museum are:

- Fluorescent lamps
- Natural daylight in the entrance hall

The museum depends mainly on fluorescent lamps for light, except for the area near the main entrance. Some of the fluorescent lamps are hung on the ceiling, while others are installed inside the showcases. Based on the assessment results of the lighting methods and equipment of this museum, it appears that light represents a challenging issue to the Natural History Museum. Although the museum exhibits a vulnerable collection, it appears that the museum suffers from unsuitable illumination in all the examined locations.

Table 4.23 gives a summary of the lighting system at the museum. The five examined locations where measurements were taken can be found in Table 4.24. The collection in this museum includes stuffed wild animals, birds and insects. At most investigated locations it was noticed that the visible light intensity exceeded the recommended level of 200 Lux. For UV, higher results were obtained more frequently.

The averages of the readings of the five locations are shown in Figure 4.26. The correlation between visible light and UV with their maximum allowable rates according to international guidelines (Thomson 1986) is also shown.

Table 4.23 The Natural History Museum / Yarmouk University

Museum type	Educational museum
Light sources	Natural light & fluorescent lamps
Day light vs. Artificial light	10% natural, 90% artificial
Type of collection	Stuffed animals

Table 4.24 Delineate the locations of the ELSEC 764 devices in the Natural History Museum / Yarmouk University

Location number	Description of location
1	Main hall against fluorescent light lamp
2	Second hall inside a showcase
3	Inside showcase against fluorescent light lamp
4	Main hall facing ceiling
5	Main hall towards the wall

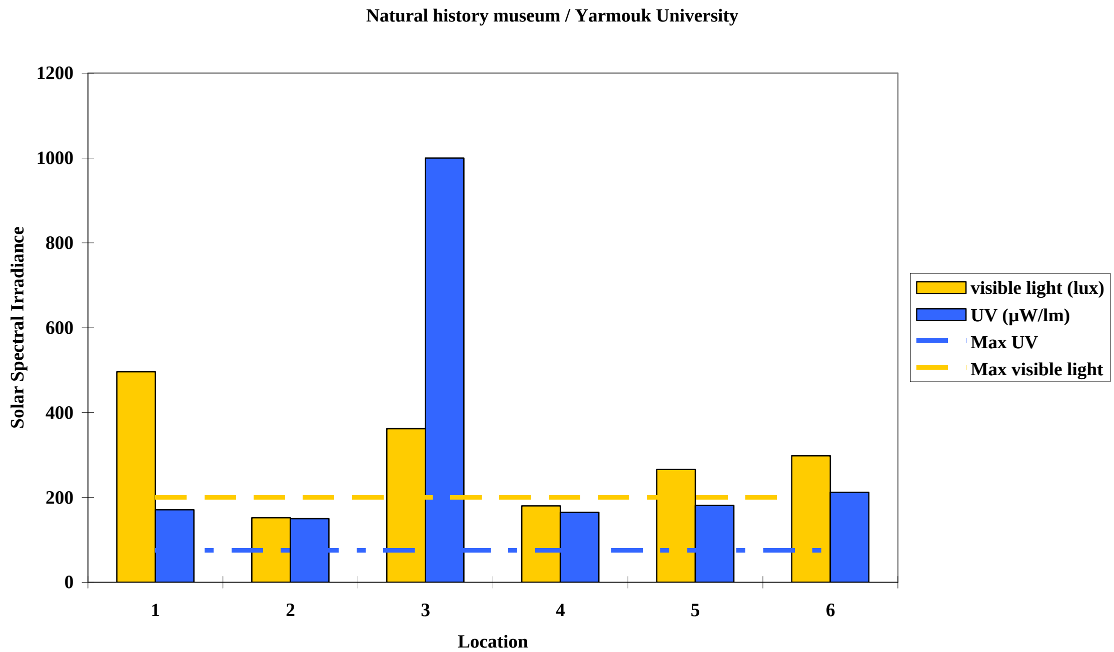

Figure 4.26 The average of the solar spectral irradiance readings at the Natural History Museum within specific locations mentioned in Table 4.24.

Discussion

The light at the Natural History Museum comes from two sources:

- Natural daylight, which comes in through the main entrance door. This light source is only available in the main entrance hall. This source was taken into consideration because there are some objects displayed at that particular area.
- Artificial light, from fluorescent lamps, which cover almost all the ceiling.

This museum exhibits a collection consisting of stuffed animals, which are susceptible to damage through high light intensity. All the examined locations showed high UV light intensity. Moreover, four of the six examined locations appear to have a high intensity in visible light as well. Objects displayed at this museum are therefore subject to degradation constantly. The degradation rate was not visible at the period of investigation and the museum curator was not convinced that the collection is under the threat of degradation because of unsuitable light. The Natural History Museum depends on artificial lights for nearly 90% of its light and so a full modification of the lighting system in the museum and the elimination of the current fluorescent lamps as soon as possible, is recommended.

3.5.12 Petra Museum

In spite of the importance of the archaeological site of Petra, the Petra museum does not perform an equivalent importance. The museum consists of three display halls. For light, this museum depends mainly on natural daylight, but despite the sufficient luminance coming from windows, the museum also uses artificial lights. These artificial lights were:

- Fluorescent lamps.
- Incandescent lamps. The intensity of these lamps varies from 75 to 100 Watt.

The results of the measurements at this museum reveal that in most display halls the visible light luminance was within the recommended levels, except for one location where the ELSEC 764 device was facing a fluorescent lamp. The UV radiation was high in six of the investigated locations at the museum, especially in the third hall, which was lit solely by fluorescent lamps.

Table 4.25 gives a summary of the lighting system at the museum. The eight locations where measurements were taken can be found in Table 4.26. This museum mainly exhibits artefacts excavated at the Petra archaeological site, such as coins, bones and pottery.

Figure 4.27 shows the averages of the readings of the eight locations. The correlation between visible light and UV with their maximum allowable rates according to international guidelines (Thomson 1986) is also shown.

Table 4.25 The Petra Museum

Museum type	Archaeological site museum
Light sources	Natural light, fluorescent lamps &tungsten lamps
Day light vs. artificial light	30% natural, 70% artificial
Type of collection	Numismatics, stone, pottery, mosaics

Table 4.26 Delineate the locations of the ELSEC 764 devices in the Petra Museum

Location number	Description of location
1	First hall, facing ceiling
2	First hall, opposite window
3	First hall, against incandescent light lamp
4	Second hall, facing ceiling
5	Second hall, towards display area
6	Second hall, towards display area
7	Second hall, against spot light
8	Third hall, facing ceiling
9	Third hall, against fluorescent light lamp

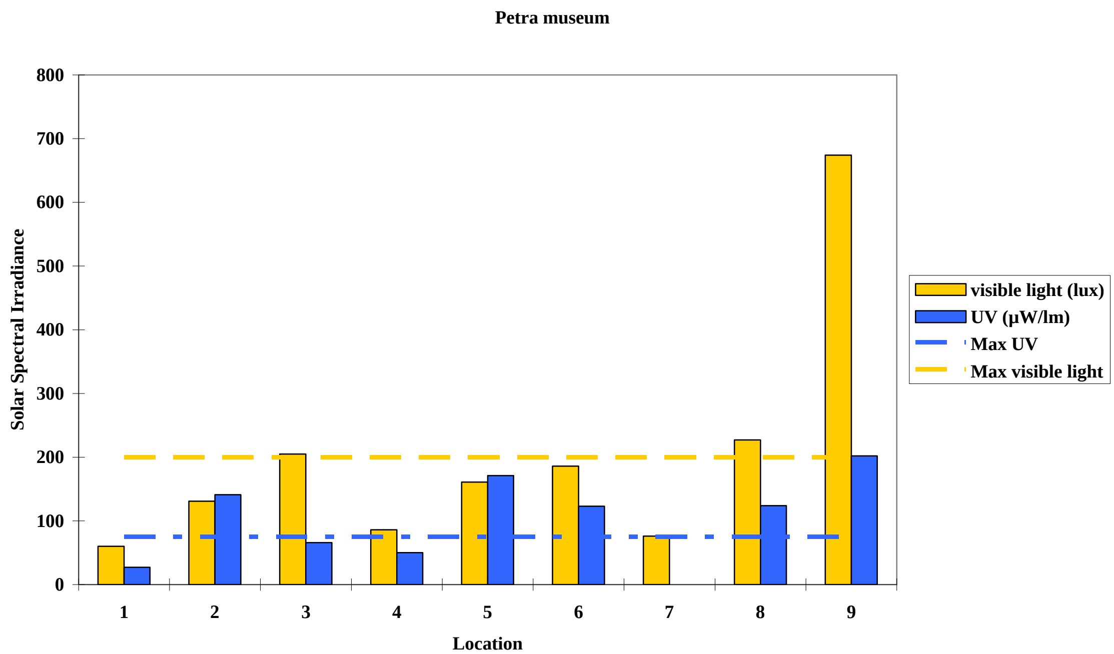

Figure 4.27 The average of the solar spectral irradiance readings at the Petra Museum within specific locations mentioned in Table 4.26.

Discussion

Petra Museum depends on both natural and artificial lighting, as it has a small side window at the western façade of the museum in the main hall and another window on the western wall of the mosaics hall. Although Petra City is located in a severe geographical location, which is hot for most days of the year, the museum windows are not covered with curtains or blinds and in addition, they have transparent glass. The artificial light is from fluorescent and tungsten lamps, which are both not UV-filtered. This was proved by the results. The results show that there was a high UV light intensity at all the measured locations, no matter the direction of the device. As for the visible light intensity, the results reveal that the recommended 200 Lux was exceeded in three of the nine measured spots. We can assume here that the lighting system at this museum is not favourable, according to the international recommendations of museum lighting (Thomson 1986). It is noteworthy that the device in all three locations was directed towards artificial light. The Petra Museum is an archaeological site museum and therefore its collection consists mainly of discoveries from the Petra site. These objects are not so vulnerable to high light intensity, although the display cases, which are made of painted wood, are at risk. If there were a plan to enhance the museum collection, there would be a need for modifying the lighting system at this museum.

4.5.13 Salt Museum

The lighting in the Salt Museum was provided by two means:

- Natural daylight
- Incandescent lamps (normal tungsten lamps and spot lights)

The interior of the Salt museum was renovated in 2006 by the Royal Embassy of the Netherlands and therefore the lighting system was changed. All of the display halls at this museum have windows. Some of these windows have curtains and others do not. Tungsten spotlights were used in the museum halls. The results show that these spotlights did not contain UV filters, because there was a portion of UV radiation in the results for these spotlights. Furthermore, it was obvious that there were two types of tungsten lamps used in the museum, as some of the investigated lamps appear to have a high portion of visible and UV light. Other than that, the results show that when an ELSEC 764 device was pointed towards a window, there was a presence of high UV radiation.

The averages of the readings of the eight locations within the Salt museum are shown in Table 4.27. This museum combines different materials in its collection, such as coins, glass, pottery and accessories. The 14 locations where measurements were taken can be found in Table 4.28.

Figure 4.28 shows the averages of the readings of the eight locations. The graph also presents the correlation between visible light and UV with maximum allowable rates according to international guidelines (Thomson 1986).

Table 4.27 The Salt Museum

Museum type	Archaeological museum
Light sources	Natural light & tungsten lamps
Day light vs. artificial light	30% natural, 70% artificial
Type of collection	Numismatics, glass, accessories, pottery, stone, accessories

Table 4.28 Delineate the locations of the ELSEC 764 devices in the Salt Museum

Location number	Description of location
1	Ground Floor. First hall, against spot light lamp
2	Ground Floor. First hall, opposite window
3	Ground Floor. First hall, against spot light lamp
4	Ground Floor. Second hall, against spot light lamp
5	Ground Floor. Second hall, opposite window
6	Ground Floor. Second hall, against spot light lamp
7	Ground Floor. Third hall, against tungsten lamp
8	1st Floor. First hall, opposite south window
9	1st Floor. First hall, opposite west window
10	1st Floor. First hall, against spot light lamp
11	1st Floor. First hall, against spot light lamp
12	1st Floor. Second hall, opposite east window
13	1st Floor. Second hall, facing ceiling
14	1st Floor. Second hall, under spot light lamp

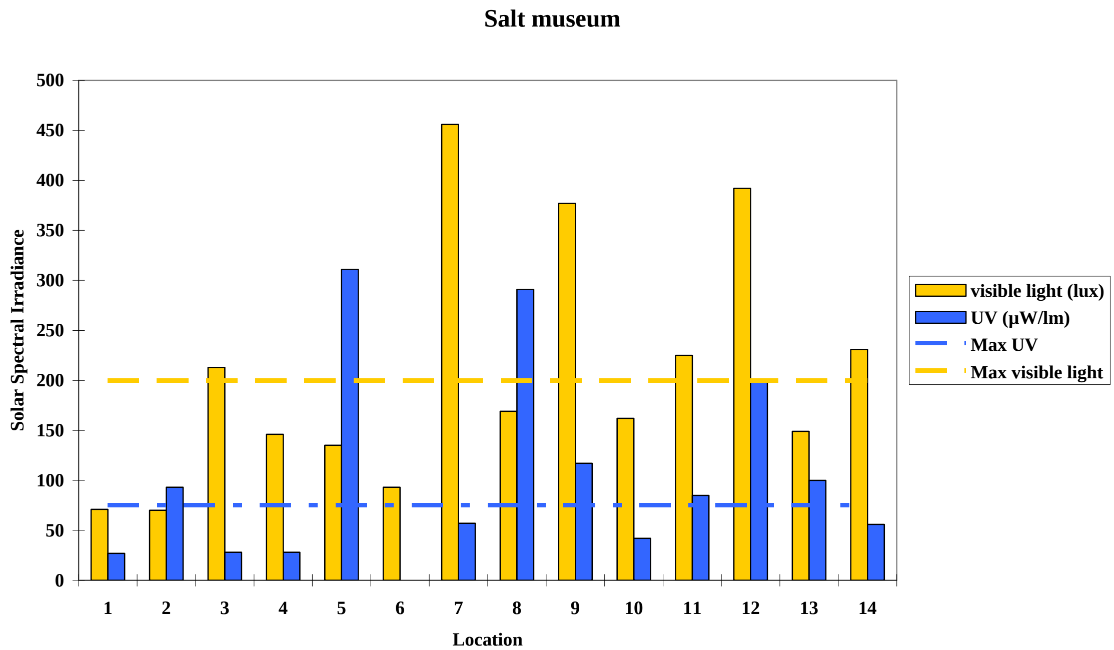

Figure 4.28 The average of the solar spectral irradiance readings at the Salt Museum within specific locations mentioned in Table 4.28.

Discussion

The Salt museum depends mainly on artificial lights, most of which are tungsten lamps. Six of the 14 examined locations have a higher proportion of visible light than the recommended 200 Lux, while seven of the monitored locations appear to have a high intensity of UV light. It was also noticed that the locations, which have a high intensity of visible light do not have inevitably high UV, light levels. The museum has big walls, especially at the southern façade of the building. The windows here are exposed to sunlight almost all day long. These windows have curtains, but these curtains do not adequately block the sunlight, because they are smaller than the size of the window. In spite of the fact that the museum was recently renovated, it seems that the renovations were not in line with the international standards for museums. Therefore, there is a vital need to install new curtains that are capable of preventing any sunlight coming through.

In terms of artificial light, the used artificial lights were non-UV lamps except in one location, at which I may assume that a non-filtered tungsten lamp was used. Therefore, I recommend continuing using the installed UV filtered lamps.

4.5.14 The Umm Qeis Museum

After measurements were taken at the Umm Qeis museum, the light intensity was evaluated. Light at the Umm Qeis Museum, was provided by:

- Natural daylight
- Fluorescent lamps

There were fluorescent lamps in each of the display halls and these lights were on even during the day when natural light could have sufficed. Therefore, light in the museum halls overlapped. This explains the high proportion of UV radiation at all the examined spots in the museum. The results also show that in the measurements taken in daylight the visible light intensity exceeded the recommended levels in two locations, in the main hall and in the sculpture hall. However, the results of the UV light measurements show that the intensity of UV light exceeded the recommended 75 µW/lm (Thomson 1986) in all examined locations.

Table 4.29 summarizes the lighting system at the museum. The six locations where measurements were taken can be found in Table 4.30. As a site museum, the Umm Qeis museum displays artefacts found in the excavations of the Umm Qeis archaeological site. Objects on display include pottery, silver, bronze and bead accessories and stone objects.

Figure 4.29 shows the averages of the readings of the six locations. The correlation between visible light and UV with their maximum allowable rates according to international guidelines (Thomson 1986) is also presented in the same graph.

Table 4.29 The Umm Qeis Museum

Museum type	Archaeological site museum
Light sources	Natural light & fluorescent lamps
Day light vs. artificial light	70% natural, 30% artificial
Type of collection	Stone, accessories, pottery, mosaics

Table 4.30 Delineate the locations of the ELSEC 764 devices in the Umm Qeis Museum

Location number	**Description of location**
1	Sculptures hall, opposite main door
2	Inside hall, against fluorescent light lamp
3	First hall, opposite closed door hung on the top of it a fluorescent light lamp
4	Second hall, towards display hall
5	First hall, facing ceiling
6	Second hall, facing ceiling

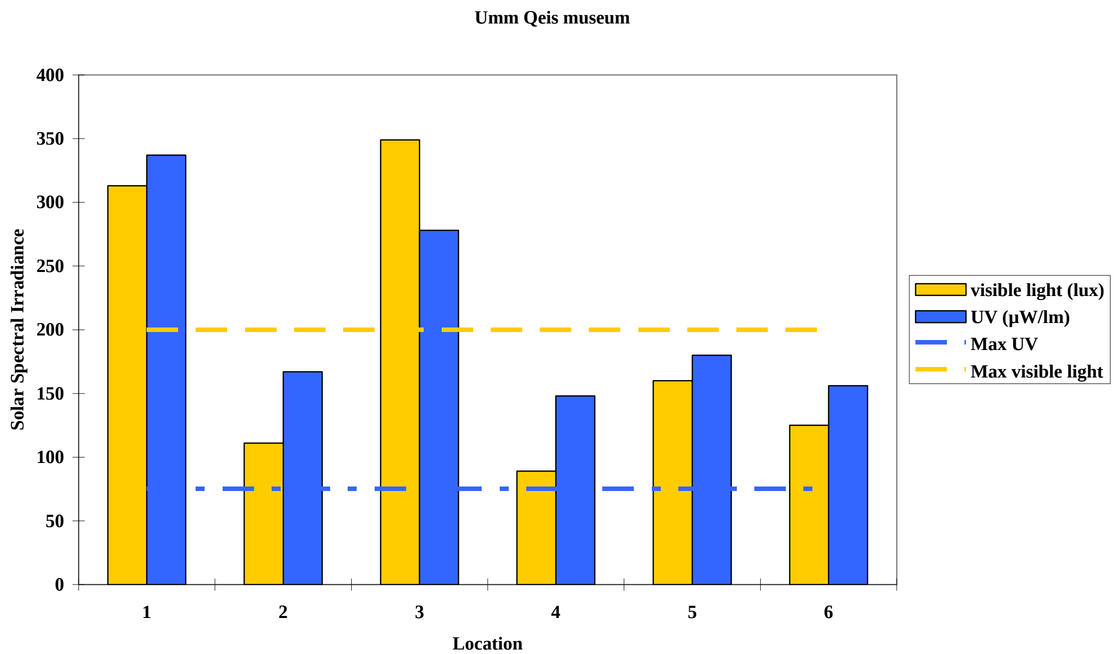

Figure 4.29 The average of the solar spectral irradiance readings at the Umm Qeis Museum within specific locations mentioned in Table 4.30.

Discussion

Based on the results, it was found that all the examined locations were exceeding the recommended 75 µW/lm for UV light. For visible light, only two of the six locations exceeded the recommended 200 Lux. The museum mainly depends on the natural daylight coming through the doors and windows that are opened during working hours to light the objects on display. The Umm Qeis Museum is located within the campus of the archaeological site, therefore it exhibits finds from the excavation of the same site. Although this museum holds a high collection of inorganic materials, the number of organic artefacts cannot be ignored. Therefore, the found levels of UV light intensity indoors have to be reduced. It was also found that in addition to natural light, the fluorescent lamps also contained UV and have therefore to be changed for less UV producing illuminants.

4.6 General discussion

Light is an important element in a museum environment, both as a direct damage source, or as a main preservation factor. In spite of the importance of light in the preservation of museum objects, the results confirm that it has been largely neglected in the selected Jordanian museums.

It is remarkable that proper light management in the examined museums is fully ignored, except in the Art Gallery. Sometimes low UV types of lighting were found in showcases. However, the responsible staff often added high UV-containing halogen lamps, as the objects could hardly be seen under the original illumination. This indicates that not only should light management be improved, but also that the current staff needs better education in terms of designing an exhibition using proper sources of light.

The results also reveal that all investigated museums depend in there lighting system on either natural daylight or artificial lighting, in different amounts for each museum. Furthermore, artificial and natural lighting overlapped in most of the museum halls.

Although there have been many studies on the effects of light on museum objects, this study of museum lighting systems is a pioneer study in Jordan.

The light sources found in these museums reflect a lack of knowledge and expertise in the field of museology in Jordan. Most of these museums were newly renovated and efforts had been made to make museum buildings from old historical buildings. However, it seems that the mission of renovating museums, according to the results of this study, was under-estimated. Therefore, the results from renovating these museums were under expectations.

The found values for UV light frequently exceeded the recommended levels (Thomson 1986). However, UV levels are less important for archaeological inorganic objects than for archaeological organic artefacts. UV light easily can deteriorate lingo-cellulose containing materials, resulting in discoloration of the surface and in the worse case embrittling of the object. For coloured surfaces on objects, UV light can be disastrous. Therefore, it is important to follow the general guidelines for the illumination of museums and exhibitions. At present, within the European Standardisation Committee CEN TC 346, new recommendations are being developed. Therefore, it is recommended that adjustments and improvements be made to the quality of lighting in Jordanian museums. Because natural light was present at many locations, it is important to filter out the amount of UV light. This can be done simply by means of UV protecting foil that can be added on the windows. Therefore, a decent amount of visible light can remain, to allow a collection to be lit attractively for visitors.

Another issue to be discussed in the field of collection management is the location of lights. For example, it was found that several showcases were not illuminated at all, while the area the showcase was standing in was illuminated with high power neon light bulbs. This gives the visitor a poor view of the objects in the showcase. Therefore, more attention should be given to visibility of the objects and on the relation between light intensity of the room and illumination of the object.

In designing the outside sun shades, mechanical devices were not considered in most Jordanian museums. To reduce the variations in lighting levels, mechanical devices such as automated louvers can be considered. Another consideration would be motorized shutters or curtains, which can block the daylight coming through the openings. In addition, daylight cannot totally replace artificial light because certain museum objects, such as jewelry, still require artificial light to show their features clearly.

This research only covers the evaluation of lighting performance using the Desktop ELSEC 764. Moreover, the lighting investigations in the selected Jordanian museums were done in September and early October 2009. However, lighting levels might vary with sky condition and time of year. Therefore, further studies are recommended in order to evaluate the lighting systems and the illumination intensities in both winter and in summer. In addition, an assessment of the effects of high intensity lighting on objects displayed at Jordanian museums is a necessity.

4.7 Conclusion

The intention of this study is to discuss light efficiency at Jordanian museums. Therefore, fourteen museums were selected and the current status of the lighting system conditions at these museums was investigated. These monitored museums were selected because they are a diverse group of institutions, representing all the different types of museums in Jordan. The selected museums differ from each other in several aspects:

- The locations of the museums.

- The collections the museums hold.
- The types of building.
- The dates the museums were established.
- The reasons for their establishment.
- The audiences they serve.

All museums were monitored using the same ELSEC 764 devices and the same process. Moreover, the light measuring process was done in each museum at the same time of day, from 10 a.m. until two p.m.

From the fieldwork study, it was found that there were four different light sources in the monitored museums: daylight, fluorescent lamp lights, incandescent lamp lights and filtered spotlights. These four sources were found combined in some of the museums, but in others only some of these sources were used. Several factors may have affected the findings of the monitoring:

- The geographical location of each museum.
- Where the device was fixed within the museum.
- What type of light the ELSEC 764 was exposed to.
- The type of lamps used in the artificial lighting of each museum.

Depending on these factors, the selected museums show differing results. These results could have been compared directly with international guidelines, so that a summary and conclusion could be quickly made. However, it was decided that the collection that each of these museums hosts should also be discussed, as light does not damage all museum objects in the same way. The museums were compared to each other. If there is any change to be made to the lighting systems in Jordanian museums, priority should be given to remediable museums first.

In addition, it can be concluded that the intensity of light needs to be improved, because the results reveal inadequate lighting intensity in most of the investigated locations within the museums of this study as it is illustrated in Table 4.31. UV light intensity exceeded the recommended levels in 62% of the examined locations in all examined museums, while visible light exceeded the recommended level in 35% of the examined locations in all examined museums. Therefore, it is safe to assume here that museums in Jordan do not provide suitable lighting systems to insure the safety of their assets.

Table 4.31 The results of the examined locations within the museums

Museum name	Type	Locations within a museum	UV exceeded locations	Visible light exceeded locations
The Ajloun Museum	Archaeology	6	6	0
The Aqaba Museum	Archaeology	9	6	2
The Archaeology Museum/ Jordan University	Archaeology	7	7	6
The Dar Alsaraya Museum	Archaeology	7	5	1
The Folklore Museum	History	7	6	1
The Jarash Museum	Archaeology	6	5	1
The Jordan Museum of Popular Traditions	History	7	3	2
The Jordan National Gallery of Fine Arts	Art	16	4	8
The Museum of Jordanian Heritage / Yarmouk University	History and Archaeology	8	1	2
The National Heritage Museum / University of Jordan	Archaeology	5	3	2
The Natural History Museum / Yarmouk University	Natural history	6	6	4
The Salt Museum	Archaeology	9	5	3
The Petra Museum	Archaeology	14	7	6
The Umm Qeis Museum	Archaeology	6	6	2
Total		113	70	40
Ratio		100%	62%	35%

Measurements were taken in different positions within the museums in order to capture different light sources. For example, in a single museum measurements may have been taken at the side of an open window, under an incandescent light, or on the ceiling opposite an artificial light.

This study seeks to reduce as far as possible the damage caused by inappropriate lighting in Jordanian museums, within the available capabilities of the selected museums. It is important to reduce the light damage to objects to a minimum.

This study did not take only the light radiation intensity into consideration, but also the period of the exposure time was one of the main issues of concern. It is possible to limit the damage caused by exposure to light by reducing the time of exposure to light at the selected museums. This is easy to achieve, as the working hours of the museums are from nine a.m. to three p.m. at some and to five p.m. at others.

The light sources found in the monitored museums varied from museum to museum. The museums can be divided into groups, depending on their light sources:

- Museums, which depend mainly on natural daylight, which enters through windows.
- Museums, which depend on natural daylight and artificial light sources. The ratio of natural light to artificial light differs in each museum.
- Museums that depend on unfiltered artificial lights.
- Museums, which depend on UV-free artificial lights.

These divisions were reflected clearly in the graphs described previously in the results section.

Although previously it has been recommended that visible light should not exceed 150 Lux inside museum halls, Garry Thomson postulated in 1986 that visible light is safe up to 200 Lux. This amount is allowable only if UV light is maintained below 75 µW/lm (Thomson 1986). Kuhn (1986) determined the level that is recommended for different materials; his recommendations are based on international researchers and experiences. He says that the ideal Lux measurement for light on sensitive objects like paintings, textiles and painted objects, should not exceed 50 Lux. For other museum objects like painted sculptures, leather, horn, bone and ivory, not more than 150 Lux should be tolerated. As an example, he mentions for general information that a 100 watt bulb results in one meter distance in light intensity of approximately 120 Lux. As a result of subsequent experience, the recommended 150 Lux has been revised upwards to 200 Lux.

4.8 Recommendations

This research focuses mainly on reducing the amount of damage to the objects of Jordanian museums and galleries through their exposure to unsuitable lighting systems. Furthermore, the research will introduce a balance between adequate illumination for the displayed objects, together with comfortable and sufficient lighting for the audiences of these museums and galleries.

The lighting levels in Jordanian museums vary according to weather conditions and the time of day and time of year. The results of this study show that luminance levels in these monitored museums exceeded 200 Lux during daylight hours in most of the cases. The total exposure times were also over the limits for materials that are moderately susceptible to damage from exposure to light. As a result, highly susceptible and moderately susceptible material should not be displayed at these museums. Among the light-susceptible collections displayed at these museums are textiles, cloth, parchment, bones and paintings. These materials are all susceptible to the presence of UV.

To reduce the lighting levels, mechanical devices such as automated blind louvers could be considered in order to avoid glare from the sunlight at these museums. Another consideration would be motorized shutters or curtains, which can block the daylight coming through openings in the buildings. In addition, daylight cannot totally replace artificial light, because certain museum objects, such as accessories, require artificial light in order for their features to be shown clearly. Whenever there is a need for artificial light to be installed, it is always recommended that UV-free spotlights be used. In some of the museums, UV-free lamps were found. It can thus be assumed that this kind of lamp is freely available and easily purchasable.

The above-mentioned suggestions can be achieved by several steps:

- Lessen the exposure time of objects to light.
- Take advantage of several variant light sources.
- Install curtains and blind louvers.

Here we can refer to the previously mentioned idea of lessening the exposure time of the museum objects to light. This can be illustrated as follow:

- Turning off the artificial lights during non-working hours and weekends.
- Installing curtains and blind louvers for museums, which have bare windows and close them tightly when the museum is closed to the public.

With these procedures, the exposure time to day light will be reduced by 44 hours per week. The reduced exposure time resembles 53% of the expected exposure time of museum objects to light per week and even more for the exposure to artificial light. Damage through light can be expected to be reduced to approximately 50%.

There are some changes that still need to be made in order to enhance the capability of the monitored museums to host their collections. This is particularly important as some of these museums host the most vulnerable materials to light among Jordanian museums. In our observation of these museums, it was noticed that some have side openings, which allow daylight into the buildings. Either these openings could be blocked permanently, or they could be provided with adjustable blind louvers. Otherwise, the openings should be replaced by UV filter glazed windows, which is highly recommended. Modern technology has provided ultraviolet filtration and energy-efficient windows, which may be used in museums for four purposes:

- Filtration of UV radiation coming from sunlight.
- Reduction of energy costs.
- Museums can benefit from this free energy source.
- This energy source is available during the opening hours.

It is worthwhile mentioning that these windows are available on the market today.
A major benefit of the Fiberglass window products is that they have the ability to block more than 99.5% of damaging ultraviolet radiation, while still looking clear and colorless. Ideally, a window would block the damaging UV rays that cause fading, while letting light pass through. An ordinary clear glass window lets in about 70% of the sun's UV radiation.

4.8.1 Ajloun Museum

This museum is located within the Ajloun archaeological castle, thus the outside shape cannot be changed. It has two wall openings, one on the eastern wall and the other on the northern wall. Looking back to the Ajloun museum results, visible light levels were within the required standards, but the results of UV radiation reached as much as 1200 µW/lm. The results of the high UV actually were found in spots lit by daylight. The museum does not host any vulnerable materials to light intensity, so it is recommended here that inside curtains be installed, especially at the eastern side windows, which are in direct sunlight from 7:00 am until midday. If it is impossible for this museum to install UV-free glazed windows, it is recommended that the museum switch to relying solely on UV-free lights.

4.8.2 Archaeology Museum / University of Jordan

The museum is located within the University of Jordan campus, thus the working hours for the museum are synchronized with those of the university. From the observation of the museum, it was obvious that the museum’s lighting system depends 90 % on natural daylight. The museum has large windows and the results revealed that all spots with in direct light, either natural or artificial, exceeded the international guidelines. The museum has some organic based materials and so it is recommended that the current situation be altered. Since the museum depends mainly on natural light, it is recommended that the western façade windows be replaced with UV-free glazed windows.

4.8.3 Aqaba Museum

Geographically speaking, this museum is located in an area of relatively high temperature in Jordan. The museum was a resident house previously and was not originally intended to be a museum. The museum depends on natural and artificial light (tungsten lamps). It hosts within its collection parchment objects, which are sensitive to light. The examination of the artificial light spots and the natural daylight spots revealed that UV radiation is active. Daylight reflects a higher proportion of UV radiation. If the museum windows were closed by curtains from the inside, this would reduce the ratio of UV inside the museum. Other than that, it is recommended that UV-free lamps be installed in this museum.

4.8.4 Dar Alsaraya Museum

The building of the Dar Alsaraya museum was originally built for the Ottoman Governor in the City of Irbid. Later, it was used as a prison by the government of Jordan. Thus, this museum has a unique architecture. The museum has limited side openings, which lead to the assumption that it depends in its lighting system 80% on artificial light (tungsten lamps and fluorescent lamps). The museum collection, except for some bone and ivory materials, is impervious to illumination damage. Since it is not likely that the building itself will be altered, it is recommended that the placement of the light-susceptible materials be changed and lit by UV filtered spotlights.

4.8.5 Folklore Museum

In the Folklore museum, it was assumed that the museum, except for the entrance area, depends 100% on artificial light. The results reveal that in all examined locations there was UV radiation, except for in one location, which was vacant of any light source. All of the museum collections were light sensitive. It is therefore urgent to change the illumination system in this museum. The proposed lamps to be installed are tungsten UV-free lamps.

4.8.6 Jarash Museum

The Jarash museum is in a building, which was used previously as a resident house. Its lighting system depends mainly on artificial light (tungsten lamps). The museum has side bar windows along the northwestern side of the building. The museum hosts few materials, which are likely to be damaged by light and so it would suffice to move the most vulnerable objects to a safer place.

4.8.7 Jordan Museum of Popular Traditions

Three types of light were found in this museum: day light, incandescent lamps and fluorescent lamps. The museum’s lighting system depends mainly on daylight. Among the artificial lights, the fluorescent lamps usually contain the highest portion of UV. The museum hosts a high number of objects that are vulnerable to damage caused by exposure to light and so it is recommended that the illumination of the museum be limited to within international standards. This can be achieved through blocking the daylight coming through windows by installing curtains or blind louvers. Additionally, the museum could change the fluorescent lamps for tungsten ones or, even better, UV-free lamps.

4.8.8 Jordan National Gallery of Fine Arts

The Jordan National Gallery of Fine Arts can be considered the best museum in this study, according to suitable lighting conditions. The museum displays an artistic collection, which is susceptible to light. The museum consists of two buildings that were both examined during the same period. Except for two locations in the second building, the results were within the required recommendations. The second building has two northern windows and these spots reveal UV light and a relatively high portion of visible light. Therefore, it is recommended that these two windows be blocked permanently.

4.8.9 Museum of Jordanian Heritage / Yarmouk University

The lighting system of the Museum of Jordanian Heritage, which is located in the campus of Yarmouk University, depends 60% on artificial light. Moreover, the museum administration recently made changes to the museum lighting system. They have installed fluorescent lamps in all the museum halls. The effect of the newly installed lamps was clearly readable in the results. The lighting system at the museum could be made better if UV-free lamps were used. However, this depends on UV free lamps being available at the local market.

4.8.10 The National Heritage Museum / University of Jordan

This museum is also located in a university campus. Therefore, the working hours and the visiting hours are limited. The museum's lighting system depends on both artificial and natural lighting, but neither is at suitable levels. It was clear the installed lamps, either incandescent or fluorescent, provided high levels of visible and UV lighting. The side windows did not prevent UV radiations from penetrating through. Since all of the museum's collection is highly susceptible to light, it is recommended that a general change be made to the lighting system. The eastern side window should be blocked permanently and the museum should grow to depend 100% on artificial lighting, specifically tungsten lamps with UV filtration. Although the museum should provide some of the displayed objects with spotlights in order to highlight their artistic values, these lights should be UV-free.

4.8.11 Natural History Museum / Yarmouk University

As was mentioned in the results, this museum depends mainly on artificial light. The lamps used in this museum are all fluorescent lamps. The museum curator stated that it was decided by the Dean of the Science Faculty to install this kind of lamp in the museum. This decision has caused harm to the museum's objects. The Natural History museum depends 90% on artificial light and this ratio can easily be increased to 100% by closing the main entrance. The lamps installed at this museum should be changed to tungsten UV-free lamps. This would help keep the stuffed animals displayed at this museum in their current shape and in a suitable condition.

4.8.12 Petra museum

High levels of UV and visible light were found in some of the examined spots of the Petra museum. According to Hermann Kuhn (1986), high UV radiation and high visible light intensity are harmful to organic-based materials. Considering this, it can be said that the collection that is on display at this museum is immune to deterioration caused by exposure to light.

4.8.13 Salt museum

The lighting system of the Salt museum depends on both artificial and natural light. A decision was made to install curtains at all the museum's windows, since the museum has windows on all sides. Curtains were fixed at some windows, while others were still bare at the time of this study. This was of course reflected in the fluctuations in results of the inspected spots. The museum was renovated recently, but a lack of expertise allowed some mistakes to happen. It would be better to install proper lamps in the lighting system and provide the rest of the windows with curtains.

4.8.14 Umm Qeis museum

The Umm Qeis museum displays archaeological objects such as pottery, mosaics and stone objects. We may assume that these objects can reasonably endure the effects of light at present. The Department of Antiquities is in the process of renovating the museum and this could provide a fantastic opportunity to change the lighting system. Because the museum is a part of a cultural heritage park, there are some restrictions on the outside shape of the building. It is advisable that the museum continues to take advantage of sunlight and it should install UV-free glazed windows, to take the chance to examine the viability of using this kind of glass in the Jordanian climate.

4.8.15 Further research recommendations

The lighting system in some of the selected Jordanian museums is in desperate need of a change, while others are in a less critical situation. For museums, which hold objects that are susceptible to light exposure, it is recommended that a new study be conducted to assess the prospective damage that might occur.

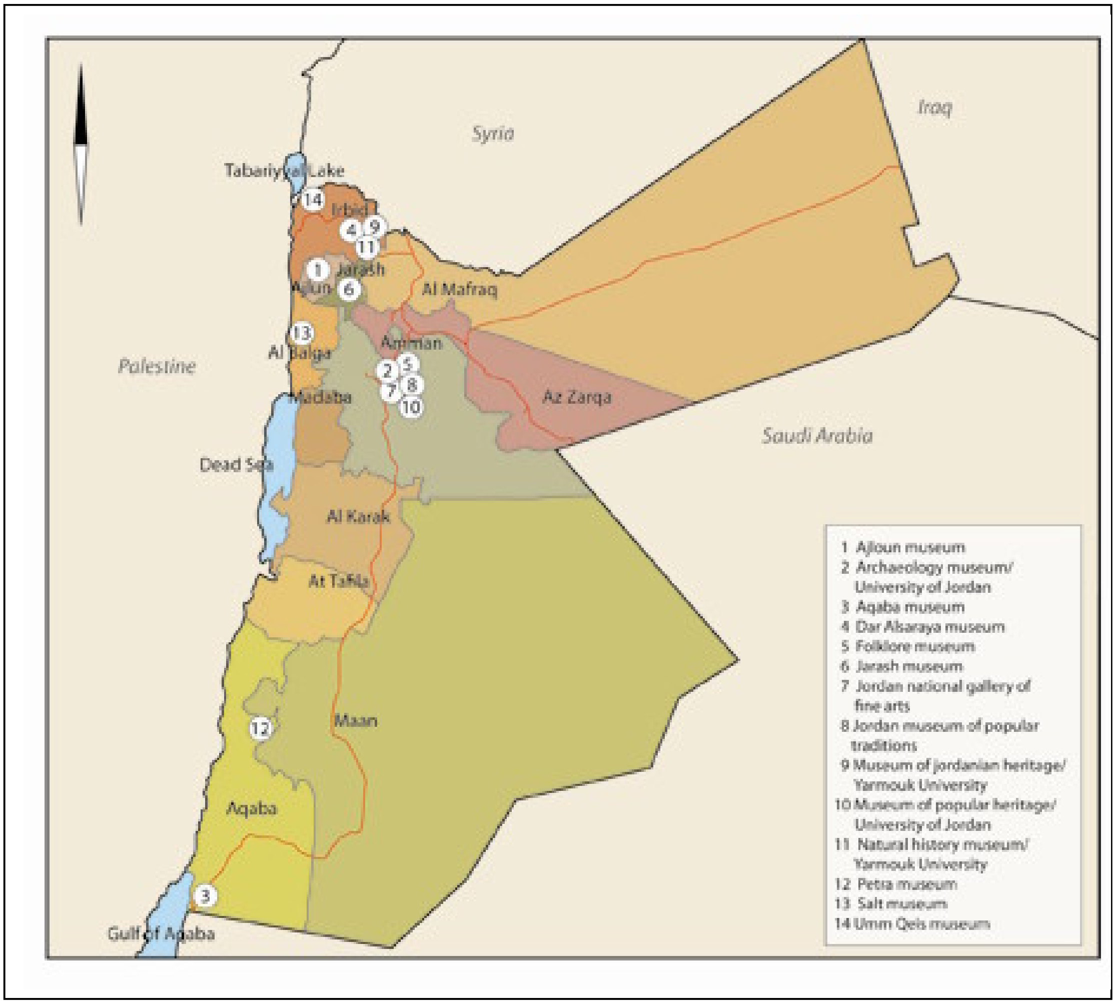

Figure 4.30. A political map of Jordan indicates the location of the monitored museums within their governorate.

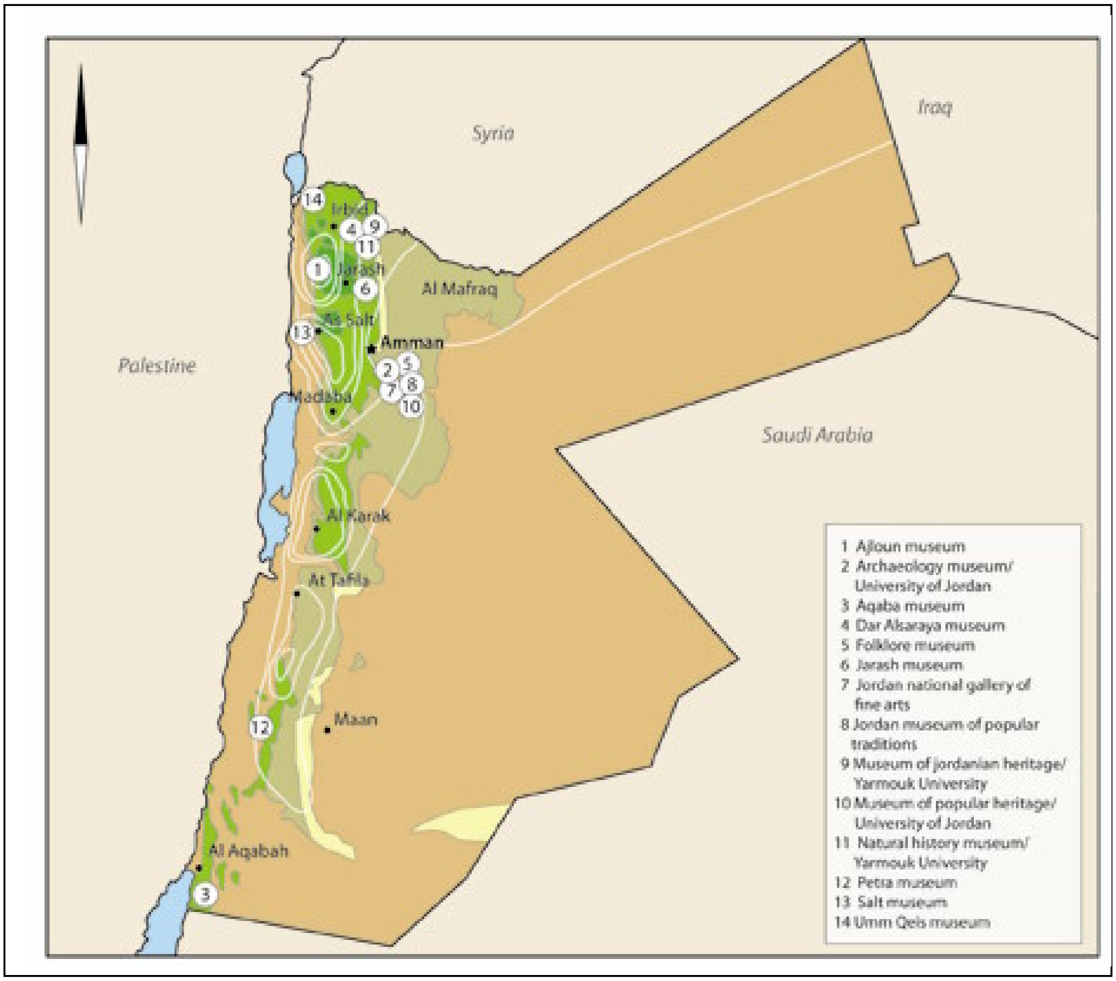

Figure 4.31 A natural topography map of Jordan, indicates the monitored museums location within their geomorphological area.

THE INDOOR AIR QUALITY OF SELECTED JORDANIAN MUSEUMS, ARCHIVES and REPOSITORY

The indoor air quality of selected Jordanian museums, archives and repository

5.1 Introduction

Since the dawn of time, Jordan has been an important centre of civilization and the country's significance is represented by its vast cultural heritage. It is important that these Jordanian artefacts are well protected and because museums are where objects are displayed and kept, they too must be well maintained.

Jordanian museums, storage areas and archives contain important collections that require a certain environment to ensure preservation of the objects and to keep deterioration at a minimum. In the absence of environmental control, these objects might be in great danger. Museums must provide the requirements needed for their protection.

Every object undergoes decay and deterioration. Museums, however, must plan to slow down the rate of decay by reducing the negative impact of certain factors that affect objects. The environmental conditions inside a museum are among the most significant of these factors (Cassar 1995).

It was only some 50 years ago with the development of central air-conditioning systems that attention began to be paid to effective control of the museum environment. In 1933, the National Bureau of Standards undertook a study of alkaline-wash systems for the removal of SO_2 in library atmospheres (Kimberly and Emley 1933). The Folger Shakespeare Library, Washington DC, installed such a system in the 1930s, but abandoned it due to maintenance problems. Since 1941, the National Gallery of Art, Washington DC has had an alkaline scrubbing system. However, until recently, interest in air purification remained limited. A comprehensive survey in 1973 of 429 museums and galleries in the United Kingdom (Group 1978) revealed that only nine per cent of exhibition areas and two per cent of showcases had relative humidity control, with similar estimates for air filtration. Only 10 per cent of those institutions with conservation staff monitored atmospheric pollutants that cause chemical and physical damage to exhibitions. It is now being recognized that, in addition to acidic gases, oxidizing pollutants can cause significant damage to cultural property (Thomson 1986). Other concerns include emissions from building materials, the introduction of anticorrosive chemicals from humidification systems and the recirculation of vapours from chemicals used in conservation processes.

In preservation environments are a number of environmental factors, which can cause the degradation of materials and artefacts. Among these are temperature, humidity, particulates and gaseous pollutants. Of these, gaseous pollutants are the most destructive.

Gaseous pollution today is caused primarily by the burning of fuels in power plants, factories, commercial and domestic buildings and automobiles. The two main types of gaseous urban air pollutants can be classified either as acidic or oxidizing. Over the years, these two types have merged and now the three main pollutant gases found throughout the industrialized world are sulphur dioxide (SO_2), ozone (O_3) and nitrogen dioxide (NO_2). Others of primary concern include chlorides (chlorine (Cl_2) and hydrogen chloride (HCl), acetic acid (CH_3COOH) and formaldehyde (HCHO).

While automotive and industrial emissions are considered as being the largest contributors of SO_2, O_3, NO_2 and chlorides, there are also many significant sources of internally-generated pollutants. Examples of these are materials and activities associated with restoration and conservation laboratories, so many artefacts and archival materials

and employees and patrons themselves, can contribute to the overall pollutant level in preservation environments.
Although gaseous pollutants are of major worldwide environmental concern, the sources of gaseous pollutants, their introduction and migration through museums and their interactions with artefacts are the least studied and least understood areas of concern within preservation environments. General reviews of pollutant sources and object vulnerabilities and information and guidelines for gaseous pollutants were scarce until the 1990s.
Some research has been done about common urban pollutants and their effects on artwork and archival materials and there are now also guidelines for their control. Generally, these guidelines call for interior concentrations of gaseous pollutants to be maintained at as low a level as attainable by gas-phase air filtration. The most commonly cited control levels for gaseous pollutants are shown below:

Sulphur dioxide	≤0.35 - ≤1.0 ppb
Ozone	≤0.94 - ≤12.5 ppb
Nitrogen dioxide	≤2.65 ppb
Chlorine	≤1 - 3 ppb
Hydrogen chloride	≤1 - 3 ppb
Acetic acid	<4 ppb
Formaldehyde	<4 ppb

5.1.1 Air pollution

Sulphur dioxide is one of the most common and destructive pollutants in the air. If the relative humidity (RH) is above 60%-65%, the presence of sulphur dioxide causes corrosion in bronze, brass, copper and other metals. Copper alloys are less vulnerable to hydrogen sulphide than to sulphur dioxide and sulphuric acid respectively (Cronyn 1990). Copper and its alloys are subject to corrosion and thus the surfaces of copper or bronze artefacts have often undergone some transformation, due to being buried in the earth, immersed in water, or exposed to the elements and environmental pollutants. Acid rain is particularly damaging, as are other air-borne pollutants such as coal-dust and soot. Artefacts should ideally be stored in boxes or covered by cloths, but if the boxes are airtight, care must be taken that the objects are not damp.
Dust is a destructive enemy to most museum objects. Dust is composed of minute particles, which, upon contact with water, can become an active chemical agent, which is corrosive. Sealing windows and putting dust excluders on doors can reduce dust. Furthermore, very particulate matter smaller than Particles Micros (PM) 2.5 might penetrate into the object in such a way, that cleaning becomes impossible (Van Grieken 2010). However, cleaning objects by dusting, shaking, wiping, or washing actually accelerates wear and tear, thereby increasing the risk of damage (Cronyn 1990).
In Jordan air pollution is a general feature in and near urban and industrial areas – often areas where also museums are located. Furthermore the variety of climatic conditions in Jordan is relevant for the destructive effects, considering the changes of humidity and temperature (Grzywacz 2006).

5.1.2 Aim of the study

The aim of studying the local environmental conditions of Jordanian museums is to conclude whether the current conditions in the museums fulfil international requirements in relation to the materials stored in the selected museums.

Furthermore, the results will be compared to the the International Organization for Standarization (ISO) standard EN-ISO 1184 and to the Purafil Environmental classifications for preservation environments done by Chris Muller.
In this study, the DoA main repository and archive and eight selected museums in Jordan were investigated. An environmental reactivity monitoring was carried out in order to examine how far these museums and storage areas conform to the recommended conditions and international standards for housing such valuable collections.

5.1.3 Research questions

To reach the aim of this work, the following research questions are postulated:

- What is the collection of these museums?
- For what kinds of objects is the indoor environment suitable?
- Does the indoor environment lead to corrosion?
- Does the rate of corrosion inside the museum correlate with the outside corrosion rate?
- Do these museums conform to the international standards for museums?

5.2 Methodology

Air quality measurements in preservation environments often make stringent demands on monitoring instrumentation and methodologies. Special modifications and protocols are often needed to adapt the techniques for use in these environments. Indoor air quality analyses have been performed by field studies using metal coupons. This methodology is well adopted in the field of indoor air quality of locations storing and exhibiting cultural artefacts. The interpretation of the results is done using the International Organization for Standarization (ISO) standard EN-ISO 1184 and to the Purafil Environmental classifications for preservation environments done by Chris Muller.

5.2.1 Air monitoring tools and techniques

Air monitoring is central to any environmental control program for achieving and maintaining air quality standards based on the presence or absence of gaseous air pollutants. Such monitoring can also provide the short-term data required to manage and mitigate contaminant-specific episodes. In addition to direct application to contamination control programs, air-monitoring data may be employed for:

- The evaluation of long-term air quality trends in a facility
- Research studies designed to determine relationships, if any, between pollutant levels and possible damaging effects

Several characteristics of any measurement technique must be evaluated to determine its appropriateness for use in indoor air-quality monitoring. Among the more important characteristics are sensitivity, cost and complexity. Sensitivity is a particularly demanding parameter for environments where near-ambient levels of many pollutants may be encountered and where control levels are approaching the sub-parts per billion (ppb) levels. Likewise, cost may be quite important when deciding on a measurement technique, particularly in large surveys (Muller 1999).
A final point of consideration is the complexity of the technique and the degree of skill and training required to obtain quality results. Other factors deserving consideration are

selectivity and portability. Most measurement techniques are not optimized for all of these parameters and one must weigh the various characteristics in order to best meet the desired goals. Often trade-offs will be necessary in selecting the techniques to be used for a specific study (Muller 1999).

The air monitoring technique with Environmental Reactivity Coupons (ERCs) is well adopted in the field of indoor air quality analyses for museums, archives and libraries. Therefore, these coupons are being used in this work as well. The ERCs and the electrochemical analyses of the exposed ERCs were offered by Twin Filter b.v., The Netherlands and Purafil Inc. Atlanta, USA. In advance, the author highly acknowledges these companies for their kind help.

5.2.2 Purafil environmental reactivity coupons (ERCs)

Figure 5.1 Environmental Reactivity Coupon (ERC)

The passive ERC monitors are typically exposed to the environment for a period of 30-90 days and are then analyzed for the amount and type of corrosion, which was formed. This technique can provide cumulative reactivity rates, an assessment of average environmental conditions over time and can give an indication of the types and relative levels of corrosive gaseous pollutants.

ERCs may be used to indicate the presence of SO_2, O_3, NO_2, Cl_2 and many other corrosive materials, which can cause the deterioration of metals, cellulose and organic materials. ERCs originally used only copper reactivity to establish environmental classifications. However, copper is not sufficiently sensitive to many of those pollutants ubiquitous to most urban environments - the same environments in which most museums are located. Furthermore, copper coupons do not detect the presence of chlorine, a particularly dangerous contaminant to metals. With this in mind, Purafil Inc. developed the use of silver reactivity monitoring for these unique environments. Silver is sensitive to chlorine and, when used with copper reactivity monitoring, can be used to detect changes in the levels of gaseous pollutants in the ambient environment as small as 1 ppb and can differentiate between different classes of contaminants (Abbott 1983; Rice 1981).

The corrosion reported from the reactivity monitoring with ERCs is actually the sum of individual corrosion films. For copper coupons, sulphide and oxide films are most commonly produced and are reported as copper sulphide (Cu_2S) and copper oxide (Cu_2O), respectively. For silver coupons, sulphide, chloride and oxide films may be produced and are reported as silver sulphide (Ag_2S), silver chloride ($AgCl$) and silver oxide (Ag_2O), respectively. Each coupon is analyzed as to the type and amount of film present and its relative contribution to the total corrosion produced (Abbott 1983; Housing 1994).

Figure 5.2 One of the used coupons. Photo by: R. Alghazawi

Recently the ISO standard EN-ISO 1184-1, Corrosion of metals and alloys, Classification of low corrosivity of indoor atmospheres was adopted describing also the different acceptable corrosion levels (ISO 2004a).

5.2.3 Analyzing ERCs using the electrolytic cathodic reduction method

The analysis of ERCs was done at the laboratories of the Department of Indoor Air-Quality at the Purafil headquarters in the USA. The method of analysis for ERCs was electrolytic cathodic reduction. The electrolytic cathodic reduction was performed in a 0.1m KC1 solution at a constant current density of 125 µA/cm². A standard three-electrode cell was used, containing N_2–purged 0.1m KCl as the electrolyte, a platinum counter electrode, a calomel reference electrode and the specimen as the working electrode. The change of the potential of the specimen was monitored during the electrolytic reduction of the corrosion products (ISO 2004). The corrosion rate r_{corr} in mg/(m²a), is given by the following equation (Faraday's law):

$$r_{corr} = \frac{i - t_{red} \,.\, M}{n \,.\, F \,.\, t}$$

Where:

- r_{corr} is the corrosion rate, in mg/m^2 a;
- i is the current density, in mA/m^2;
- t_{red} is the total time for reduction of corrosion products, in seconds;
- *M* is the relative molecular mass, in g, i.e. 107.9 for silver and 63.5 for cupper;
- *n* is the valance state, i.e. +1 for silver, +1 or +2 for copper;
- *F* is Faraday's constant, 96 485 C/mol;
- *t* is the exposure time, in years;

In ANSI/ISA- S71.04-1985 and IEC 60654-4, the classification of reactive environments is based on the copper reactivity, expressed as the thickness of the copper corrosion film. From the corrosion rate, r_{corr} determined above, a corresponding film thickness, t_f, is obtained from the following equation:

$$t_f = \frac{t_{corr} \,.\, M_{film} \,.\, t}{M - \sigma_{film}}$$

Where:

- t_f is the thickness of the corrosion film in nm (10^{-9} mg/m^2)
- r_{corr} is the corrosion rate, in mg/m^2 a;
- *t* is the exposure time, in years;
- *M* is the relative molecular mass, in g, i.e. 107.9 for silver and 63.5 for cupper;
- M_{film} is the relative molecular mass of the corrosion film, in g, e.g. Ag_2S = 247.8; Cu_2O = 143.1; CuO = 79.5;
- σ_{film} is the density of the corrosion film in g/cm^3, e.g. Ag_2S = 7.32; Cu_2O = 6.0; CuO = 6.4; (ISO 2004)

5.2.4 Direct gas monitoring

The biggest problem today for museums regarding objects and indoor air pollution is not whether specified levels of air quality can be reached, but whether they can be accurately measured to assure compliance with any standards or control criteria. One consideration faced in designing an indoor air-quality monitoring program is the choice of passive versus active sampling. The immediate feedback of an active monitor is a most desirable aspect and is what often precludes the use of passive monitors. Another consideration is the option of direct versus indirect monitoring techniques (Kishkovich 1997; Muller 1999).

Electronic devices designed for real-time gas monitoring respond to changes in the measured variable very quickly. They are capable of detecting pollutant levels in the ppb range and are available for a wide range of pollutants. Individually, chemical pollutants may be monitored using various analytical techniques and this gives the most accurate low-level, real-time monitoring. The major disadvantage of the use of real-time gas monitors is the relatively high cost when compared to other techniques. Table 5.1 lists a number of different pollutants and the levels, which can be monitored with real-time monitors. Even though it is possible to identify and quantify (almost) all-chemical species one may encounter in preservation environments, the question still remains "What do I do with this information?" To date, there has been no study performed (or at least published) which provides definitive information as to the cause-and-effect relationship between specific levels of gaseous pollutants and the damage they may cause to paper documents, artwork and historical artefacts. Because of this, a number of institutions are turning to environmental classification via what is referred to as reactivity, or corrosion, monitoring. The validity for this air monitoring technique lies in the fact that many of the pollutants targeted for control are corrosive in nature and therefore, can be effectively measured using this technique (Muller n.d.).

Table 5.1 Currently available real-time chemical/gas monitors

Pollutant	Concentration Range, ppb	Lower Detection Limit, ppb	Response time, sec	Selectivity	Susceptibility to Interferences
Ammonia	0-200	1.0	900	Medium	Low
Formaldehyde	0-1000	0.2	300	High	Low
Hydrochloric acid	0-200	1.0	900	Medium	High
Hydrogen sulphide	0-200	1.0	120	Medium	Low
Nitrogen oxides	0-200	0.1	90	NO-High, NO_2-Low	Low
Ozone	0-1500	1.0	50	High	Low
Sulphur dioxide	0-200	0.1	120	High	Low
TVOC	0-20,000	20.0	120	Low	Low

Reactivity monitoring can characterize the destructive potential of an environment. The growth of various corrosion films on specially prepared copper, silver and/or gold(-plated) sensors provides an excellent indication of the type(s) and level(s) of essentially all corrosive chemical species present in the local environment (Kishkovich 1997; Muller 1999).

5.3 Damage that might occur from corrosion

All organic materials are subject to the same physical and biological processes of deterioration caused by inappropriate humidity levels. In contrast, inorganic materials are subject principally to deterioration as a result of chemical processes and in one special instance to mechanical processes (salt crystallization in porous material) (Torraca 1982).

5.3.1 The four main agents of corrosion

Corrosion is the degradation of a material due to the action of chemical, electrochemical or biological corrosive agents present in the environment. The material is transformed into salts, oxides or both, with one or more of the following consequences:

- Changes in colour
- Modification of form
- Increase in volume
- Loss of mechanical resistance
- Modification of the material's reaction to water

Corrosive agents work on stone, metals, glass, fossils and shells.
The four main corrosive agents that shall be presented here are:

- Pure air, which always contains *inter alia*, a combination of oxygen (O_2), carbon dioxide (CO_2) and water vapour (H_2O).
- Polluted outdoor air, which contains chemicals such as sulphur dioxide (SO_2) and nitrogen dioxide (NO_2).
- Polluted indoor air, which contains chemicals such as organic acids, aldehydes, etc.
- Marine air, which contains chlorides such as natural salt (NaCl).

Pure air: Humidity, oxygen and carbon dioxide
Oxygen is one of the principal components of air. It is responsible for the "natural" oxidation (corrosion) of metal. Metals react chemically with the oxygen in the air, therefore, they will transform into metal oxides. This oxidization is slow and generally only affects the surface of the material. The film of oxides, which forms as a result of this oxidization, is stable and impermeable to air and so the chemical corrosion ceases. On the other hand, if the film is broken, or if the products of corrosion are permeable to air (as in the case of iron oxide), the corrosion will continue until the transformation into metal oxide is total. This oxidization rarely happens in isolation and most of the time it is combined with other, more active types of corrosion.
Carbon dioxide (CO_2) is one of the main components of the atmosphere. Combined with the humidity present in air, it forms a weak acid (carbonic acid -H_2CO_3) which reacts:

- In a minor way with limestone. Calcium carbonate and magnesium carbonate are converted into bicarbonates. These in turn gradually dissolve in water (humidity) and the stone is weakened as a result (Torraca 1982).
- In a major way with unstable glass. It does not initiate the process, but contributes to the change that is started by humidity (Torraca 1982).

Polluted outdoor air
Sulphur dioxide (SO_2) is a gas and is the most dangerous pollutant for museum objects found in the atmosphere around urban centres. It is produced by the combustion of fuels such as coal, petrol or fuel oil, which contain sulphur (S). In Jordan for instant, the most common used element for heating is fuel oil; also, it is used for all types of transportation in Jordan. The reaction is:

$$S + O_2 \rightarrow SO_2$$
$$\text{Sulphur} + \text{oxygen} \rightarrow \text{sulphur dioxide}$$

Sulphur dioxide then combines with more oxygen to form sulphur trioxide (a gas)

$$2SO_2 + O_2 \rightarrow 2SO_3$$

Sulphur dioxide + oxygen → sulphur trioxide

Finally, in the presence of humidity, the sulphur trioxide forms sulphuric acid:

$$SO_3 + H_2O \rightarrow H_2SO_4$$

Sulphur trioxide + water → sulphuric acid

As a result, in polluted atmospheres when the humidity condenses on materials, a solution of sulphuric acid is found in drops of condensation (Torraca 1982).

Polluted indoor atmosphere

Various products found in materials used in museum decoration (wood, textiles, glues, plastic, paints, etc), can slowly decompose and produce either organic acids (e.g. acetic acid or formic acid), sulphur-based compounds (e.g. hydrogen sulphide, sulphur oxides), or oxidizers (e.g. aldehydes). Other stored or exposed materials in the same closed environment can absorb several of these emitted volatiles, where the concentration of unwanted volatiles may accumulate. This can be dangerous for museum objects when vapours concentrate in sealed spaces such as showcases.
Three main categories of objects are sensitive to these vapours: items made of lead, silver, or shell (Padfield 1982; Tetreault 1992).

Marine air
Marine air contains sodium chloride (NaCl – common salt) in suspension. This salt:
- When it comes into contact with copper and iron objects, initiates a very aggressive deterioration process. In case the museum, storage room, or archive is located close to the marine environment, NO_x produced by traffic may react with NaCl forming $NaNO_3$. This often can be found as a white deposit on the outside of a showcase, wall etc. in case $NaNO_3$ enters a showcase it even might decompose and form the harmful pollutant NO_2 (Van Grieken 2010).
- When it penetrates a porous material like stone or ceramic, can have a physical effect (Guichen 1995).

5.3.2 Action of corrosive agents on ceramics, stone and shell

The following table summarizing the principal changes that affect the most commonly encountered inorganic materials. Delineated notes of the table are described as follows.

Table 5.2 Summary of principal changes to some inorganic materials

Material	**Agent**		
	Clean air	**Outdoor polluted air**	**Indoor polluted air**
Ceramics	Not affected [a]	Not affected [b]	Not affected
Limestone	Not affected [c]	Transformed into soluble gypsum [d]	Not affected
Marble	Not affected[e]	[f]	
Sandstone	Swelling [g]	Swelling[h]	
Shells	Not affected	Not affected	Growth of white soluble salts [i]
Mineralogical specimens with iron	Forms iron oxide (rust), which splits the specimen [j]		
Mineralogical specimens with fluorite	Deliquesce [k]		

[a] *Changes caused by pure air on ceramics*: ceramic is chemically almost inert. In the absence of foreign substances, humidity will in no way damage the material. Only the alkaline oxide glazes of faience dissolve very slowly in water.

[b] *Changes caused by polluted air on ceramics*: as in [a], ceramics are not sensitive to pollutants.

[c] *Changes caused by pure air on limestone*: in practice, none, because the process is exceptionally slow. Humidity and carbon dioxide transform the carbonates into bicarbonates. After exposure to rain, the surfaces of limestone rock, lime mortars and plasters:
- Are weakened because the rain dissolves the bicarbonates
- Become covered with a hard layer due to re-crystallization of the bicarbonates in surface carbonates on areas protected from the rain.

[d] *Changes caused by polluted air on limestone*: when condensation occurs on materials, which contain calcium carbonate ($CaCO_3$), such as limestone, marble, plaster with a lime base, frescoes, alkaline sandstone, etc., the following chemical reaction occurs:

$$CaCO_3 + H_2S \rightarrow CaSO_4 + H_2O + CO_2$$

Calcium carbonate + sulphuric acid → calcium sulphate + water + carbon dioxide

The acid reacts with the carbonates to produce effervescence and a discharge of carbon dioxide. Insoluble calcium carbonate is transformed into a white powder of calcium sulphate (gypsum), soluble in water, with the result that when the stone is exposed to rain, the gypsum is washed away and when the stone is protected from the rain, a powdery, salty, black layer is formed. It is not a protective layer, as it is rarely impermeable and unbroken. Deterioration can therefore continue underneath the crust. The stone will lose its cohesion and it will be attacked deeply inside.

[e] *Changes caused by pure air on marble*: none.

[f] *Changes caused by polluted air on marble*: identical to [d]. When H_2SO_4 comes into contact with marble as a result of condensation, it chemically attacks the bonds of the crystals on the surface. The crystals are detached and can be rubbed away with fingers. The surface of the marble becomes tough and pitted.

[g] *Changes caused by pure air on sandstone*: soft sandstone swells when exposed to water vapour. It is a physical phenomenon and one, which causes the stone to break up.

[h] *Changes caused by polluted air on sandstone*: this is not a chemical reaction as such, in fact it is a layer created by the accumulation of dust and pollutants. This is not a protective layer.

[i] *Changes caused by polluted indoor vapours on shell*: shell deteriorates in the presence of organic acid vapours (mainly formic and acetic acids) given off by oak, larch, teak, etc. The organic acids react with the shells to form salts, which are a mixture of calcium formate and acetate. To protect shells from this type of deterioration, a coating of wax or varnish can be applied.

[j] *Changes caused by pure air on mineralogical specimens*: in the presence of humidity, iron sulphur present in marcasite and pyrites is transformed into limonite, recognizable by its oozing reddish and yellow-brown colours. These reactions are accompanied by the release of sulphuric acid, which leaves the material subject to

attack by environmental substances such as limestone and results in the total destruction of the material.

[k] Mineralogical specimens containing fluorite absorb water vapour and they hydrate and either change their chemical composition, or gradually dissolve as they change into a watery solution. This process is known as deliquescence. Conversely, in the absence of humidity, some specimens containing hydrates can lose their water crystals and dry up (Waller 1992).

5.3.3 Actions of humidity and corrosive agents on glass

Glass is made by heating sand (silica oxide – SiO_2) at a very high temperature. Pure sand melts at about 1700 °C. In order to lower the temperature of fusion to below 1000 °C, over time different workshops have added various chemicals to the melt. Most commonly, alkaline salts potassium oxide (K_2O) or sodium oxide (Na_2O) have been used as a flux. To avoid crystallization of the glass, the flux must be stabilized. Calcium oxide is commonly used for this. Glass will be either stable or sensitive to humidity depending on the proportion of SiO_2, K_2O and Na_2O. By chance, about 90% of glass objects contain the right ratio of the three elements and so are very insensitive to water. The other 10% contain an excess of flux or too little stabilizer and they become sensitive to moisture (Newton 1989).

Table 5.3 Summary of principal changes to glass

Material	Agent		
	Clean air	Outdoor polluted air (H_2SO_4)	Indoor polluted air
Glass and enamels	Not affected		
Very sensitive glass (often very finely worked, of the 'Venetian' type)	bitter tasting droplets form on the surface - loss of transparency caused by a network of small fractures [a]		
Sensitive glass; stained glass (12th and 13th century)	Localized pitting {b}	Generalized crust and opacity [b]	

[a] *Change caused by humidity on sensitive glass*: the flux slowly hydrates in an invisible reaction:

$$Na_2O + H_2O \rightarrow 2NaOH$$

$$\text{And} \quad 2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

This phenomenon is still under study, but one can observe two types of deterioration: weeping and crizzling.

Weeping glass: droplets of water on the surface of the glass. The hydrate fondants migrate to the surface; this will lead to change into hygroscopic salts when they are in contact with the air. They hydrate further, deliquesce and an oily looking alkaline film forms (Thomson 1986).

Crizzling: soluble salts may crystallize in low RH. The glass quickly becomes opaque and develops a network of micro-cracks, known as crizzling. At first, this change is visible only when the glass is held in a certain light. Later, it becomes obviously milky-looking. Later still, the glass looks like the broken windscreen of a car and can collapse at a mere touch (Brill 1975; Newton 1989).

5.3.4 Action of corrosive agents on metals

There are six metals and their alloys, that are commonly found in museum objects: gold, silver, copper (and its alloys of bronze and brass), lead, tin and iron (and its alloys of steel and cast iron).
With the exception of gold and copper, metal objects in a collection are rarely in their natural state. They are mineral extracts obtained through metallurgical operations requiring large amounts of heat. As a result, metals are the most unstable of the inorganic materials and are always trying to return to a mineral state. This phenomenon, which can either be natural or due to the interaction of different agents, is called 'corrosion' (Hamilton 1976).
Some of the products of corrosion are given in Table 5.4, followed by further information on how these products develop. The descriptions of the processes of corrosion have been simplified in order to show:

- How corrosion slows down on its own
- The primary role of humidity in corrosion
- The role of other substances (chlorides) in increasing the speed of corrosion.

Table 5.4 Information on processes of corrosion

Material	Agent			
	Pure air (O_2, H_2O, CO_2)	Outdoor polluted air	Indoor polluted air	Air with chlorides
Iron	Pits, then surface layer swells with brown colour ($Fe_2O_3.H_2O$)[a]	Surface turns black-yellow due to sulphur (FeS, FeS_2)	No specific damage	Orange spots ($FeCl_2$, $FeCl_3$) [b]
Lead	Thin surface layer forms of grey-brown oxide (PbO_2)[c]	Surface turns black (PbS)	Surface turns a powdery white ($2PbCO_3.Pb(OH)2$) [d]	Surface turns white ($PbCl_2$, $PbCO_3.PbCl_2$) [D]
Copper and copper alloys	Surface turns red-brown; in high humidity + CO_2, surface can turn blue or deep green [e]	Surface turns pale green ($3Cu(OH)_2$. $CuSO_4$) [f]	No specific effects	Surface develops coating of pale green waxy powder ($CuCl$) [g]
Silver	Surface tarnishes to brown-black oxide (Ag_2S) [h]	Accelerated surface tarnishing to black sulphide (Ag_2S) [i]	No specific effects	Surface tarnishes to a grey colour ($AgCl$) [j]

5.3.5 Iron

[a] *Changes caused by pure air on iron.*
In the presence of humid air, iron is first transformed into ferrous hydroxide ($Fe(OH)_2$). As oxidation continues, ferric hydroxide ($Fe(OH)_3$) appears. In the presence of oxygen, the following reaction takes place:

$$4Fe(OH)_2 + O_2 \rightarrow 2H_2O + 2Fe_2O_3.H_2O$$

The resulting orange to reddish-brown compound is what we call rust. The chemical transformation of healthy iron into iron oxides is characterized by pits, spots, or layers of rust. This corrosion is slow. Cut polished metals or those in good conditions can easily be ruined by just a few pits of rust.
Excavated objects form oxides of other forms and colours, depending on the level of oxygen in their environment. If an object is in an advanced state of rusting, it may be difficult to recognize its original shape. The surface will become swollen, cracked and powdery (Hamilton 1976).

[b] *Changes caused by marine air on iron.*
In an environment containing chlorides, corrosion of iron is accelerated as various salts are introduced into the core of an object, which is already porous. These salts include ferrous chloride ($FeCl_2$) and ferric chloride ($FeCl_3$).

$$Fe + 2H_2O + 2NaCl \rightarrow FeCl_2 + 2NaOH + H_2$$

Iron + water + common salt → ferrous chloride + sodium hydroxide + hydrogen

These orange salts are not stable and decompose easily in the presence of oxygen and water.

$$4FeCl_2 + 4H_2O + O_2 \rightarrow 2Fe_2O_3 + 8HCl$$

The result is iron oxide (Fe_2O_3) and hydrochloric acid (HCl).
The hydrochloric acid formed attacks the metal once again:

$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$

A vicious circle is created; chlorides continue to be generated and in their turn attack healthy iron. This cycle continues until the metal is completely destroyed. This is why this process is called ‘active’ or ‘unstable’ corrosion. In an advanced state of corrosion and in the presence of abundant oxygen, plaques start forming and peel off. In oxygen-poor environments, as when an object is buried in the ground or submerged in water, the cycle advances quite slowly. However, once an object is excavated, the abrupt change of environment combined with exposure to oxygen can cause it to split into fragments in a matter of days. To protect objects from this corrosion, a museum must eliminate the chlorides and keep the objects in a dry environment (Hamilton 1976).

5.3.6 Lead

[c] *Changes caused by pure air on lead.*
Lead is virtually unaffected by pure air and humidity. It has a fine oxide layer, which is impervious to water and protects it. However, recent research shows that non-metallic impurities in lead may be linked to its deterioration. These impurities, together with soluble salts, can react to humidity (Stambolov 1985).

[d] *Changes caused by indoor polluted vapour on lead.*
In the presence of humidity and organic acids, mainly those from materials used in exhibitions, – oak containers *inter alia* – the surface of lead can become pitted with corrosion. There may be small clumps of whitish powder, or the object may appear

milky-white with a flaky powder. If the process continues, the metal is completely transformed into a pile of grey powder. These symptoms are indicative of the active corrosion of lead with the formation of basic lead carbonate ($2PbCO_3.Pb(OH)_2$, (Stambolov 1985). Based on work by Niklasson, it was concluded that there is a severe deterioration of lead in presence of acetic acid and formic acid (Niklasson *et al* 2005; 2008).

5.3.7 Copper and copper alloys

Copper is used in three alloys, mainly. These three are bronze (copper + tin), brass (copper + zinc) and lead bronze (copper + lead). All suffer from corrosion problems similar to those of copper.

[e] *Changes caused by pure air*
In its pure state, copper looks salmon pink. In air, it oxidizes rapidly, forming a protective layer of cuprite (Cu_2O) which is a dull brick red to brown, adherent and slightly porous.
Sometimes, with CO_2 and high humidity, copper hydroxycarbonates are formed, including green malachite ($Cu_2CO_3(OH)_2$) and blue azurite ($Cu_3(CO)_2(OH)_2$).
These products of change can protect the metal from more serious deterioration because they are stable and not soluble in environments, which are slightly acid or slightly alkaline.

[f] *Changes caused by polluted external air*
In the presence of SO_3 and humidity, a chemical reaction transforms copper oxides into basic copper sulphate:

$$4Cu_2O + 2SO_2 + 3O_2 + 6H_2O \rightarrow 2(3Cu(OH)_2.CuSO_4) \text{ (green colour)}$$

When humidity and SO_2 levels are high, corrosion is accelerated considerably.

[g] *Changes caused by marine air*
Copper and its alloys are subject to a dangerous cycle of corrosion when exposed to humid air containing chlorides. Once the marine metal artefacts are recovered from the sea to the atmosphere, the artefacts contaminated with chlorides become active and the flaking of the original surface is usually observed. This is particularly true for iron-based artefacts. Therefore, these artefacts should be immediately stored in alkaline solution (North and MacLeod 1987 ; Scott 2002). This cycle is similar to that of iron, even though the mechanisms of the corrosion are different. The corrosion product is a pale-green, waxy powder. First, electrochemical corrosion takes place between the copper and its oxides. It spreads with the introduction of chlorides (Leyssens 2006; North and MacLeod 1987).

$$Cu^+ + Cl \rightarrow CuCl$$

$$2CuCl + H_2O \rightarrow CU_2O + 2H^+ + 2Cl^-$$

$$Cu^+ + Cl^- \rightarrow CuCl \qquad \text{- and the cycle repeats.}$$

Humidity is essential for this phenomenon to take place. All alloys containing copper will be affected by it. This self-perpetuating cycle is commonly called 'bronze disease' and continues in the presence of humidity until all the metal has been totally destroyed. This is also called 'unstable' or 'active' corrosion (Leyssens 2006; Scott 2002).

5.3.8 Silver

Silver is often not pure, but mixed with copper. In this case, the copper is attacked before the silver and a layer of corrosion, giving the impression of a copper object, covers the object. Silver artefacts are tarnished when they are exposed to sulphur atmospheres or chlorinated media (such as human sweat). When pure silver corrodes, it proceeds as set (Adriaens and Dowsett 2007).

[h] *Changes caused by pure air*
Silver tarnishes slowly, with the formation of a very thin brown protective layer of silver oxide (Ag_2O).

[i] *Changes caused by polluted outdoor or indoor vapour*
In the presence of sulphur containing pollutants, tarnishing is accelerated, with the creation of black silver sulphide (Ag_2S).

[j] *Changes caused by marine air*
In the presence of chloride, a grey layer of powdery silver chloride (AgCl) forms.

5.4 Environmental classifications

The ISA standard S71.04-1985 "Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants" (ISA 1986), which is used to verify the efficiency of an HVAC air-conditioning system's filtration unit, can be helpful in assessing the results of semi-quantitative monitoring methods as shown in Table 5.5.
Although there is no direct correlation between these ISA classes and preservation targets, the corrosion of metal coupons can be a useful method for providing an indication of improvement after a change in control strategy or for semi-quantifying different environments (Tetreault 1992).

Table 5.5 ISA environmental classes

ISA S71.04 classes				
Copper coupon Film thickness (nm)	G1	G2	G3	GX
	0-29	30-99	100-199	≥200
Gas concentrations (μg m^{-3}), RH<50%				
H_2S	<4	<10	<70	≥70
$SO_2.SO_3$	<30	<300	<800	≥800
Cl_2	<3	<6	<30	≥30
NO_x	<100	<200	<2000	≥2000
NH_3	<400	<7000	<20 000	≥20 000
O_3	<4	<50	<200	≥200

Table 5.5 lists a standard classification scheme, which directly correlates corrosion rates to environmental classifications. Typical uses of reactivity monitoring to date have been for the characterization of outdoor air used for ventilation, the identification of 'hot spots' within a facility and the effectiveness of various preventive measures. Reactivity monitoring is being used for the purpose of identifying the cause-and-effect relationship between gaseous pollutants and the damage they may cause within preservation environments and to paper documents, artwork and historical artefacts.

Table 5.6 Purafil Environmental classifications for preservation environments

Silver Corrosion			Copper Corrosion		
Class	Air Quality Classification	Corrosion Amount	Class	Air Quality Classification	Corrosion Amount
S1	Extremely Pure	< 40? / 30 days	C1	Extremely Pure	< 90? / 30 days
S2	Pure	< 100? / 30 days	C2	Pure	< 150? / 30 days
S3	Clean	< 200? / 30 days	C3	Clean	< 250? / 30 days
S4	Slightly Contaminated	< 300? / 30 days	C4	Slightly Contaminated	< 350? / 30 days
S5	Polluted	≥ 300? / 30 days	C5	Polluted	≥ 350? / 30 days

5.4.1 Air purity requirements

Based on the work of Muller and the ISO standard EN-ISO 1184 the following classification can be given:

Class S1/C1: Archives, Metal Collections, Rare Books
Class S2/C2: Museums, Museum Storage, Libraries
Class S3/C3: Historic Houses
Class S4/C4: Short Term Acceptable
Class S5/C5: Not Acceptable

Generally speaking, the silver and copper corrosion rates should be class S2/C2 or better. The individual corrosion films quantified using reactivity monitoring may be used to further characterize the environment and to determine the proper control strategies. Based upon these recommended control levels and test results from laboratory and field-exposed silver coupons, acceptance criteria relevant to these applications has been determined. These criteria take into account total corrosion as well as the relative contribution of each individual corrosion film. The control specifications for the individual corrosion films are listed in Table 5.6. These specifications are more general in their application than those listed above and are most often used for the characterization of an environment prior to the implementation of pollutant control measures (Muller 1996).

Table 5.7 General reactivity monitoring acceptance criteria

Silver Reactivity Acceptance Criteria		Copper Reactivity Acceptance Criteria	
Silver Corrosion Reaction Products	Corrosion Film Thickness	Copper Corrosion Reaction Products	Corrosion Film Thickness
Silver Chloride, AgCl Silver Sulphide, Ag_2S Silver Oxide, Ag_2O	0? / 30 days <50? / 30 days <50? / 30 days	Copper Sulphide, Cu_2S Copper Oxide, Cu_2O Copper Unknowns	0? / 30 days <150? / 30 days 0? / 30 days
Total Silver Corrosion	<100? / 30 days	Total Copper Corrosion	<150? / 30 days

As long as the total corrosion and each individual corrosion film meet the recommended criteria, the local environment in which that particular coupon has been exposed meets the requirements of a Class S2/C2 classification. Any of the criteria, which are not met, indicates that the local environment may not be sufficiently well-controlled to minimize the decay of artefacts and materials due to the presence of gaseous pollutants. Steps should be taken to determine what problems exist and what corrective actions may be appropriate (Muller 1996).

5.5 Applications

Figure 5.3 A sample of deteriorated objects displayed on a bare shelf at the storage of the DoA.
Photo by: R.Alghazawi

The study of deterioration processes is the most important part of conservation, as it is only when these processes are properly understood that realistic protective measures can be taken. In 2009, it was obvious that most of the artefacts in the monitored museums were suffering from deterioration and damage, caused by unsuitable environmental conditions. Moreover, poor handling as a result of lack of knowledge and training of the staff contributes to and accelerates the deterioration of the collections (Cronyn 1990). The study follows a procedure of detecting the gaseous pollution of the selected museums. For this purpose, ten museums were selected, illustrated in Table 5.8. These museums differ in their locations, types and buildings.

Table 5.8 Overview of the monitored museums

Museum	Location	Geographical location	collection	Coupons location
Dar Alsaraya museum	*Urban*	*North of Jordan*	*-pottery; -bones; -parchment; -metal; -accessories; -glass; -mosaics*	*DSM1–in the ancient era hall DSM2–in the metallurgy hall DSM3–in the classical period hall DSM4–in the classical hall DSM5–in the sculptures hall DSM6–in the mosaics hall DSM7–in a storage case DSM8–on a shelf of the storage*
DoA (Storage and Archive)	*Urban*	*Middle of Jordan*	*-excavated archaeological objects; -paper*	*DAA1–in the archive hall DAA2-in the archive hall in a drawer DAA3–in a case DAS1–in a storage room DAS2–in a small room in the storage area DAS3–in the storage area DAS4–in the main hall DAS5–at the entrance DAS6–in the cave DAS7–in the cave*
Karak museum	*Within a historical castle*	*Middle-West of Jordan*	*-numismatics; -ceramics; -accessories; -glassware; -inscriptions*	*KM1–in the main hall KM2–inside a showcase KM3–in the second hall KM4–in the storage area KM5–in the storage area*
Madaba archaeological museum	*Urban*	*Middle of Jordan*	*-numismatics; -glass; -metal; -bones; -pottery*	*MM4–in the first hall MM5–in the inside hall MM6–in the storage area MM7–in the main hall*
Madaba folklore museum	*Urban*	*Middle of Jordan*	*-cloth; -textiles*	*MM1–in the main hall MM2–in the textile hall MM3–in the main hall*
museum of Jordanian heritage	*Urban*	*North of Jordan*	*-epigraphy; -glass -basketry; -textiles; -agricultural tools; -pottery; - furniture; -numismatics;*	*MJH5–in the reception hall MJH6–in the first display hall MJH7–in the lead sarcophagus MJH9–in the rural house MJH8–in the Islamic hall MJH10–inside a safety deposit*
Numismatics museum	*Urban*	*North of Jordan*	*-numismatics*	*MJH4–in the outside air-conditioning unit MJH1-3–coupons inside the numismatics hall*
Petra museum	*Archaeological site*	*South of Jordan*	*-pottery; -bronze objects; -ceramic wares; - jewellery; -numismatics*	*PM1–in the first hall PM2–in the inside hall*
Salt museum	*Urban*	*West of Jordan*	*- pottery; - copper objects; -bronze bracelets; -numismatics; -glass collection; -mosaics*	*SM1–in the Islamic hall SM2–in the Hellenistic hall SM3–in the Late Bronze Age hall SM4–at the entrance hall*
Umm Qeis museum	*Heritage site*	*North of Jordan*	*-flint tools; -stone sculptures; -statues; -glass; -metallic objects; -accessories*	*UMQ1–in the mosaic hall UMQ2–in the sculptures hall UMQ3–in the sculptures hall UMQ4–in the first hall*

5.5.1 The Dar Alsaraya Museum

The Saraya Castle was built in 1886 as a residence for the Ottoman governor. Later the Jordanian police used it as a local prison until 1994.

The museum hosts a valuable collection of archaeological objects (pottery, bones, parchment, metal, accessories, glass and mosaics) and uses a variety of display methods.

The main display halls at this museum do not have windows within their walls, thus the air changes in the halls is limited.

This museum was monitored from June 6 2008, until January 29, 2009. For this case study, eight coupons were used to measure the climate:

Figure 5.4 Dar Alsaraya museum
Photo by: R.Alghazawi

- The first coupon, DSM1, was installed in the Ancient Era hall behind a glass portrait, near a window, but hidden from light, to measure the exact indoor climate of this hall.
- DSM2 was placed in the metallurgy room, inside a showcase, to see if there is a difference between the microclimate of the cases and the indoor climate.
- DSM3 was placed in the Classical Period room, behind a portrait in the middle of room, far from light and windows.
- DSM4 was placed in the Classical Period room, inside a well-sealed glass showcase.
- DSM5 was placed behind a portrait in the Sculptures hall in the middle of the room, far from light and windows.
- DSM6 was placed in the corner of the mosaic hall next to the security camera, far from the window and facing direct artificial light.
- DSM7 was installed in the storage area of the Dar Alsaraya Museum, inside a closet of pottery objects, far from light and any interactive agent.
- DSM8 was hung in the storage area on a shelf facing a main window.

Further details about this museum can be found in annex three.

5.5.2 The Department of Antiquities archive

The Department of Antiquities (DoA) archive is located in the Third Circle area of Amman (the capital), an area which is considered to be at the old city centre of Amman. The archive is part of the main building of the DoA, which consists of three floors. It was built in two phases: the lower two floors were built during the 1970s and the upper two floors in 1994. The collection of the archive consists mainly of paper documents.

Figure 5.5 The DoA Archive
Photo by: R.Alghazawi

The archive was monitored from August 11, 2008, until February 1, 2009.
The archive is fairly small and so three coupons were sufficient to monitor the inside environment:

- The first coupon, DAA1, was installed opposite a window (with curtains)in the archive hall. Fluorescent Neon lights light the archive hall and there is central heating throughout the hall.
- DAA2 was placed inside a drawer with manuscripts. These drawers were not sealed.
- DAA3 was placed inside a closet facing a window.

5.5.3 Department of Antiquities storage

Figure 5.6 The main hall of the Department of Antiquities Storage.
Photo by: R.Alghazawi

The DoA's storage (DoAS) was built in the 1996 and is located next to a main highway which is always congested with traffic. In this storage, mainly the findings from Archaeological excavations are kept.
The storage is a pre-engineered steel building, which is not resistant to the outdoor atmosphere.
This storage was monitored from August 11, 2008, until February 1, 2009. The coupons installed in the Department of Antiquities were named DAS1-DAS7. The storage area is divided into three different climate zones. The first is the main hall, the area that holds the most objects. The second is a rather smaller room, which hosts the more sensitive materials and the last is a cave, located near the storage area and used mainly for storing pottery. In these three climate zones, seven coupons were installed:

- The first coupon, DAS1, was installed in the small storage room (the sensitive materials hall). It was hung on a shelf, located near the entrance of the room.
- DAS2 was also installed in the small room, but was hung in the far corner, far from the door.
- DAS3 was installed in the main hall of the storage area. It was hung at the entrance, on a window of an interior room near the main door of the museum.
- DAS4 was installed in the main hall of the storage area. It was hung on a shelf under a closed window, facing a direct neon light.
- DAS5 was hung near the cargo entrance, with a possibility of outside atmospheric interaction.
- DAS6 was installed in the cave (the third zone of the storage area), hung from the roof which was approximately two meters high, near the entrance. The electric lights in this cave are rarely used.
- DAS7 was also installed in the cave, hung from the roof, but at the opposite end to the entrance.

Further details about the DoA storage and archive can be found in annex three.

5.5.4 The Karak Museum

Figure 5.7 The Karak Museum
Photo by: R.Alghazawi

The Karak museum was established within the ancient Castle of Karak, which was built in the first decade BC. The castle was renovated in 1142 and in 1980, the museum was established as a part of the castle. The museum underwent its first restoration in 2001. The Karak Museum consists of two connected halls and has its own storage area. The museum hosts numismatics, ceramics, accessories, glassware and inscriptions and the collections vary in their date and shape.

This museum was monitored from August 17, 2008, until February 4, 2009. In this case, the coupons were named KM1-KM5.

- The first coupon, KM1, was installed in the main hall near the main entrance and the reception hall. It was hung on a bar behind a picture showcase.
- KM2 was installed inside a showcase, at the far end of the main hall, far from light and outside atmospheric interaction.
- KM3 was installed in the second hall. It was hung on a bar behind a big map, beside a spotlight where it could be reached by sunlight.
- KM4 was installed in the storage area of the museum. This storage area is part of the castle. Located at the underground level of the castle, it was hung on a shelf near the main entrance, with a spotlight at the top of it.
- KM5 was hung on a shelf in the middle of the storage area under an open space in the ceiling. There was direct interaction with the outside atmosphere.

Further details about this museum can be found in annex three.

5.5.5 Madaba archaeological museum

Figure 5.8 Madaba archaeological Museum
Photo by: R.Alghazawi

The two Madaba museums consist of three adjoining buildings. These buildings, with their mosaic flooring, represent the core of the archaeological museum in the city, which was established in 1978. Most of the museum display halls have one or more side openings, which mean that the rooms are open to the outside atmosphere. There is a storage area, which serves the two museums, located within the administration offices area.

The two museums host a collection of numismatics, textiles, glass, cloth, metal, bones and pottery. Here it should also be noted that the collection includes one of the biggest mosaics in the world.

These museums were monitored from August 18, 2008, until February 2, 2009. The coupons here were named MM4-MM7:

- MM4 was hung on a small fence (one meter high) in the first room of the museum, far from the window and door.
- MM5 was installed in the inside hall, hung in the corner of the room two meters high, far from the window and door.
- MM6 was installed in the museum storage area. It was hung on a shelf between some unsealed boxes. The storage area has a window, which is open most of the time.
- MM7 was installed inside a showcase. The showcase was not airtight and though far from light was near a main door.

Further details about this museum can be found in annex three.

5.5.6 Madaba Folklore Museum

The establishment of the Madaba folklore museum was synchronized with the establishment of the Madaba archaeological museum. The collection of this museum is mostly cloth and textiles.

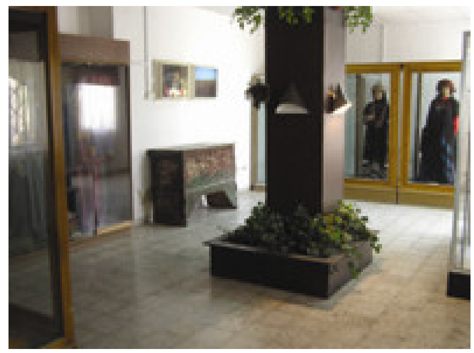

Figure 5.9 Madaba folklore museum.
Photo by: R. Alghazawi

This museum was monitored from August 18, 2008, until February 2, 2009. The coupons here were named MM1- MM3:

- The first coupon, MM1, was installed in the main hall. It was hung on the wall behind a display closet, near a closed window. This Museum has transparent curtains and it has no air-conditioning devices installed. The museum mainly depends on natural daylight in its illuminating system.
- MM2 was installed in the textiles hall, near a window without any artificial light nearby.
- MM3 was installed next to a window, with a possibility of outside atmospheric interaction.

5.5.7 The Museum of Jordanian Heritage

The Museum of Jordanian Heritage (MJH) is a part of the Faculty of Archaeology and Anthropology at Yarmouk University. The museum reflects the research and field projects conducted by the faculty, researchers and technicians of the faculty, whether independently or in cooperation with other local or foreign institutes.

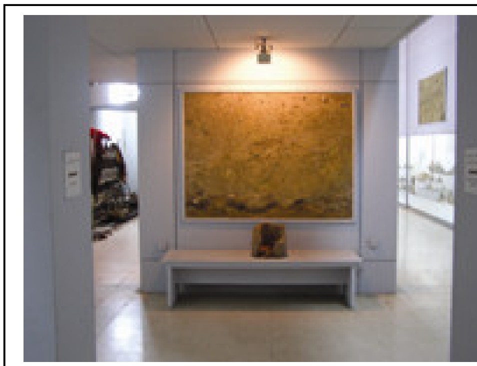

Figure 5.10 The Museum of Jordanian Heritage.
Photo by: R.Alghazawi

The museum was established in 1988 and was opened to the public in the same year. The museum used to have the Numismatics Hall as part of its facilities, but recently this has become an independent museum, the Numismatics Museum. The main gallery of the Jordanian Heritage Museum consists of four Rooms. Room one shows in Figure 5.10, deals with Jordan's prehistory and features exhibits on "Hunters, Gatherers and Food-Collectors" and "Agricultural tools". Room Two displays Pastoralist and Bedouin objects.

Room two, the courtyard, displays basic local architectural elements; a furnished living represents local guest rooms in a peasant house and there is a stable and a bread oven room.

The mezzanine floor, room three, displays stone-implements and rock-art, metallurgy, basketry and textile techniques, pottery and pottery-making and glass. In addition, there are displays on numismatics, epigraphy and seals and amulets.

Near the entrance to the museum, a special hall, room four, accommodates temporary exhibitions. The museum does not have side openings, except for the main entrance.

The museum of Jordanian Heritage was monitored from July 14, 2008, until February 8, 2009.

The coupons in this museum were named MJH5-MJH10:

- MJH5 was installed in the main hall of the Jordanian Heritage Museum. This coupon was hung in the reception hall of the museum.
- MJH6 was installed inside a showcase of a bronze dagger.
- MJH7 was installed in a showcase of a lead sarcophagus.
- MJH8 was hung on the wall of the interior hall, against an interior door.
- MJH9 was hung inside the Rural Room.
- MJH10 was installed in the safety deposit case with coins.

Further details about this museum can be found in annex three.

5.5.8 The numismatics museum

The Numismatics Museum consists mainly of one room. This hall displays a specialized exhibition of numismatics.

The Numismatics museum was monitored from July 14, 2008, until February 8, 2009.

The coupons were named MJH1-MJH4:

- The first coupon, MJH1, was installed in the Numismatics Hall, near the main door attached to the bottom of the display case. This coupon was the closest in the museum to the outside atmosphere.
- MJH2 was installed also in the Numismatics Hall. It was attached to the bottom of the display case, in the opposite corner to the entrance.
- MJH3 was installed in the Numismatics Hall, opposite the air-conditioning system.
- MJH4 was installed on the outside air-conditioning unit of the Numismatics Hall. It was hung outside, at the back of the museum.

Figure 5.11 Numismatics museum. Photo by. R. Alghazawi

5.5.9 The Petra Museum

Figure 5.12 Petra museum
Photo by: R.Alghazawi

Petra is one of the new UNESCO Seven Wonders of the Ancient World and one of the UNESCO heritage preserved sites. Petra museum is located at the west side of the city, approximately 1500m from the *Siq* entrance to Petra. The museum was established in 1994, it consists of two main halls and an entrance hall. This can be otherwise described as one environmental unit, separated into two main halls.
The entrance hall presents an introduction to the Nabataean kingdom and the geological facts about Petra. The second hall shows the excavated objects found in Petra, displayed in chronological order. The third hall shows within its cases a pottery collection, bronze objects, ceramic wares, jewellery and a numismatics collection.
Petra museum was monitored form August 20, 2008, until February 5, 2009. The coupons in this case were named PM1 and PM2.

- The first coupon, PM1, was hung on the wall in the first main hall against the western window. The window is always closed but is without curtains. The room is lit by natural light.
- PM2 was installed in the second main hall. This hall does not have any windows, but it is connected directly to the first hall and it is lit by neon light.

Further details about this museum can be found in annex three.

5.5.10 The Salt Museum

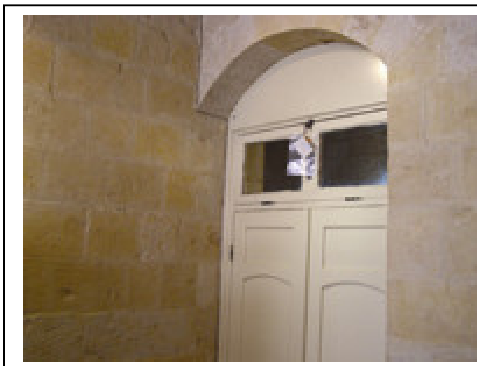

Figure 5.13 ERC hanging inside the Salt Museum
Photo by: R.Alghazawi

The Salt Museum was established in 1986, it is located in the middle of the new city centre of Salt, which experiences daily traffic jams. The museum hosts a diversity of objects including pottery, copper objects, bronze bracelets, a collection of numismatics, a glass collection and a mosaic. The Salt museum consists of two floors. On each floor, there are separate rooms and in each room, one coupon was installed.
The museum has side openings on all of the museum's façades. The main door and the doors leading to the halls are always open during working hours. The windows are open occasionally.
This museum was monitored from August 28, 2008, until February 2, 2009. In this case, the coupons were named SM1-SM4.

- The first coupon, SM1, was installed in the middle Islamic hall (the Rural Landscape). It was hung at the top of an interior door, facing a closed window.

- SM2 was installed in the Hellenistic / early Islamic period room (from forts to village). This coupon was hung on the wall between two closed windows without curtains.
- SM3 was installed in the Late Bronze Age room. It was hung on the wall between the rooms, far from windows and light.
- SM4 was installed at the entrance hall facing the main door and was exposed to sunlight and spotlights.

Further details about this museum can be found in annex three.

5.5.11 The Umm Qeis museum

In 1987 the Department of Antiquities in Jordan renovated one of the houses at the Umm Qeis archaeological site and the building has been used as a museum ever since. The museum consists of two separate halls, the first of which has three showcases. One displays the pottery collection from the Hellenistic period to the Islamic period. Another showcase displays objects that have been excavated at Umm Qeis. The last showcase displays stone and flint tools. The second hall displays statues and stone sculptures, which belong to the Roman-Byzantine period. Each display hall has a small window and a door, which is always open during working hours.

Figure 5.14 The Umm Qies Museum
Photo by: R.Alghazawi

The museum has its own courtyard, in which there are basalt sarcophagi and tombstones, plus mosaics.
This museum was monitored from July 22, 2008, until January 28, 2009. In this case, four coupons, UMQ1-UMQ4, were used to monitor the environment of the museum. Plus some out-door coupons, see table 5.18:

- UMQ1 was installed in the mosaic hall to measure the outside climate.
- UMQ2 was installed in the sculptures hall, to measure the indoor climate. This coupon was installed near the main door of the hall, to see how far the indoor climate interacts with the outside atmosphere.
- UMQ 3 was also installed in the sculpture hall, in the interior section of the hall far from doors and windows.
- UMQ 4 was placed in the first hall behind a closet. This hall has unsealed windows and a door.

Further details about this museum can be found in annex four.

5.6 Results

After their specified period in each museum, the coupons were then transferred to the Purafil headquarters to be analyzed. The results were transferred to excel sheets. The results of each museum will be shown in a separate graph below. A summary of the data can be found in annex four.

5.6.1 Dar Alsaraya Museum

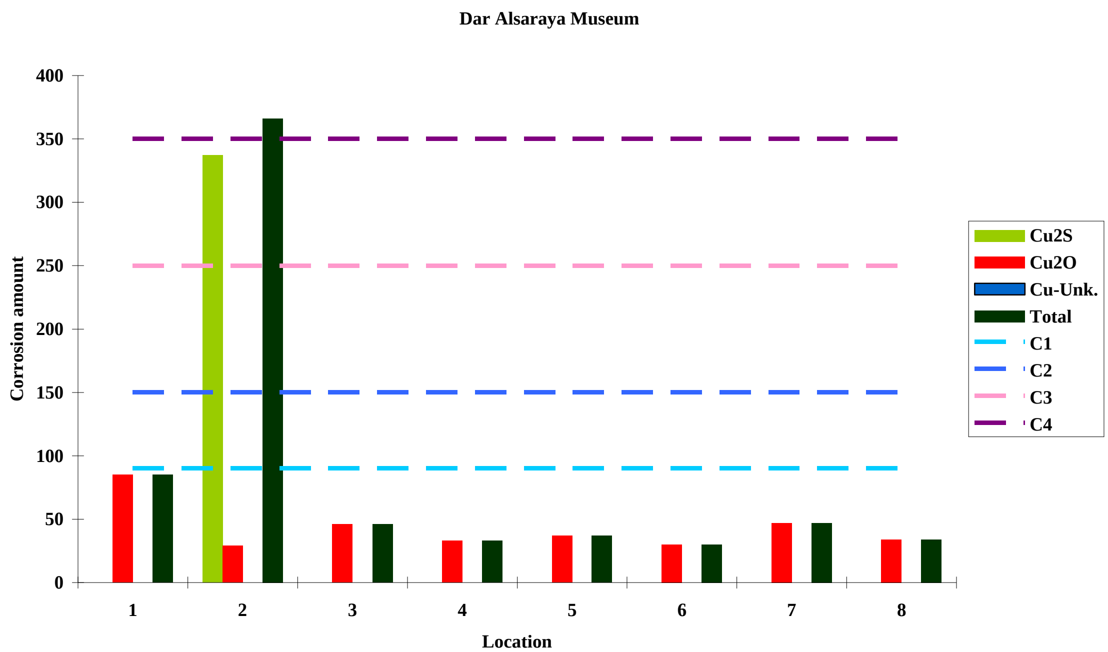

Figure 5.15 The ERC corrosion results of the copper film at the Dar Alsaraya Museum. The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted copper corrosion in ? / 30 days.

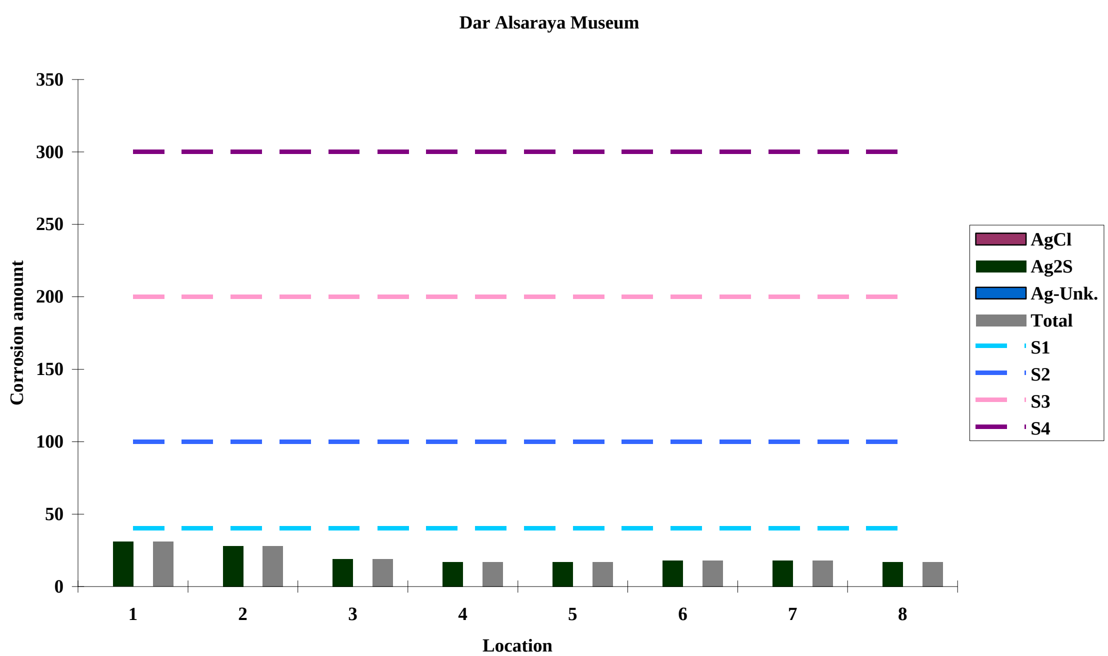

Figure 5.16 The ERC corrosion results of the silver film at the Dar Alsaraya Museum. The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines

describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted silver corrosion in ? / 30 days.

Table 5.9 Description of the locations of the coupons in the Dar Alsaraya Museum

Location number	description of location	The coupon code
1	Mosaic Hall	DSM 6
2	Ancient Period Hall	DSM 1
3	Islamic Period Hall inside case (glass case)	DSM 4
4	Metallurgy room inside case	DSM 2
5	Inside case	DSM 7
6	Outdoor	DSM 8
7	Classical periods hall	DSM 3
8	Sculptures Hall	DSM 5

The air quality for this museum is also generally acceptable as is shown in Figures 5.15 and 5.16. However, in the Ancient Period Hall (coupon DSM1) the Cu_2S levels exceed the recommended classification C2. The presence of this corrosion, combined with the relatively low level of Ag_2S, indicates the presence of active sulphur compounds in the air. Active sulphur compounds include hydrogen sulphide, elemental sulphur and organic sulphur compounds “such as mercaptans”. These gases could have been emitted from organic materials like wood or cellulose material for instance. In this location, it is advised to take measures against the gas phase contamination. An air filtration unit is capable of purifying the indoor contaminations and removing any undesirable gases easily, because this museum has a slightly closed indoor environment.

5.6.3 Department of Antiquities “Storage and Archive”

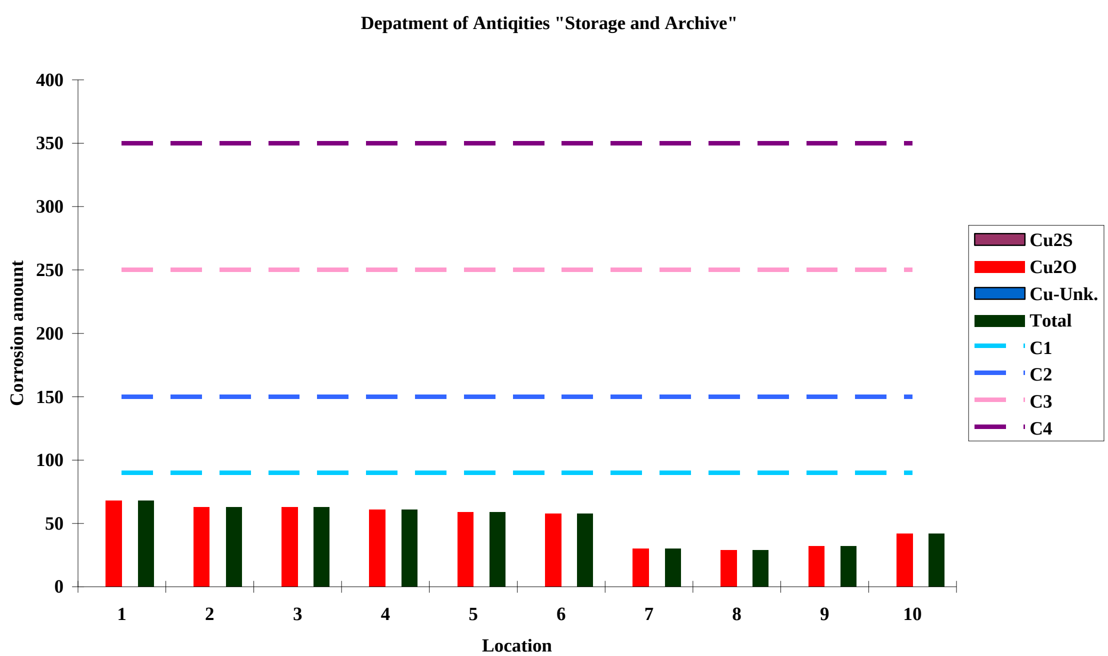

Figure 5.17 The ERC corrosion results of the copper film at the DoA “Storage and Archive”.

The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted copper corrosion in ? / 30 days.

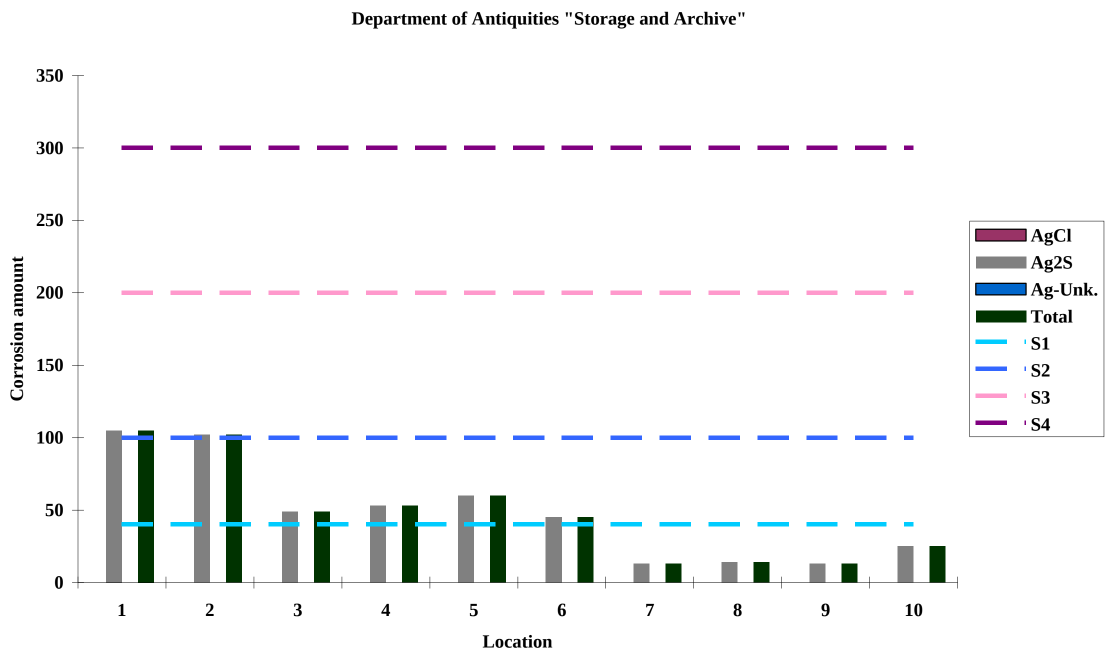

Figure 5.18 The ERC corrosion results of the silver film at the DoA "Storage and Archive".

The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted silver corrosion in ? / 30 days.

Table 5.10 Description of the locations of the coupons in the Department of Antiquities "Storage and Archive"

Location number	description of location	The coupon code
1	Main storage-exit	DAS 5
2	Storage no. 1	DAS 2
3	The Cave-inside	DAS 7
4	Main storage, Entrance	DAS 3
5	The Cave-Entrance	DAS 6
6	Main storage ,back	DAS 4
7	Archive Drawers	DAA 2
8	Storage	DAS 1
9	Archive	DAA 1
10	Archive Closet	DAA 3

The tests performed in this site show low levels of corrosion on copper at all locations. However, S2 and S3 levels were reached by the silver coupon corrosion level at six locations. Four of the coupons had Ag_2S levels that exceed the recommended maximum. At three locations the description mentions an exit or entrance, which would indicate that the location has a connection with the outside air. High levels of Ag_2S with no corresponding Cu_2S indicate the presence of oxidized forms of sulphur such as sulphur dioxide or sulphur trioxide. These gases are typically formed with the combustion of fossil fuels, like petrol or diesel. It is recommended to clean the air with chemical filters. To determine the exact type of air filter, a site survey is needed to observe the situation.

5.6.4 Karak Museum

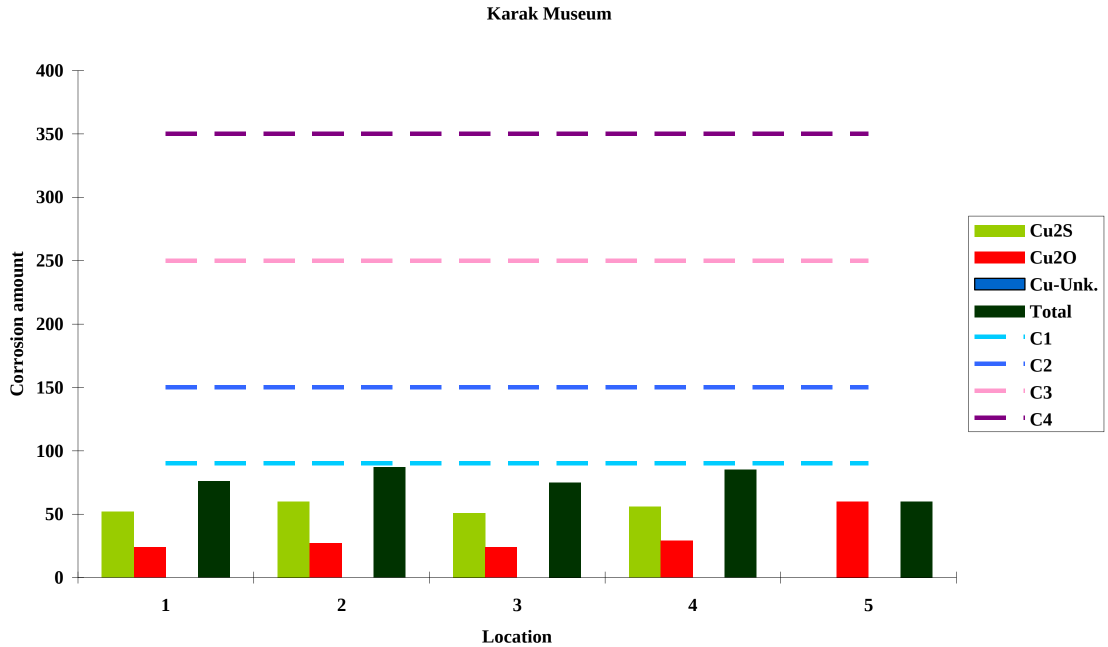

Figure 5.19 The ERC corrosion results of the copper film at the Karak Museum.

The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted copper corrosion in ? / 30 days.

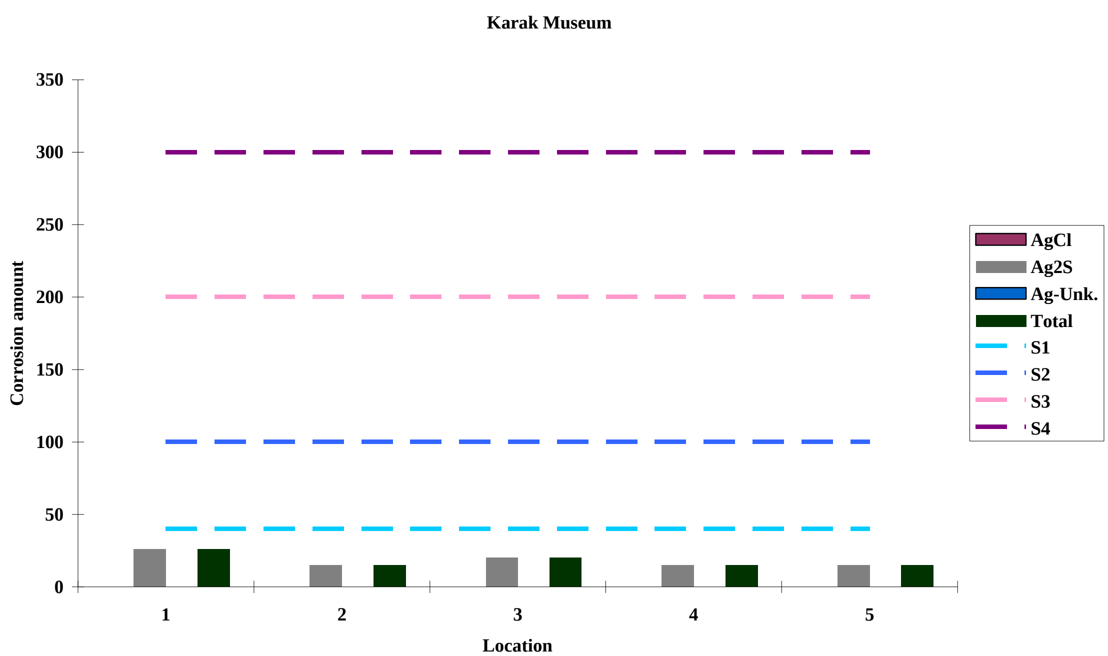

Figure 5.20 The ERC corrosion results of the silver film at the Karak Museum.

The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted silver corrosion in ? / 30 days.

Table 5.11 Description of the locations of the coupons in the Karak Museum

Location number	description of location	The coupon code
1	Main Hall entrance	KM 1
2	Entrance	KM 4
3	Main Hall back side	KM 3
4	Entrance	KM 5
5	Main Hall inside closet	KM 2

The total corrosion measured in this museum is generally acceptable. However, when looking at the individual corrosion layers, four of the locations exceeded the recommended maximum level for Cu_2S. The presence of this corrosion, combined with the relatively low level of Ag_2S, indicates the presence of active sulphur compounds in the air. Active sulphur compounds include hydrogen sulphide, elemental sulphur and organic sulphur compounds such as mercaptans. Since H_2S is a very aggressive gas, preventive measures are recommended to control this contaminant and reduce it to acceptable levels. Additionally, it is further recommended that reactivity monitoring be continued to monitor the levels of gas contamination in the air, as well as the air outside the building.

5.6.5 Madaba Archaeology Museum

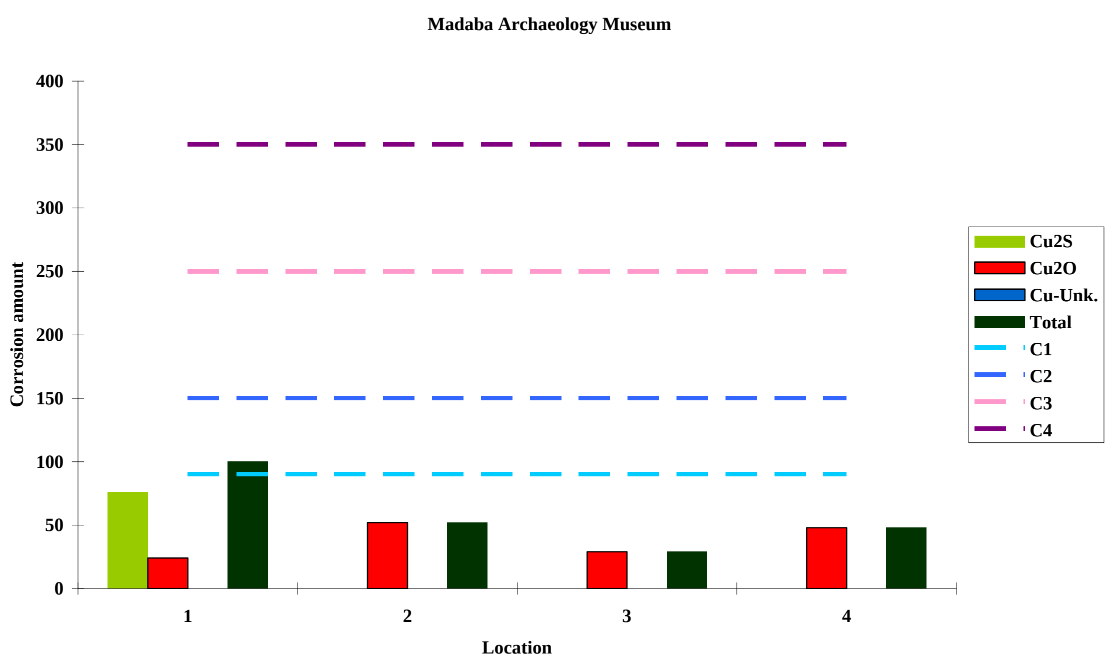

Figure 5.21 The ERC corrosion results of the copper film at the Madaba Archaeology Museum.

The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted copper corrosion in ? / 30 days.

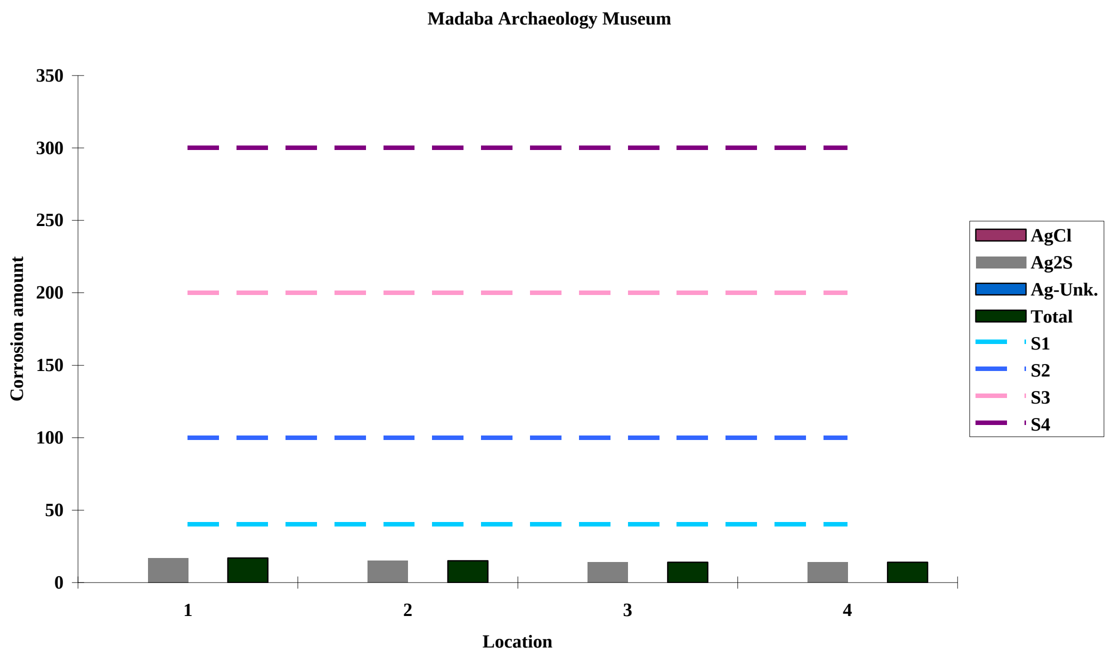

Figure 5.22 The ERC corrosion results of the silver film at the Madaba Archaeology Museum.
The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted silver corrosion in ? / 30 days.

Table 5.12 Description of the locations of the coupons in the Madaba Archaeology Museum

Location number	description of location	The coupon code
1	Storage	MM 6
2	Second show room	MM 5
3	In show room case	MM 7
4	Main show room	MM 4

Except for room with the MM6 coupon, the measurements taken at this museum show low corrosion levels. In the room where the MM6 was placed, the copper corrosion is at a C2 level and combined with a high Cu_2S level, this is reason for some concern. This situation should at least be monitored and if the source is not known, installing an air-filtration unit of active sulphur gases is recommended.

5.6.6 Madaba Folklore Museum

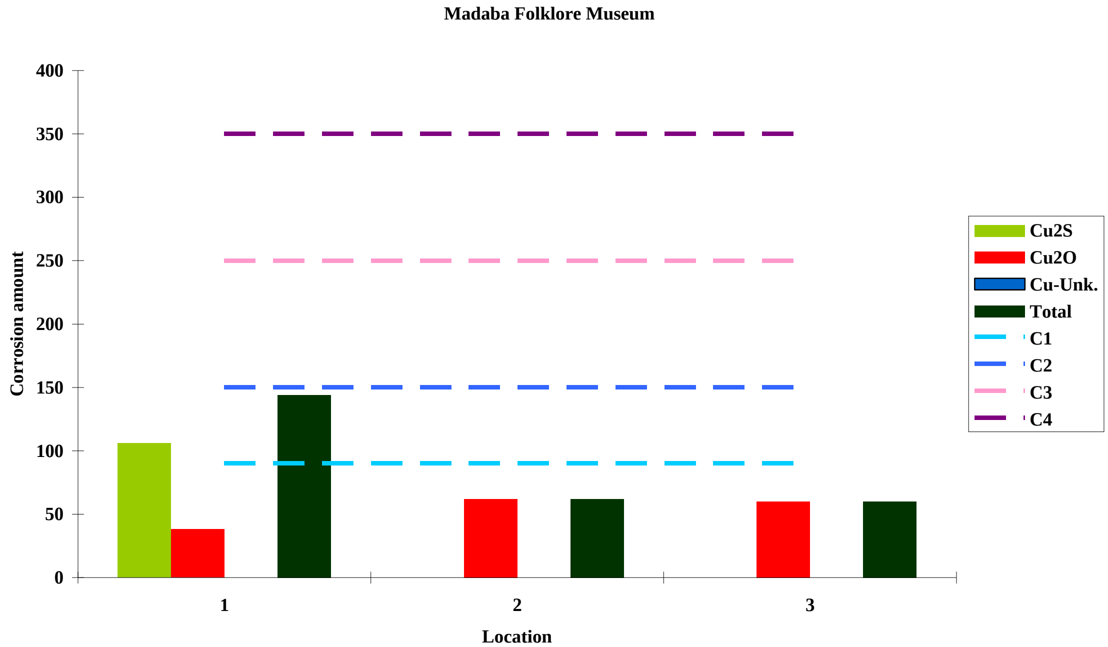

Figure 5.23 The ERC corrosion results of the copper film at the Madaba Folklore Museum.

The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted copper corrosion in ? / 30 days.

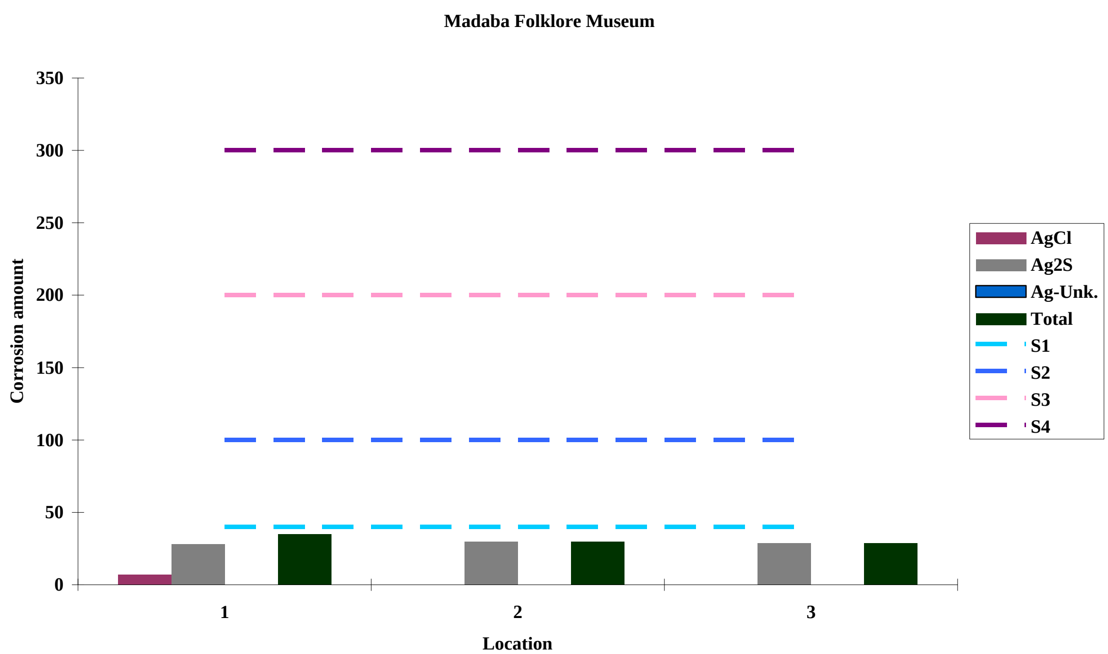

Figure 5.24 The ERC corrosion results of the silver film at the Madaba Folklore Museum.

The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of

Corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted silver corrosion in ? / 30 days.

Table 5.13 Description of the locations of the coupons in the Madaba Folklore Museum

Location number	description of location	The coupon code
1	Main Hall	MM 1
2	Textile Hall	MM 2
3	Main Hall Entrance	MM 3

With the Exception of the main hall in which the coupon MM1 was placed, the results of measurements, which were taken at this museum, show low corrosion levels. In the MM1 room however, traces of chlorine and active sulphur contamination were found which are of particular concern in preservation environments. It is highly recommended that reactivity monitoring be continued to determine potential sources of these contaminants and direct gas monitoring may be required. Installing chemical filters in the outside air-conditioning units serving this area should also be considered, in order to control these contaminants and reduce them to acceptable levels.

5.6.7 Museum of Jordanian Heritage

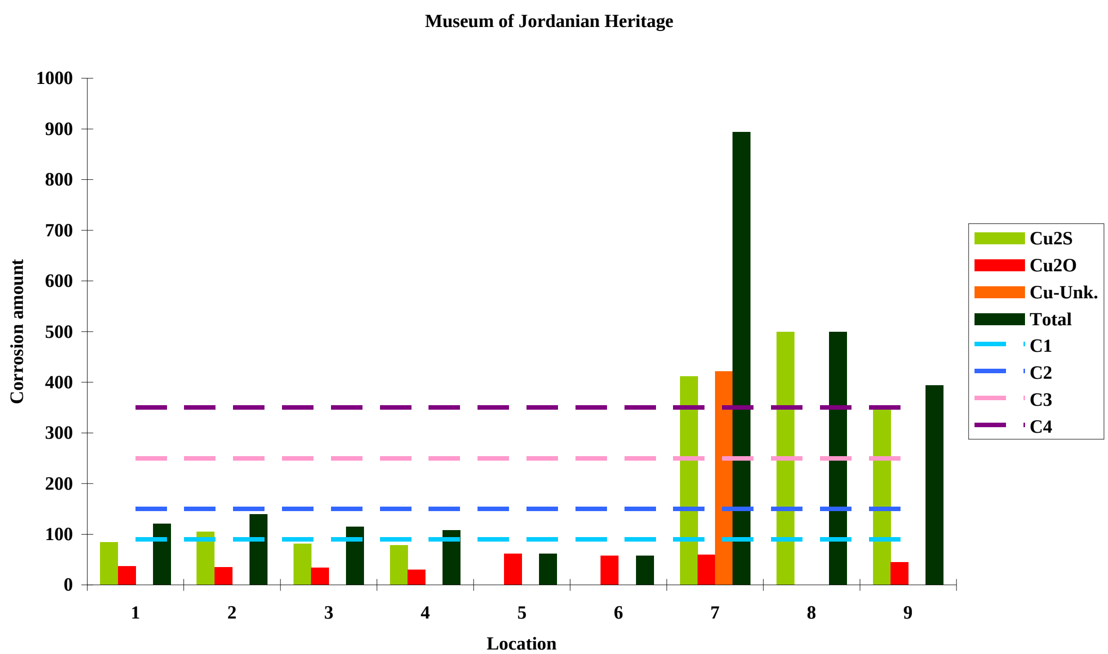

Figure 5.25 The ERC corrosion results of the copper film at the Museum of Jordanian Heritage.

The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted copper corrosion in ? / 30 days.

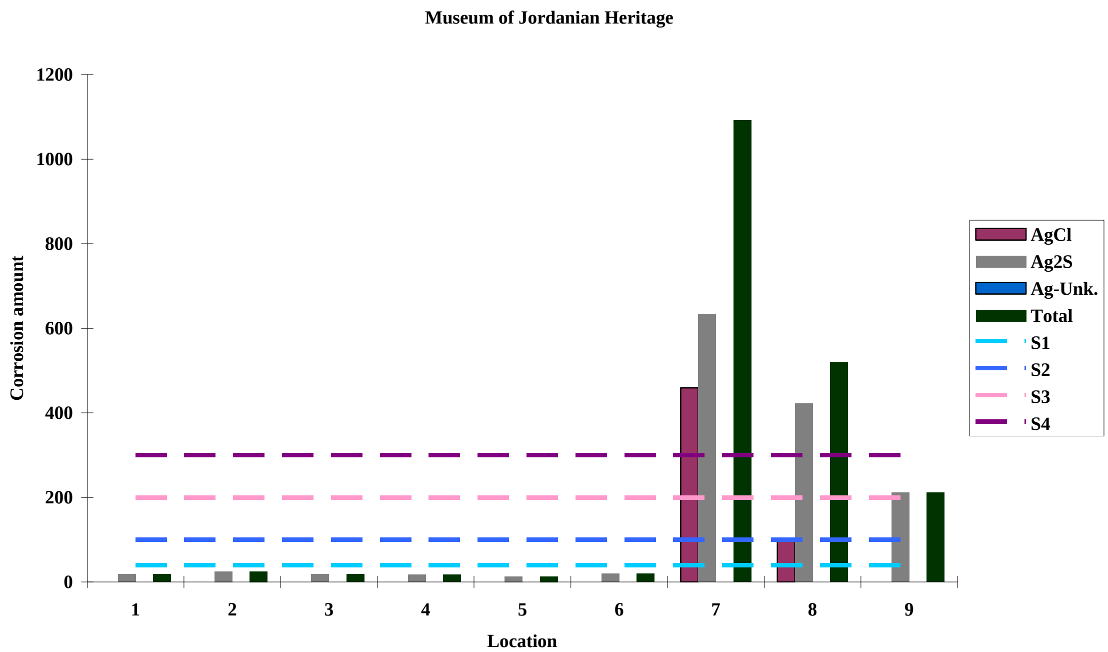

Figure 5.26 The ERC corrosion results of the silver film at the Museum of Jordanian Heritage.

The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted silver corrosion in ? / 30 days.

Table 5.14 Description of the locations of the coupons in the Museum of Jordanian Heritage

Location number	description of location	The coupon code
1	Inside show case Lead Sarcophagus	MJH 7
2	Bayet Refe (pesant house)	MJH 9
3	Warehouse (storage)	MJH 10
4	Inside show case	MJH 6
5	Entrance	MJH 5
6	Forth hall Islamic period objects	MJH 8
7	W outside Airco-Inlet	MJH 11
8	SW Outside Airco-Inlet	MJH12
9	E Outside window	MJH13

Looking at the total corrosion levels of the test coupons in this museum, the situation is not too bad. However, when looking at the individual corrosion layers, in four locations the Cu_2S levels are too high. The presence of this corrosion, combined with the relatively low level of Ag_2S, indicates the presence of active sulphur compounds in the air. Active sulphur compounds include hydrogen sulphide, elemental sulphur and organic sulphur compounds such as mercaptans and carbonylsulphide (Costa and Dubus 2007). Since H_2S is a very aggressive gas, preventive measures are recommended. It is necessary to continue the monitoring of the levels of gas contamination in the air, as well as the outside air around the building.

5.6.8 Numismatics Museum

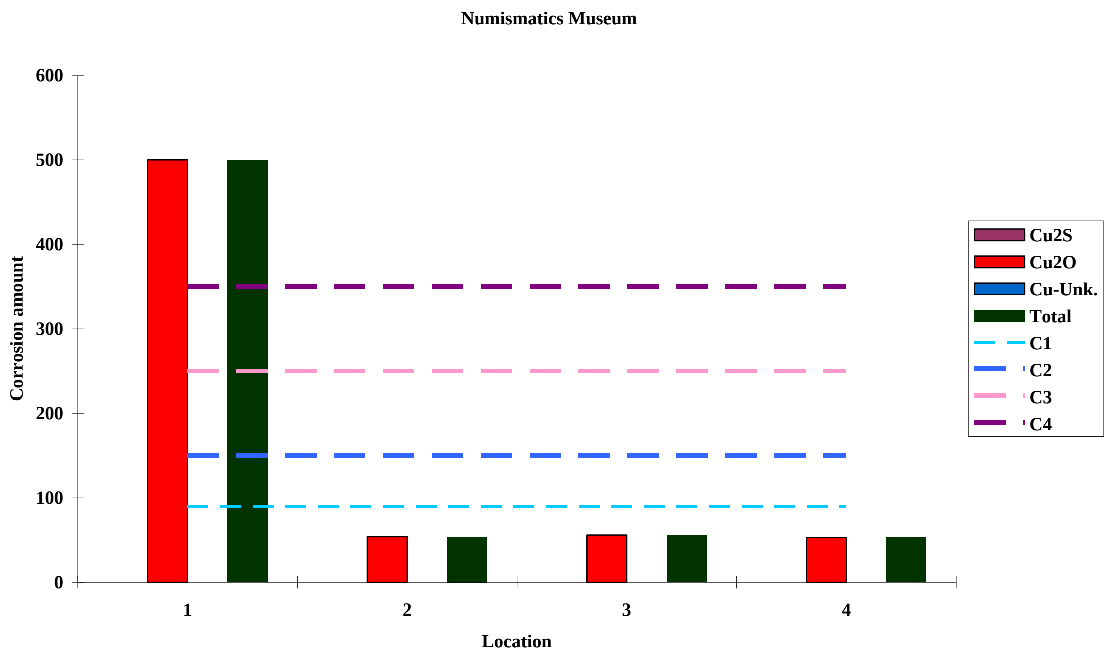

Figure 5.27 The ERC corrosion results of the copper film at the Numismatics Museum. The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted copper corrosion in ? / 30 days.

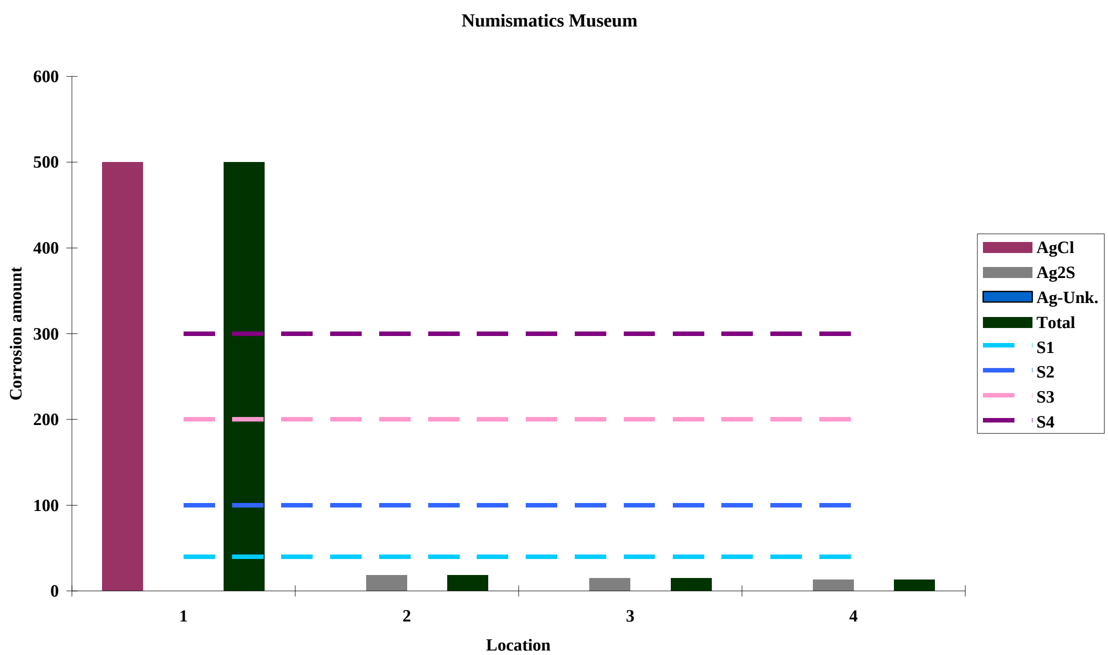

Figure 5.28 The ERC corrosion results of the silver film at the Numismatics Museum. The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines

describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted silver corrosion in ? / 30 days.

Table 5.15 Description of the locations of the coupons in the Numismatics Museum

Location number	description of location	The coupon code
1	Outside air Yarmouk	MJH 4
2	Main Hall Yarmouk Entrance	MJH 1
3	Main Hall Yarmouk Far corner from entrance	MJH 2
4	Main Hall Yarmouk Out coming air from (ac)	MJH 3

Looking at Figures 5.27 and 5.28 it can be clearly seen that there is a difference in air quality between inside and outside the building. The indoor air appears good according to the obtained results. However, the outdoor air is a serious thread to the environment inside the building. The test reported is performed during the winter season and the question remains what would happen during the summer season, when possibly more ventilation is introduced.

Based on this work, it is recommended 'at least' to check the building's physics and check the building on leakage, in order to prevent the outdoor air to enter the indoor air before the chemical filters for filtering the outdoor air are installed. It is also recommended to monitor the indoor air quality continuously, using e.g. OnGuard^{TM} 3000 monitors. Finally, a test with coupons in the summer time is recommended.

5.6.9 Petra Museum

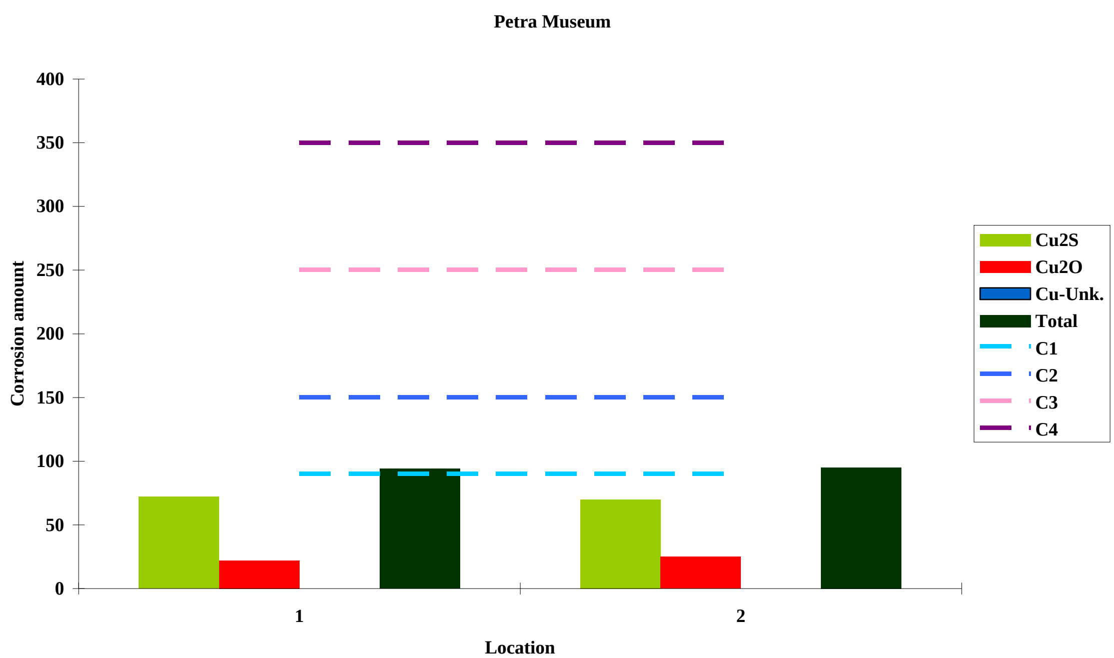

Figure 5.29 The ERC corrosion results of the copper film at the Petra Museum. The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted copper corrosion in ? / 30 days.

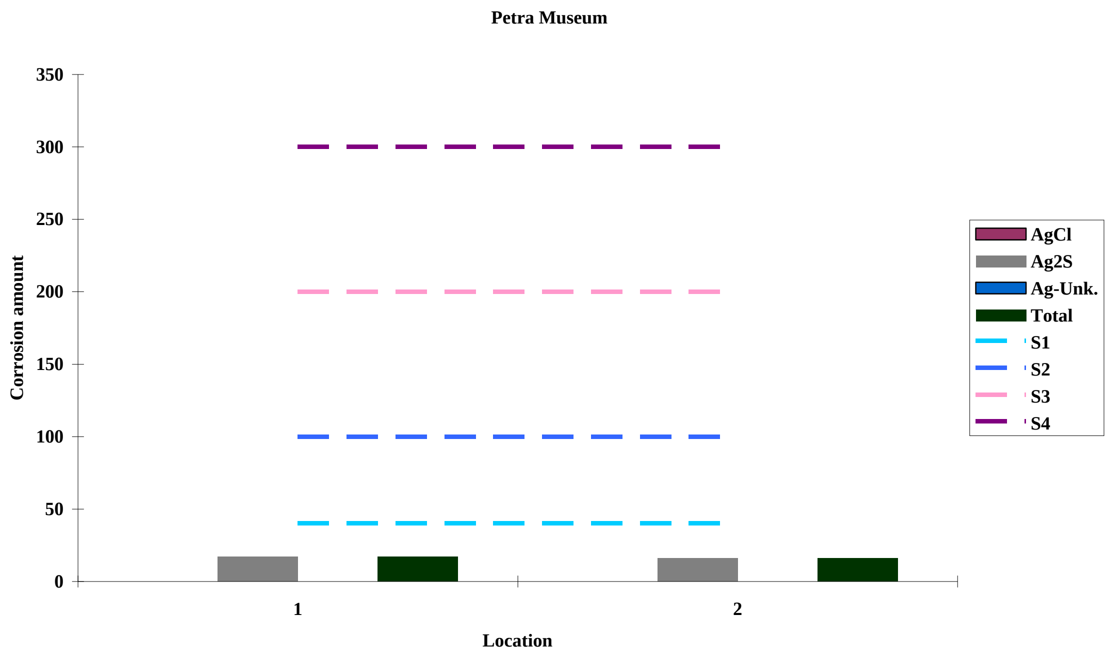

Figure 5.30 The ERC corrosion results of the silver film at the Petra Museum.
The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted silver corrosion in ? / 30 days.

Table 5.16 Description of the locations of the coupons in the Petra Museum

Location number	description of location	The coupon code
1	Second Hall	PM 2
2	First Hall	PM 1

Both ERCs installed in this museum showed similar air quality. Generally, the air quality meets recommended guidelines. However, upon examination of the individual corrosion layers, the Cu_2S is exceeds these guidelines. The presence of this corrosion, combined with the relatively low level of Ag_2S, indicates the presence of active sulphur compounds in the air. Active sulphur compounds include hydrogen sulphide, elemental sulphur and organic sulphur compounds such as mercaptans. Since H_2S is a very aggressive gas, preventive measures are recommended to in order to control and maintain this contaminant at the recommended levels. It is necessary to continue the monitoring of the levels of gas contamination in the air, as well as in the outside air around the museum.

5.6.10 Salt Archaeology Museum.

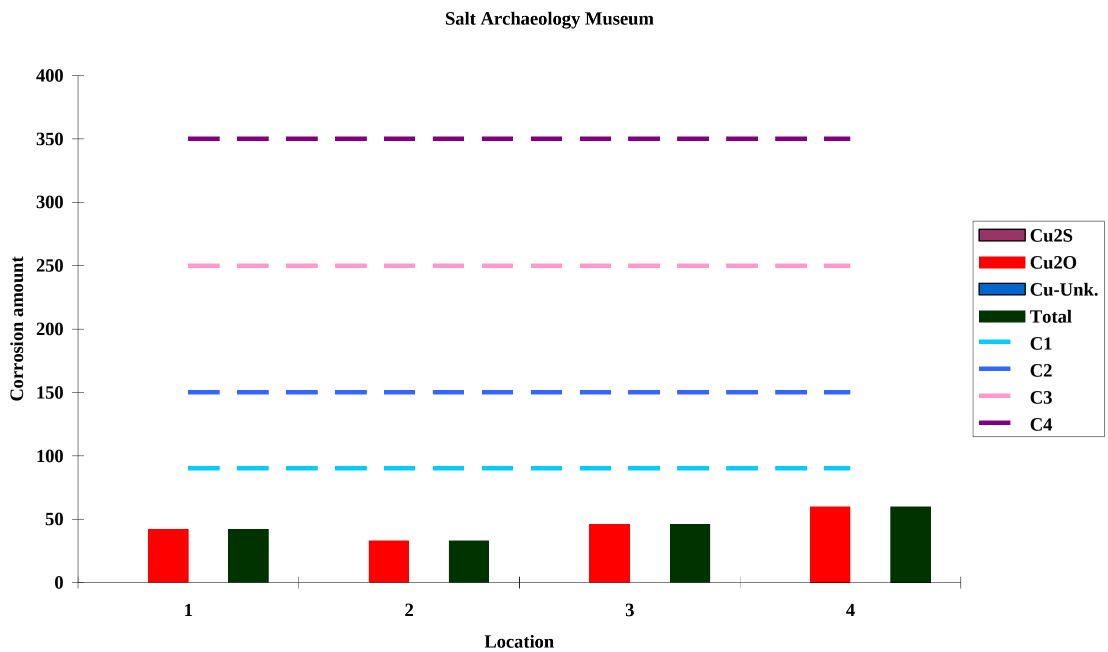

Figure 5.31 The ERC corrosion results of the copper film at the Salt Archaeology Museum. The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted copper corrosion in ? / 30 days.

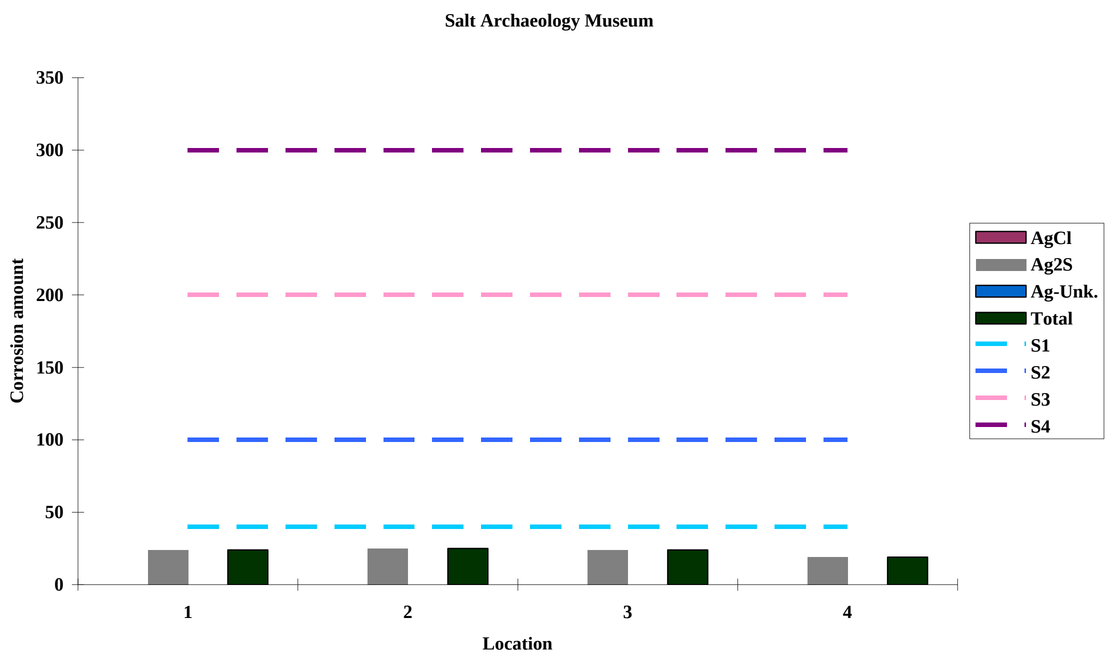

Figure 5.32 The ERC corrosion results of the silver film at the Salt Archaeology Museum.

The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted silver corrosion in ? / 30 days.

Table 5.17 Description of the locations of the coupons in the Salt Archaeology Museum

Location number	description of location	The coupon code
1	Entrance	SM 4
2	Late Bronze Age Hall	SM 3
3	Hellenistic -early Islamic Hall	SM 2
4	The Rural Landscape Middle Islamic	SM 1

Based on Figures 5.31 and 5.32, it is shown that the air quality in the locations monitored in this museum meet the general acceptance criteria. Both the total corrosion levels, as well as the level of the individual corrosion layers, are below the maximum allowable levels, which do not lead the collection for deterioration.
It is not possible to determine whether all of the ERCs installed have been exposed only to indoor air, or they have been exposed to outdoor air as well, because most of the investigated museums were in direct contact with the outside climate. Nevertheless, some coupons were installed inside showcases that are in a slightly isolated environment. Information on the outdoor air quality is important as it gives an idea of potential threats from contaminants with sources outside the building (e.g. automobiles, trucks and manufacturing). In addition, these measurements were taken in wintertime with the associated lower humidity and temperature, which may not reflect the corrosion potential. It is therefore advised to repeat the measurements during summer time, to determine the seasonal influences.

5.6.11 Umm Qeis Museum.

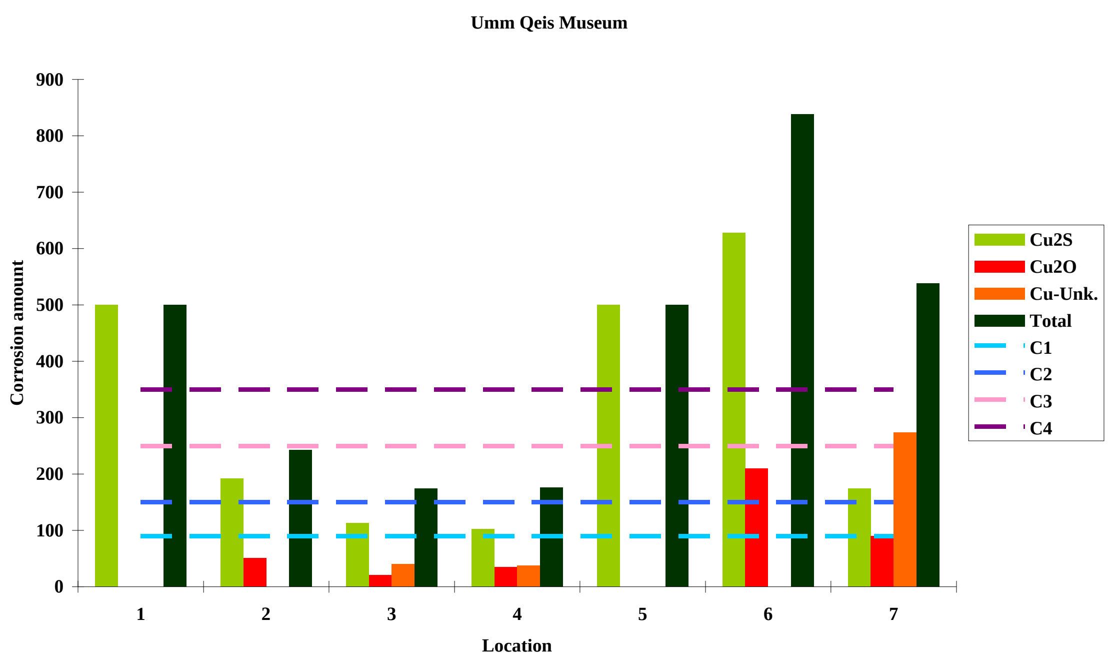

Figure 5.33 The ERC corrosion results of the copper film at the Umm Qeis Museum.
The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines

describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted copper corrosion in ? / 30 days.

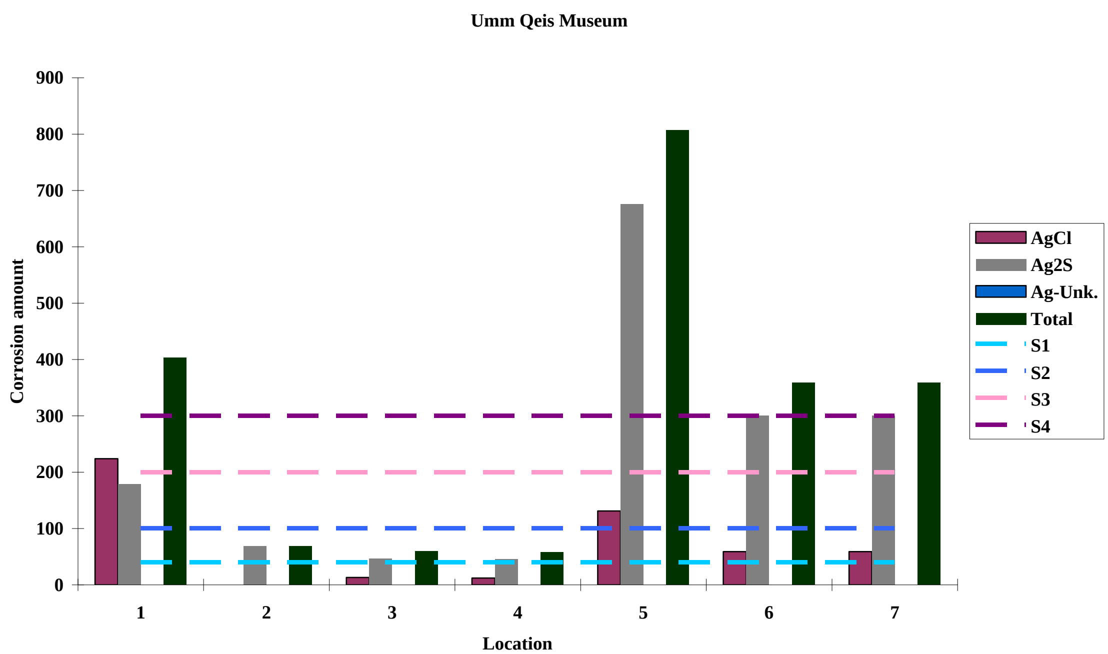

Figure 5.34 The ERC corrosion results of the silver film at the Umm Qeis Museum. The x-axis shows the location number where the measurement took place while the amount of corrosion is presented on the y-axis. The horizontal intermittent lines describe the levels of corrosion classifications, while the continual vertical lines indicate the concentration rate of the resulted silver corrosion in ? / 30 days.

Table 5.18 Description of the locations of the coupons in the Umm Qeis Museum

Location number	description of location	The coupon code
1	Open air display	UQM1
2	Main Hall	UQM4
3	Sculpture Hall	UQM2
4	Sculptures Hall	UQM3
5	Outdoor atmosphere	UQM5
6	Main hall,	UQM6
7	Main hall	UQM7

Examination of the overall ERC data indicates that the indoor air quality is correlated with the outside air. Therefore, the Umm Qeis museum presented the worst scenario out of the investigated museums. From the analysis of the copper film, it was found out that sulphur is present in all the investigation spots within the museum. In addition, analyzing the silver film of the same coupons in the same investigated locations also reveals a presence of sulphur and chlorine elements. These results do not meet any recommended guidelines. The same contaminations were seen at the investigations of the outside air at the ambient of the museum, which leads us to conclude that there is an overlapping and inseparable environment between the outside and the indoor environment at the Umm Qeis museum.

5.7 Discussion

The effects of air pollution on the deterioration of historical materials are well described by others. However, no information is known on the environmental effects on historical Jordanian collections. The results in this study can therefore not compare with previous measurements in Jordan and forms now a base for further research.
Based on the results of the indoor air quality measurements as described in the paragraph above, the indoor air quality can be generally considered as clean. However, there are a few exceptions. In one museum and some exhibition halls in other museums, the air quality can be considered as poor.
There is some evidence that the source of the active sulphur contamination observed as the Cu_2S layer from any ERC is also found outside the museum. Active sulphur compounds include hydrogen sulphide, elemental sulphur and organic sulphur compounds such as mercaptans.
Looking back to the Purafil environmental classifications for preservation environments in Table 5.6, most of the monitored museums were classified as C1, which means that the environments of the museums are suitable for hosting most vulnerable materials. However, particular spots in some museums were classified as C3 and C5. This means that these areas are not suitable for the collections.
In spite of the importance of the effects of air pollution on a museum's collection, this present study seems to be the first research detecting and determining environmental gaseous air pollution in Jordan.
It should be noted that the amount of copper corrosion observed in the outdoor air from Umm Qeis (ERC UQM1was so high that a reliable analysis was not possible. The active sulphur contamination levels were so high that the copper layer was totally stripped from the coupon.
The unknown copper products that were found in Umm Qeis in the two sculpture halls (UQM2 and UQM3) are further evidence that the inorganic chlorine levels are far in excess of what would be considered acceptable for this type of environment. Chlorine gas revealed itself on copper as an unknown. The Umm Qeis museum is located at the top of a mountain, which is surrounded on its south and north sides by hot springs. As it was assumed, that the presence of chlorine and sulphur components is coming from the hot springs, a water sample from one of the hot springs was analyzed at the Royal Scientific Society – Environmental Research Centre – in Jordan. The results are given in Table 5.19.

Table 5.19 Results of analysis of a water sample collected from *Alshonah As-shamaliyah* hot spring.

Parameter	Unit	Results	Test method No & date*
NO_3	mg/L	<0.1	4110 – B, 2/7/2009
SO_4	mg/L	96.5	4110 – B, 2/7/2009
Cl	mg/L	141	4500 – Cl, D, 2/7/2009
* : Standard methods for the examination of water and wastewater, Online http://www.rss.gov.jo.			

The analysis of the water sample form the hot spring reveals a presence of SO_2^{2-} and Cl^- in the sample. Therefore, it is suggested that chlorine and sulphur present in the surrounding environment and in the indoor environment of the Umm Qeis museum, comes from the hot springs.
When interpreting the results for the individual corrosion films, the detection of a silver sulphide (Ag_2S) film without a corresponding copper sulphide (Cu_2S) film usually indicates the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3).

- Oxidized forms of sulphur are generated as combustion products of sulphur-bearing fossil fuels. Low parts-per-billion levels of sulphur oxides can passivate reactive metals and thus retard corrosion. At higher levels, they attack certain types of masonry, metals, elastomers and plastics. The reaction with masonry and metals normally occurs when these gases dissolve in water to form sulphurous and sulphuric acid.
- The chief materials to suffer from sulphur dioxide pollution are calcium carbonate (marble, limestone, frescoes, alkaline sandstones), cellulose (paper, cotton, linen, wood veneers), silk, iron and steel. Leather, parchment and wool are also susceptible to attack. Many other materials, including certain bronze alloys, synthetic rubbers, dyes and textiles, may be affected.
- All cellulose, whether paper, cotton, or linen, is attacked by sulphuric acid resulted from sulphur dioxide. Light and more importantly UV radiation, increases the damage. Poor quality paper deteriorates more quickly than rag paper, firstly because it contains more acid materials that are introduced during manufacturing and secondly because it absorbs more acidic gaseous pollutants because of the lignin that is also present.
- A few modern dyes and pigments have been found to be specifically sensitive to sulphur dioxide. The elasticity of certain elastomers (synthetic rubbers) can be destroyed. Paints are also affected.
- Iron is the chief metal to suffer from the presence of sulphur dioxide. Iron corrodes to rust electrolytically. This means that both moisture and an electrolyte must be present on the iron surface. All water-soluble salts, acid and alkalis form electrolytes. Those electrolytes that attract moisture, form soluble corrosion products and are non-volatile, are the most corrosive. Sulphuric acid and the ammonium sulphate to which it is often partly converted fulfil all these conditions.

When both silver and copper films are detected it more often than not indicates of the presence of active sulphur compounds such as elemental sulphur, hydrogen sulphide (H_2S) and organic sulphur compounds (e.g. mercaptans, COS). When both films are present and the amount of Cu_2S is greater than 50% of the total corrosion, this is further evidence of the presence of active sulphur compounds in the subject environment.

- Active sulphur compounds include hydrogen sulphide, elemental sulphur and organic sulphur compounds such as the mercaptans. When present at low parts-per-billion levels, they rapidly attack copper, silver, aluminium and iron alloys. The presence of moisture and small amounts of inorganic chlorine compounds greatly accelerates sulphide corrosion. Note, however, that attack still occurs in low relative humidity environments. Active sulphurs rank with inorganic chlorides as the predominant cause of atmospheric corrosion.

Chloride corrosion (AgCl) was not detected on any of the coupons reported here. Its presence would have indicated the presence of inorganic chlorine compounds, e.g. chlorine (Cl_2), chlorine dioxide (ClO_2), or hydrogen chloride (HCl). High levels of chloride (halogen) contamination can also serve to effectively mask any evidence of sulphur contamination on the corresponding copper coupons and can cause a large unknown copper corrosion film to appear.

- Chlorine contamination, whether as chlorine or hydrogen chloride, is a most dangerous contamination for metals. At elevated levels, many elastomers and some plastics are oxidized by exposure to chlorinated gases.
- Particular care must be given to materials that are exposed to environments containing chlorinated contaminants.

From these observations, we can conclude that the main pollutants are inorganic chlorine and active sulphur compounds and their sources are from outside the building. Purification of the incoming outdoor air might result in a cleaner indoor air with, of course, less corrosive components that deteriorate metal objects. This work is not covering seasonal influences; therefore, it would be welcome to study this effect in the near future. It is important to shorten the outdoor exposure time due to the heavily polluted outdoor air.
As most of the measurements were taken inside of the buildings, the actual outdoor composition was not fully analyzed and therefore it is unknown. Information of the outdoor composition can be crucial in order to establish needs in preventive conservation. It has to be mentioned that the outdoor and the indoor relative humidity during this work was less than in summer periods.

5.8 Conclusion

In this work, the indoor environment of nine selected Jordanian Museums, the Department of Antiquities (DoA) main repository and the (DoA) archive were reviewed and analyzed by means of Environmental Reaction Coupons. Due to the easy use and reliability of these ERCs, it can be concluded that for reviewing the indoor air quality of museums, these ERCs are extremely useful. They can be used at different locations within one museum. For outdoor air quality control, it can be concluded that the use of ERCs is somehow difficult, because the corrosion occurs extremely fast. Therefore, more measurements using different exposure times would be welcome; however, this is beyond the scope of this work and therefore, not further investigated.
The indoor air is in direct contact with the outdoor air in most cases of the Jordanian museums. Therefore, in case of museums with non-sealed windows, open showcases and open doors, it can be concluded that there is a serious contribution of the outdoor air to the indoor environment. Subsequently, based on several locations there might be even a serious influence of the geographical location of the museum. For instance, if the location is higher than the urban level of the city such as the case in the Dar Alsaraya museum in Irbid, wind might transport in some cases cleaner air than can found at street level. In addition, the opposite is possible. Therefore, further research on these possibilities is highly recommended.
The classification based on the work of Muller seems to be realistic also for the Jordanian museums and could therefore be adopted. There are several classes for acceptable levels of pollutants based on the results of ERC measurements. For locations storing e.g. historical paper materials the classification S1/C1 (<40? and <90 ? / 30 days, respectively) representing a very clean environment can be adopted and for museums in general S2/C2 can be adopted. Based on the classification, it is possible to conclude about the quality of the indoor air of the reviewed museums. This is presented in Table 5.20.

Table 5.20 Differentiated conditions of the monitored museums

Museum	Good (acceptable)	Medium	Bad (not acceptable)
The Dar Alsaraya museum		*	
DoA (Storage and Archive)		*	
The Karak museum		*	
The Madaba archaeological museum		*	
The Madaba folklore museum		*	
The museum of Jordanian heritage		*	
The Numismatics museum	*		
The Petra museum		*	
The Salt museum	*		
The Umm Qeis museum			*

It is concluded that, based on the qualification, most of the reviewed museums should improve the management of a good indoor environment.
According to the environmental classifications for preservation environments by Chris Muller (Purfil, Inc.), silver dioxide is less active in dry atmosphere than copper dioxide. This reflects clearly in the research results as Jordan has a dry atmosphere. Therefore, in all monitoring spots it was found that the amount of copper corrosion was higher than silver corrosion. The dry environment is passive for inorganic materials; however, it might damage inorganic materials.
It is therefore concluded that environmental museum management should include not only actions to prevent the unwanted outdoor pollutants outside of the collection to enter, but also actions in order to have an “as good as possible” indoor environment. This means to have three stable and acceptable environmental elements: temperature, humidity and low level of pollution.

5.9 Recommendations

There is substantial evidence that indoor air pollution causes significant damage to cultural property. Therefore, raising awareness among the management staff at the Jordanian museums about the seriousness of different air-pollution contaminants is necessary. Much of the SO_x, Cl_x and particulate matter directed in the Jordanian museums, storages and archives environment is introduced by way of either the side-openings or by the HVAC system. Even in buildings with HVAC systems that lack the capability of pollutant gas removal.
Based on this work, it is recommended to improve the environmental museum management. Simple actions should be taken as closing doors and keeping pollutions outside of the collection.
Based on this work, environmental guidelines can be established for Jordanian museums. However, as most of the buildings are showing technical problems (see chapter 3) more research has to be carried out in order to establish whether the current buildings are indeed suitable for housing important valuable museum collections.
It is further recommended that reactivity monitoring be continued - with either ERCs, or the OnGuard™ 3000 Atmospheric Corrosion Monitor (see Chapter 6) - to provide a continuous environmental assessment of air quality. While information on individual contaminants can be obtained by using the ERCs, real-time reactivity monitoring can provide a more accurate assessment of the total corrosion being formed due to the presence of chemical contaminants.
Due to the elevated levels of active sulphur and inorganic chlorine contamination detected in the outside air-conditioning units, it is recommended that additional sets of ERCs be placed in the outside air-conditioning units and inside the facility to determine

if and where these contaminants are being distributed throughout the facility. Direct gas monitoring may also determine the sources of the sulphur and chlorine corrosion measured. This could help determine if these results were an anomaly, or due to episodic events, or if there are some other gaseous contaminants present which may have synergistic effects and need to be accounted for. Indoor sources of contamination should also be investigated.

The measurement period for this research was very limited and was only carried out during the winter. Consequently, it is recommended that further investigations be carried out during the summer, in order to compare the results and determine whether there are any changes between the two seasons' results. Finally, it is recommended that a comprehensive air pollution research takes place in all museums in Jordan.

THE POTENTIAL AND LIMITS FOR INDOOR ENVIRONMENT OF A MUSEUM AND A MUSEUM'S REPOSITORY IN JORDAN

The potential and limits for indoor environment of a museum and a museum's repository in Jordan

6.1 Introduction

Within museums there are number of environmental factors, which can cause degradation of materials and artefacts. Among these are temperature, humidity, particulates and gaseous pollutants.

The passage of time itself can negatively affect artefacts, but once an artefact has been brought into a museum environment, it becomes the museum's responsibility to exert every possible effort to prevent any further deterioration. These objects once served specific purposes and yet when they become part of a museum collection their function changes and they serve as testimony to humankind's rich heritage and history (Alghazawi 2003).

So far, the effects of climatic factors and of corrosive agents on healthy materials have been investigated in Jordan. The assumption in these investigations, however, is that the materials are in perfect condition to begin with. In actual practice, the normal ageing process means that when objects arrive at a museum they are may be soiled, weakened, corroded, etc. and so no longer have the properties of new materials. Additionally, objects composed of more than one material are at risk of one of the components reacting with and causing damage to the other materials (ICCROM 1998).

The preservation of museum collections depends upon the knowledge of how materials and objects in the collection behave and how environmental influences affect them. Some aspects of preservation are obvious; factors of relative humidity, temperature and pollution will deteriorate or damage most collections. It is also obvious that such threats should be controlled or minimized and this can be described as the main task of museums.

In order to detect air pollution and gaseous contamination and to determine where these contaminants originate from, two sequential researches were done; the first research was presented in a previous section of this thesis and conducted at several Jordanian museums, galleries and museum storage areas in Jordan in 2008-2009, using the Purafil Environmental Reactivity Coupons (ERCs) -a silver and copper film placed on a piece of glass (see photo 5.1). Consequently and in order to determine the correlation between the outdoor climate and the indoor climate the second research presenting a real-time measurements of relative humidity (RH), temperature and corrosion levels of two Jordanian cultural heritage sites took place in 2009, using the latest device OnGuard™ 3000 Atmospheric Corrosion Monitor (ACM). In addition to detecting air pollution, the ACM also has the ability to monitor RH and temperature. The data from the ACM can be transferred to a computer to be analyzed.

The two selected locations for the monitoring using the OnGuard™ 3000 are The Museum of Jordanian Heritage (MJH) at Yarmouk University in Irbid and the Department of Antiquities main storage (DoAS) in Amman. These sites were chosen because of their importance as cultural heritage sites and because of the immense bulk of objects, they hold. The monitoring periods were divided into two stages of approximately one month per stage.

Reactivity monitoring is being used for developing the cause-and-effect relationship between gaseous pollutants and the damage it may cause within preservation environments and to paper documents, artwork and historical artefacts. The standard classification scheme, which directly correlates corrosion rates to environmental classifications is considered being the first guideline for museum's conservation and preservation procedures. These guidelines were first mentioned by the Advisory guideline for the air quality in archives presented by the Dutch government in 1994 (published as *Advisory guide-line air quality archives*, The Hague 1995). In 1996, it was Muller who tuned the work performed within the Delta Plan for Conservation and established these comprehensive guidelines. The Delta Plan for the preservation of Cultural Heritage is launched in 1991 with the aim of clearing the package of management and conservation work affecting large parts of the Dutch cultural heritage. The main aim of the Plan was to improve the conditions of the Dutch national collections under which they are kept (Van Dijken 2001). In 2004, these guidelines were developed again and adopted by the International Organization for Standarization (ISO). They will be used in this study as a measure to compare the indoor environmental conditions of the Jordanian museums.

6.1.1 Geographical aspects

Jordan's geography consists mainly of a plateau between 600 and 1500 meters above seas level (Ufimtsev 2007), which is divided into ridges by valleys and gorges. There are also a few mountainous areas and so there is a diversity of climatic zones in Jordan. Fractures in the earth's surface are evident in the great geological rift that extends southward from the Jordan Valley through the Gulf of Aqaba and the Red Sea, gradually disappearing south of the Nile Basin countries in East Africa. These fractures have also added to this diversity. Although Jordan is an earthquake-prone region, no severe shocks have been recorded for several decades (Casto and Dotson 1938).

6.1.2 Research questions

- Do the indoor environments of the Museum of Jordanian heritage (MJH) and the Department of Antiquities Store (DoAS) conform to the international standards for temperature and relative humidity (CCI 2006)?
- Do the indoor environments of the MJH and the DoAS conform to the Muller's guidelines and to the guidelines of the International Organization for Standarization for preservation and conservation of museums?
- Is there a correlation between the indoor climates of the MJH and the DoAS and the outside atmosphere?
- Do the indoor climates of the selected sites lead to metal corrosion?
- To what extent do the MJH and DoAS provide a safe environment for their collections?

6.2 Environmental standards

The norms of climatic conditions in museum environments were first determined from experience gained during the Second World War. A certain number of collections, especially of easel paintings were transferred from exhibition rooms where the air was not conditioned and were stored in subterranean shelters where the RH was stable at 58%. Over the five years of the war, the need for restoration interventions gradually diminished until none was necessary. After the war, when the works were returned to their exhibition rooms, the paintings suddenly began to flake and peel.
Such experiences have been of the utmost importance in illustrating the effects of the environment on museum objects and the importance of a stable climate in reducing the speed of deterioration. Norms of RH and temperature have also been determined

through scientific studies of the behaviour of healthy objects. However, most of these studies were done in military or industrial contexts, not in the context of conservation (Plenderleith 1971).

6.2.1 Control specifications

As far as I know, there has been relatively little research carried out worldwide to determine what levels actually cause deterioration of historical artefacts and archival materials. Experience has come from the determination of the normal background levels of pollutants to which these materials have been exposed over the years. It has been postulated, as is sometimes assessed, that more deterioration has occurred in the last fifty years than in the previous two thousand. It was not until the industrial revolution in the late 18th century and the early l9th century and more specifically 'the age of the car', that global pollutant levels dramatically increased (Kishkovich 1997; Muller 1999). 'Normal' background pollutant levels measured in non-industrial versus industrial areas today frequently show differences of the magnitude of their contribution in the outdoor atmosphere pollution, as illustrated in Table 6.1.

Table 6.1 Common levels of gaseous pollutants

Pollutant	Normal Background Concentrations	Peak Concentrations (Urban Areas)
Sulphur dioxide	6-30 ppb	100-750 ppb
Ozone	0.4 ppb	20-40 ppb
Nitrogen dioxide	1.0-1.5 ppb	40-100 ppb
Chlorine	0.06-0.6 ppb	20-130 ppb
Hydrogen chloride	20-50 ppb	200-450 ppb
Acetic acid	4-10 ppb	20-100 ppb
Formaldehyde	3-15 ppb	10-40 ppb
Hydrogen sulphide	5-10 ppb	100-500 ppb

Just as there are wide variations between background and peak gas concentrations, there are also wide variations in what are considered acceptable levels for these pollutants. Some institutions specify that sulphur dioxide, nitrogen dioxide and ozone are to be removed completely. Other institutions recommend levels from fractional particles-per-billion (ppb) up to the low figures of particles-per-million (ppm) Table 6.1. One might argue that although there is still considerable variation in the recommended allowable pollutant levels, at least attempts have been made to set standardised levels. Whether or not the levels specified are realistic or attainable is another question (Kishkovich 1997; Muller 1999).

Based on joint research by Purafil Inc., the Dutch Government (Archives 1994), the Swedish Corrosion Institute (Forslund 1996) and the Comitato Termotechnical Italiano (C.T.I) (AICARR 1997), reactivity monitoring using either copper or silver corrosion rates has been accepted as an alternative to - and in many instances preferred over - direct monitoring of low-level gaseous pollutants in preservation environments. This reactivity monitoring technique has been proposed as a European standard. The specifications are shown in Table 6.2.

Table 6.2 Control specifications for preservation environments

Contamination Measured	Concentration ppb	Concentration µg/m3	Reactivity Level, ? /30 days
Sulphur dioxide	≤0.35 - 1.0	≤1 - 2.85	-
Ozone	≤2.65	≤1.8 - 24.5	-
Nitrogen dioxide	≤0.94 - 12.5	≤5	-
Chlorine	≤1 - 3	≤3 - 9	-
Hydrogen chloride	≤1 - 3	≤1.5 - 4.5	-
Acetic acid	<4	<10	-
Formaldehyde	<4	<5	
Silver Corrosion			<100a
Copper Corrosion			<150b
a - with no sulphur corrosion evident, b - with no chloride corrosion evident			

The amount of corrosion over any given period is a primary indicator of how well-controlled an environment may be. Where gas-phase air filtration is employed to maintain the interior concentrations of gaseous pollutants at as low a level as possible, corrosion rates 15-20 ? / 30 days range can be routinely maintained. Subsequent gas monitoring for the previous perspective indoor environment should indicate that pollutant levels are at or below the limits of detection for the analytical techniques employed (Muller n.d.; 1994). This “no detectable pollutants” scenario is being used to set up environmental classification systems based on reactivity monitoring. Here it might be assumed, that if an environment exhibits corrosion rates of S1/C1 (<40 ? and <90 ? / 30 days, respectively) as it is described in Table 5.4, then, there is nothing else that can be done to improve the environment (Muller 1996).

6.2.2 Environmental Classifications

The Institute Society of America (ISA) standard S71.04-1985 "Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants" (ISA 1986), which is used to verify the efficiency of heating, ventilation and air-conditioning (HVAC) system's filtration unit, can be helpful in assessing the results of semi-quantitative monitoring methods as shown in Table 6.3.

Although there is no direct correlation between these ISA classes and preservation targets, the corrosion of metal coupons can be a useful method for providing an indication of improvement after a change in control strategy or for semi-quantifying different environments (Tetreault 2003).

Table 6.3 ISA environmental classes (ISA, 1986)

ISA classes				
Copper coupon Film thickness (nm)	G1	G2	G3	GX
	0-29	30-99	100-199	≥200
Gas concentrations (μg m^{-3}), RH<50%				
H_2S	<4	<10	<70	≥70
$SO_2.SO_3$	<30	<300	<800	≥800
Cl_2	<3	<6	<30	≥30
NO_x	<100	<200	<2000	≥2000
NH_3	<400	<7000	<20 000	≥20 000
O_3	<4	<50	<200	≥200

Table 6.4 lists a standard classification scheme, which directly correlates corrosion rates to environmental classifications (Muller 1996). Typical uses of reactivity monitoring to date have been for the characterization of outdoor air used for ventilation, the identification of “hot spots” within a facility and the effectiveness of various preventive measures. Reactivity monitoring is being used for the purpose of developing the cause-and-effect relationship between gaseous pollutants and the damage it may cause within preservation environments and to paper documents, artwork and historical artefacts (Van Dijken *et al*. 2001). The work of van Dijken dated already from the mid nineties, as in the Netherlands a large resque operation fo conservation and preservation was funded by the Dutch government under the flag Delta Plan for Conservation (Van Dijken *et al*., 2001; Vousteen, 1994). It was Muller who tuned the work performed within the Delta Plan for Conservation and established finally Table 6.4 (Muller 1996).

Table 6.4 Environmental classifications for preservation environments (Muller 1996)

Silver Corrosion			Copper Corrosion		
Class	Air Quality Classification	Corrosion Amount	Class	Air Quality Classification	Corrosion Amount
S1	Extremely Pure	< 40 ? / 30 days	C1	Extremely Pure	< 90 ? / 30 days
S2	Pure	< 100 ? / 30 days	C2	Pure	< 150 ? / 30 days
S3	Clean	< 200? / 30 days	C3	Clean	< 250 ? / 30 days
S4	Slightly Contaminated	< 300 ? / 30 days	C4	Slightly Contaminated	< 350 ? / 30 days
S5	Polluted	≥ 300 ? / 30 days	C5	Polluted	≥ 350 ? / 30 days

Classes in Table 6.4 are categorized upon the thickness of the corrosion on the silver and copper films per month. The amount mentioned in Table 6.4 is the cumulative value per 30 days, later in the results and the discussion sections the amount of the corrosion will be mentioned in incremental value. This value will be attainable by dividing the cumulative value on 30, which are the cumulative days (Muller 1996).

6.2.3 Air purity requirements

Based on the work of Muller and the ISO standard EN-ISO 1184 the following classification can be given:

Class S1/C1: Archives, Metal Collections, Rare Books
Class S2/C2: Museums, Museum Storage, Libraries
Class S3/C3: Historic Houses
Class S4/C4: Short Term Acceptable
Class S5/C5: Not Acceptable

The difference between ISO standard and Muller's work is that Muller used the Angstrom (Å) which is a unit of length, in measuring the thickness of the corrosion, while ISO was measuring the thickness of the corrosion in mg/m^2 which is a mass unit. However, I think that it is easier and more prosperous to measure the thickness in Å.
Generally speaking, the silver and copper corrosion rates should be class S2/C2 or better. The individual corrosion films quantified using reactivity monitoring may be used for further characterizing the environment and to determine the proper control strategies. Based upon these recommended control levels and test results from laboratory and field-exposed silver coupons, acceptance criteria relevant to these applications has been determined. These criteria take into account total corrosion as well as the relative contribution of each individual corrosion film. The control specifications for the individual corrosion films are listed in Table 6.5. These specifications are more general in their application than those listed above. Moreover, are most often used for the characterization of an environment, prior to the implementation of pollutant control measures (Muller 1994; 1996).

Table 6.5 General reactivity monitoring acceptance criteria

Silver Reactivity Acceptance Criteria		**Copper Reactivity Acceptance Criteria**	
Silver Corrosion Reaction Products	Corrosion Film Thickness	Copper Corrosion Reaction Products	Corrosion Film Thickness
Silver Chloride, AgCl	0 ? / 30 days	Copper Sulphide, Cu_2S	0 ? / 30 days
Silver Sulphide, Ag_2S	<50 ? / 30 days	Copper Oxide, Cu_2O	<150 ? / 30 days
Silver Oxide, Ag_2O	<50 ? / 30 days	Copper Unknowns	0 ? / 30 days
Total Silver Corrosion	<100 ? / 30 days	Total Copper Corrosion	<150 ? / 30 days

As long as the total corrosion and each individual corrosion film meet the recommended criteria, the local environment in which that particular coupon has been exposed meets the requirements of a Class S2/C2 classification. Any of the criteria, which are not met, indicates that the local environment may not be sufficiently well-controlled to minimize the decay of artefacts and materials due to the presence of gaseous pollutants. Steps should be taken to determine what problems exist and what corrective actions may be appropriate (Muller 1994; 1996).

6.2.4 Environmental guidelines for museums - Temperature and relative humidity

In this study, the classification of the Canadian Conservation Institute standards for temperature and relative humidity in museums, art galleries, libraries and archives will be adopted.
In Table 6.6, the conditions of the climate in museums are classified based on the museums ability to control temperature and RH. The well-controlled climate is

classified as class A. On the other hand, the worst scenario is classified as class F (CCI 2003).

Table 6.6 Classifications of control for museums and archives, upon RH and temperature seasonal changes (CCI 2003)

Maximum fluctuations and gradients in controlled spaces		**Class of control**
Short-term* fluctuations and space gradients	**Seasonal adjustments in system set point**	
±5% RH ±2 °C	RH no change. Up 5 °C and down 5 °C.	A Precision control, minimal seasonal changes to temperature only.
±5% RH ±2 °C	Up 10% RH and down 10% RH. Up 5 °C and down 10 °C.	B Good control, some gradients or seasonal changes.
±10% RH ±2 °C	RH no change. Up 5 °C and down 10 °C.	C Good control, seasonal change to temperature only.
±10% RH ±5 °C	Up 10% RH and down 10% RH. Up 10 °C (but not above 30 °C) and down as low as necessary to maintain RH control.	D Control, some gradients plus winter temperature setback.
Within range 25–75% RH year-round. Rarely over 30 °C, usually below 25 °C.		E Prevent all high risk extremes.
Reliably below 75% RH.		F Prevent damp.
*Short-term fluctuations are any fluctuations less than the seasonal adjustment; however, some fluctuations are too short to affect some less-sensitive artefacts and those that are kept under cover.		

Class A

Precision control, minimal seasonal changes to temperature only.
Permissible short-term fluctuations of ±2 % RH and ±2 °C, with a seasonal set point change in temperature of up 5 °C and down 5 °C. No seasonal change in RH set point is allowed.
Both Figures 6.1 and 6.2 show the worst-case scenario with maximal permissible fluctuation.

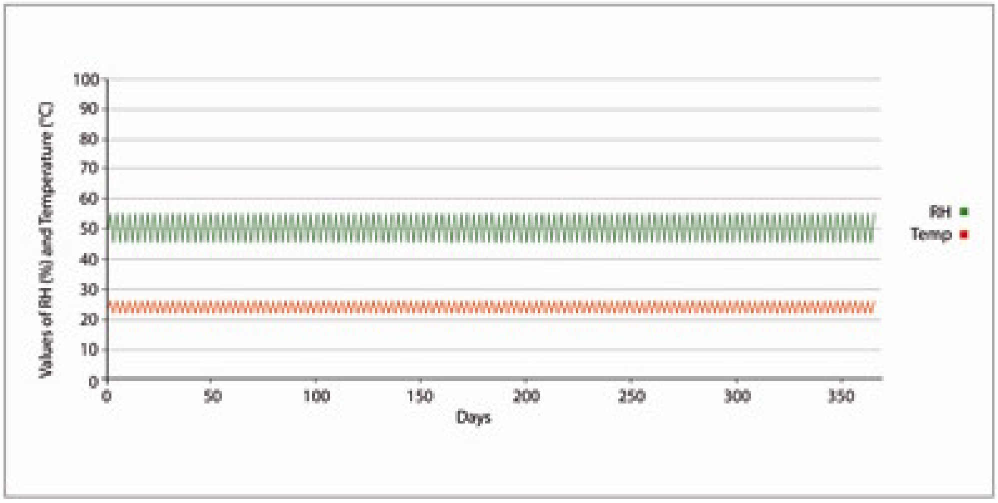

Figure 6.1 class A of control – No seasonal setback.

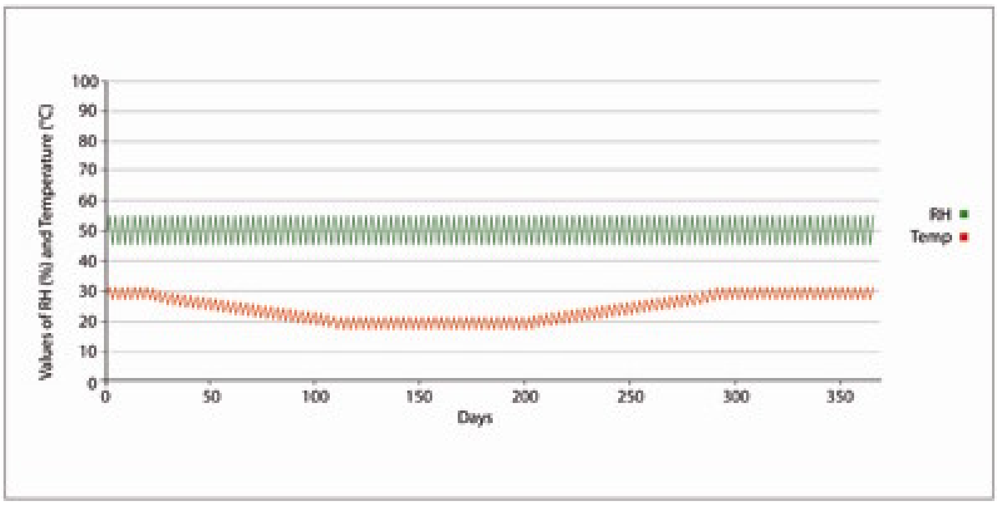

Figure 6.2 Class A of control with maximum allowable seasonal temperature setback of ± 5 ?C.

If temperature and RH are kept as it is in the class A of control, then there is no risk of mechanical damage to most artefacts and paintings, however, there might be a minimal risk to objects of very high vulnerability. Also, chemically unstable objects will become unusable after decades from displaying at the same climatic conditions.

In fact, the very narrow specification for climate control for museum collections, is allowing for a modest amount of seasonal temperature adjustment. However, the specifications of the Canadian Conservation Institute (CCI) must not be taken as being the 'perfect' specification. It does not address the large problem of chemically unstable materials in 21st-century collections and furthermore that specification may be unnecessary for some of the museum's collection. In addition, even systems that keep fluctuations of temperature and RH within the range of class A 97% of the time, although it might fall outside a few days a year. However, even the specifications of the "American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE)" are still ambiguous up to date, about the strict design definition of these classes of control (ASHRAE 1999; 2001).

Classes B and C

These classes indicate good control, some gradients or seasonal changes, but not both.
This degree of control has two subcategories:

- Short-term fluctuations of ±5 % RH and ±2 °C, with a seasonal temperature change of up 5 °C and down 10 °C and a seasonal humidity change of up 10% RH and down 10% RH
- Short-term fluctuations of ±10% RH and ±2 °C, with a seasonal temperature change of up 5 °C and down 10 °C

Both Figures 6.3 and 6.4 show the worst-case scenario with maximal permissible fluctuation.

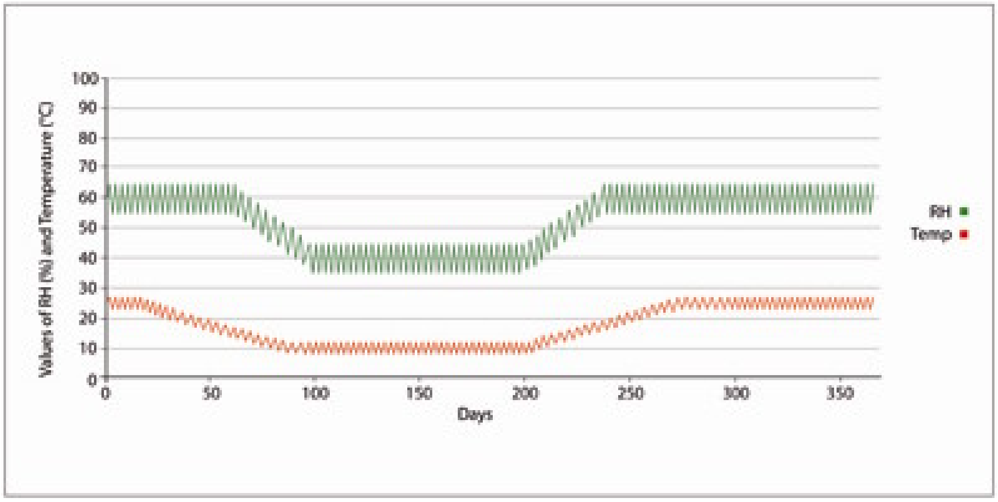

Figure 6.3 Class B of control with maximum allowable temperature and RH setbacks and fluctuations.

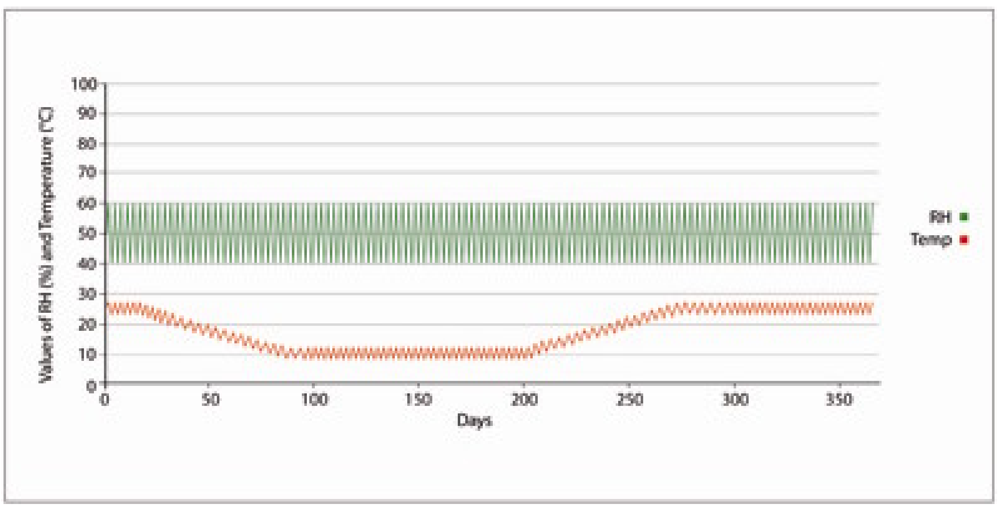

Figure 6.4 Class C of control with maximum allowable RH fluctuation and temperature setback of five ?C up and 10 ?C down.

In class B, there is a possibility of low risk of mechanical damage to highly vulnerable artefacts. Chemically unstable objects kept in Class B environmental conditions are expected to become unusable as museum artefacts within decades.
The letter B is assigned to indicate the most cost-effective degree of control specification for most museum collections, given the ability to provide a climate-

controlled building. Such systems will probably operate within class A levels most of the time. To stay reliably within class B conditions throughout the year is a resource-intensive task in most climates.
This degree of control allows short-term fluctuations of ±10% RH and ±5 °C, with a seasonal temperature change of up to 10 °C. Note that the temperature cannot be allowed to rise above 30 °C but can fall as low as necessary to maintain RH control (ASHRAE, 2001; CCI, 2003).

Class D

The class indicates a controlled climate but with some gradients plus winter temperature setback.
Figure 6.5 shows the worst-case scenario with maximal permissible fluctuation.

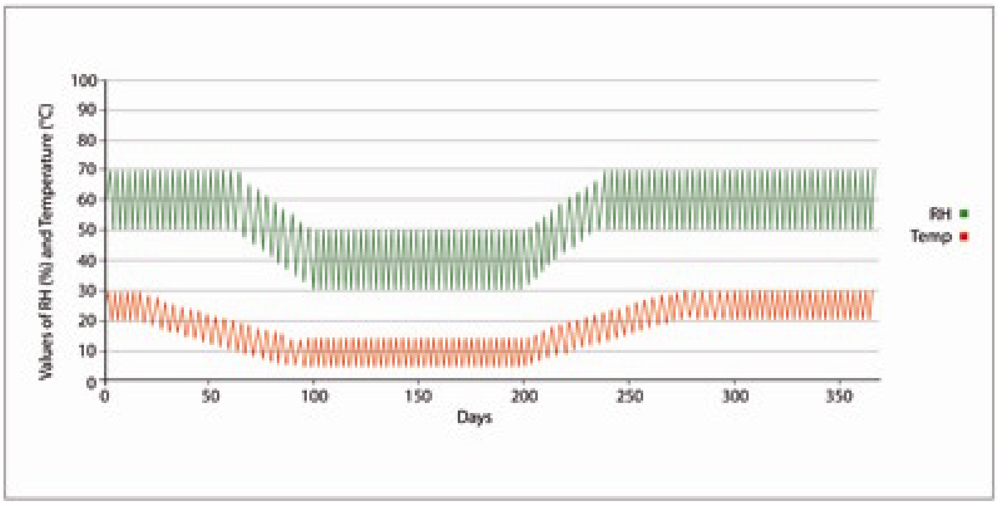

Figure 6.5 Class D of control – maximum allowable RH and temperature setbacks.

In class D the high vulnerability artefacts are under moderate risk of mechanical damage. It can be assumed here, that there is a small risk of damage to objects which are considered as medium vulnerability objects. Therefore, there will be a small risk of damage to most paintings, most photographs and some books and conversely, the other museum artefacts will be immune to mechanical damage in this class of specifications. In addition, this environment will make decay of the chemically unstable objects possible and within decades the museum artefacts will become unusable and even sooner if collections are routinely maintained at 30 °C.
In general, high vulnerability artefacts in most historic collections have already experienced fluctuations in temperature and RH and may have formed cracks. Further fluctuations of the same size for the historical buildings as the first ones they were exposed to, have a very low risk of causing further damage. This is known as the 'proofed fluctuation'. Thus the risk to high vulnerability objects stated above must be recognized as applying only to objects that have come from better conditions than the existing environment, or have been repaired (CCI 2003).

Class E

This class is an indication to prevent all high-risk extremes.

Within 25–75% RH around the year. Temperature rarely reaches over 30 °C, usually below 25 °C.

Class E provides a high risk of mechanical damage to high vulnerability artefacts, a moderate risk to most paintings, most photographs and some books and a very small risk to many artefacts and most books. Chemically unstable objects also are under a great threat.

High vulnerability artefacts in most historic collections have already experienced large fluctuations in temperature and RH and may have formed cracks. Further fluctuations of the same size as the experienced ones have a very low risk of causing further damage (ASHRAE 2001). Thus, the assessment of risk to high vulnerability objects stated previously must be recognized as applying only to objects that have come from better conditions than the ones the objects will be displayed in, or have been repaired. Class E of control recognizes that most of the damage potential of uncontrolled climate can be prevented simply by avoiding extremes in humidity. To be kept stable at some point between 25% 75% RH and mould and rapid corrosion are avoided. Class E of control can be more suitable for open display collections in historic buildings, which are as important as the collection (CCI 2003).

Class F

This class means prevention of dampness.

This degree of control dictates only that humidity is “reliably below 75% RH”.

High risk of sudden or cumulative mechanical damage to most artefacts and paintings including objects of low vulnerability due to low humidity fractures. However, high humidity also delaminating and deformations many objects for example: veneer paintings, papers and photographs.

Avoiding mould and rapid corrosion, due to high humidity, is probably the most important aspect of climate control for museums. Although such a target is not normally considered a condition for modern building design , but it is to be applied at poor quality historic buildings. It is also a legitimate target for any collection in a simple building in a humid climate, such as that in Maritime Museums (CCI 2003).

6.3 Damage assessment

Much has been written on the complex subject of climate as a cause of deterioration in materials. In some instances the processes are well known, in others, research is still under way to fully understand them.

‘Deterioration’ can be defined as “a change for the worse in one or more characteristics of material” (see also Lafontaine and Wood 1982). In general, the damage caused by incorrect temperature and RH falls into three broad categories:

- Biological (bio-deterioration)
- Chemical
- Mechanical (change in size and shape)

It is not always easy to identify the factors involved when confronted with a particular case of deterioration. Often more than one process is involved, with one process often allowing for the occurrence of a second process (Lafontaine and Wood 1982).

6.3.1 Biological Damage

The biological threat, which is directly related to RH, is mould growth. Also most insect pests flourish at a higher humidity. However, the optimum RH for some types of mould is about 65%-75%. Mould is always undesirable in a collection. It causes irreversible and often devastating damage. Mould spores are naturally present in the air around us and it is impossible to eliminate them. However, it is only when mould spores have sufficient nutrients, time and moisture that they grow into destructive mould. As suitable nutrients are readily available in almost any environment, the route to controlling mould is to control moisture. Without moisture, mould spores cannot grow. All organisms require a specific humidity to flourish and will not tolerate either extreme desiccation or extreme cold or heat (Cronyn 1990). On the other hand, insect damage may be discouraged but cannot be fully prevented by humidity control (Thomson 1986).
The safe RH boundary usually cited to prevent mould growth is 65%. Below the safe RH boundary, mould will not grow at any temperature. In contrast, mould is very likely to grow at a high RH. For example, at 85% RH, mould will probably appear in less than a week. Establishing what happens in borderline conditions, that is, in RH between 60% and 70% with different temperatures, is a bit more challenging (Hueck 1972; Szent-Ivany 1968).
It is relatively easy to maintain ambient RH and temperature levels that will preclude mould growth. The danger, which is often hidden, lies in microclimates that can inadvertently be created within a building.
Many rooms have temperature gradients and colder spots have higher RH than warmer ones. For example, during cold weather, exterior walls or floors may become considerably colder than the rest of the room, creating pockets of high humidity or even condensation. The tools designed to condition the air can create their own problems; near the output of humidifiers, RH will be too high and near dehumidifiers, there is the risk of water leaks. Even attempts to protect objects by enclosing them in a protective wrapping can backfire. Consider what happens if a package, containing an object that is stored where the temperature is uneven. The colder part of the package will have much higher RH than the warmer part, leading to mould growth. In summary, protective wrapping is beneficial in many ways, humidifiers and dehumidifiers can play important roles and most storage rooms are better for collections than no storage room at all. Each of these improvements to collections, however, needs to be applied carefully so as not to create new sources of damp and mould.

6.3.2 Chemical Damage

The chemical deterioration of materials can be classified into three areas:

- The corrosion of metals
- The fading of dyes
- The weakening of paper and textile

Temperature and RH are both affecting chemical processes in two different ways; heat speeds up any chemical reaction, while RH is significant because some reactions require moisture before they can take place.
Since most museums form mixed collections it is indeed unfortunate that the very level chosen as the lower safe limit for moisture-absorbent materials (40-45 % RH) should also be the upper limit for unstable iron and bronze with traces of chloride (Majewski 1972; Organ 1963). On the other hand, good quality iron, especially if clean and suitably coated and bronze with stable patinas will exist in safety at 55% RH. This implies that special showcases may have to be built for valuable but unstable metal objects (Thomson 1986).

The great majority of cotton, linen, wool and silk fade more rapidly at a high RH than at a low RH. The lifetime of paper is highly variable and depends on the make-up of the paper, with fibre type, fibre length, degree of beating of the pulp, chemicals used in manufacture, basis weight and thickness all affecting how long the paper can be expected to last. Although none of these factors can be changed, the temperature and RH conditions of the environment where paper is stored can influence its relative permanence.

Chemical damage is caused by chemical reactions taking place within a material. The key reactions are hydrolysis and oxidation, which account for most natural aging processes. Hydrolysis is a reaction between a substance and water that results in the chemical breakdown of the original substance and the formation of one or more new substances. Oxidation is a reaction between a substance and oxygen, often resulting in a physical breakdown (ASHRAE 1999).

Acid hydrolysis is of primary concern to museums and especially to archives. It affects cellulose-based materials, including photo negatives and cine film, magnetic media and paper. In paper, acid hydrolysis splits the long cellulose chains into shorter ones, making the paper less flexible, more brittle and more susceptible to damage. This breakdown process will continue as long as acid is present and, because the process itself produces acid, the degradation will actually accelerate as it progresses (ASHRAE 2001).

6.3.3 Mechanical Damage

Extremes in temperature or RH make many objects vulnerable to mechanical damage. For example, materials that become stiff or brittle when cold are more likely to break at low temperatures. Luckily, extremes are usually easy to avoid, except in rare cases such as sudden failure of an environmental control system. Fluctuations in temperature or RH, however, are the main cause of most mechanical damage. Unfortunately, these are less easily controlled and not as well understood. Usually, objects will respond to fluctuation very slowly from the outside inwards (Thomson 1986).

The explanation for the dangers of fluctuations lies in the basic mechanical properties of materials. Inorganic and organic materials respond to temperature changes by expanding when hot and contracting when cold. Organic materials, which are hygroscopic, respond to changes in RH by shrinking when the RH drops and swelling when the RH climbs. All moisture-absorbent materials, such as wood, leather, textiles and adhesives, swell when the RH rises and shrink when it falls, causing warping, dislocation between parts, splitting, breaking of fibres, etc. (Tiemann 1944).

These responses in themselves do not cause damage. However, damage can occur when objects are made of materials that respond in different ways, placing one material under restraint of another. For example, a wooden panel that is not restrained in any way can expand and contract in response to changing conditions without harm. However, if the wooden panel is part of a chest of drawers, or an agricultural machine, or an architectural element and it is attached to other elements that restrict its movement, then damage is likely when the wood attempts to move during RH changes. A painting presents a more complex example. A typical painting is composed of many layers that expand and contract in differing ways. The internal stresses thus created can cause flaking, cracking and warping of wood over time. The damaging nature of very wide fluctuations in RH and temperature has been known for a long time (Berger and Russell 1956; Cornelius 1967).

6.4 Methodology

In this study two heritage preservation sites in Jordan were selected to be monitored, investigated and evaluated. The first was the Museum of Jordanian Heritage (MJH); it was selected because it is the only museum in Jordan, which has the potential to be transformed into a better place for the safeguarding of objects inside its walls (Alghazawi 2003). The second selected heritage preservation site was the main storage of the Department of Antiquities (DoAS). This storage is considered to be the first destination for objects coming from excavations, which are taking place in Jordan.

Humidity, temperature, air pollution and atmospheric corrosion were monitored in the MJH and the DoAS over a period of four weeks during the winter of 2009 and four weeks in the summer of the same year. Using the OnGuard^{TM} 3000 (ACM), which was borrowed from the company Twin Filter, Incorporated, data were recorded once every two hours, showing the actual maximum and minimum temperatures, RH and corrosion levels for both silver and copper. Following a specific period of observation of approximately one month in each semester of investigating and monitoring the indoor air climate and air purification. Next the obtained data resulted from the silver and cupper corrosion, were processed and compared to Muller's standard and to the ISO standard EN-ISO 1184. The RH and temperature data were compared to the Canadian Conservation Institute international standards and guidelines for temperature and relative humidity in museums, art galleries, libraries and archives. Furthermore, the results of the indoor environment were compared to the results from outdoors, in order to determine any correlation between the two atmospheric zones (CCI 2006).

Monitoring and effective control of temperature, relative humidity and corrosion levels is of vital significance in order to safeguard the museum's collection, whether on display or in storage. Additionally, the variation in humidity, temperature and the effects of air pollution inside the monitored museum and storage area were compared to variations in these factors outside, to assess the degree of the fluctuations of these values inside the MJH and DoAS (Grzywacz 2006).

At the MJH, the OnGuard^{TM} 3000 was installed inside a showcase located in the middle of the museum. The device was installed inside a showcase in order to protect the device from vandalism or theft; also, the device would monitor the indoor environment of the museum, as the showcases at the MJH are not isolated from the ambient environment. Within the DoAS, the OnGuard^{TM} 3000 device was put on an empty shelf, because the storage was closed to the public and the curator is the only person with a key.

Consequently, depending on theoretical studies and following the analysis of the monitoring data, recommendations were made regarding the practical measures to be taken in respect of environmental control. Awareness and implementation of international standards urgently needs to be highlighted at Jordanian museums, if they are to preserve their national legacies.

6.4.1 Air monitoring tools and techniques

Air monitoring is central to any environmental control program for achieving and maintaining air-quality standards based on the presence, or absence, of gaseous air pollutants. Such monitoring can also provide the short-term data required to manage and mitigate contaminant-specific episodes with some actions and precautions. In addition to contamination control programs, air-monitoring data may be employed for:

- The evaluation of long-term air quality trends in a facility

- Research studies designed to determine relationships, if any, between pollutant levels and possible damaging effects (Muller 1999).

Air quality measurements in preservation environments often mean stringent demands on monitoring instrumentation and methodologies. Special modifications and protocols are often needed to adapt the techniques for use in these environments.

Several characteristics of any measurement technique must be evaluated to determine its appropriateness for use in indoor air-quality monitoring. Among the more important characteristics are sensitivity, cost and complexity. Sensitivity is a particularly demanding parameter for environments where near-ambient levels of many pollutants may be encountered and control levels approach the sub-parts per billion (ppb) level. Likewise, cost may be quite important when deciding on a measurement technique, particularly in large surveys. Another important point of consideration is the complexity of the technique and the degree of skill and training required to obtain quality results. Other factors deserving consideration are selectivity and portability. Most measurement techniques do not fit within all of these parameters and one must weigh the various characteristics, in order to, best meet the desired goals. Often, trade-offs will be necessary in selecting the techniques to be used for a specific study (Muller 1999).

6.4.2 OnGuard™ 3000 Atmospheric Corrosion Monitor (ACM).

Figure 6.6 OnGuard™ 3000 Atmospheric Corrosion Monitor

In general, the measuring of atmospheric corrosion on metallic surfaces has been carried out with a variety of techniques. The simplest and most reliable is the measurement of the mass gain on a metal sample strip, which is often referred to as a 'coupon' (see Chapter 5). The OnGuard 3000 uses a patented technology to measure the corrosion that occurs on copper and silver surfaces using quartz crystal microbalance sensors plated with either copper or silver. The plated crystal has a natural resonance frequency based upon its mass. As corrosion films are formed, the sensor mass increases by the mass of the contaminant gases that have reacted with the base metal plating. As a result, the crystal's resonance frequency decreases (Purafil 2006).

Typical corrosive gases are: hydrogen sulphide (H_2S), chlorine (Cl_2), oxides of sulphur and nitrogen (SO_2, SO_3, NO, NO_2, etc.), ozone (O_3), ammonia (NH_3) and hydrogen fluoride (HF). Therefore, corrosion films may be composed of reaction products such as copper sulphide and oxide (Cu_2S and Cu_2O) for copper surfaces and silver sulphide and chloride (Ag_2S and AgCl) for silver surfaces (Abbott 1983; Rice 1981). These reaction products cause an associated mass gain, which can be directly correlated to the average corrosion thickness occurs at the film, in angstroms (?), on the metal surface (England *et al*. 1991).

By applying the proper conversion factors contained in the software of the OnGuard™ units, the corrosion build-up that occurs over the life of the corrosion sensor can be determined. This is referred to as the 'Cumulative Corrosion'.

The rate of corrosion build-up over a given time period can also be determined. The term for this is 'Incremental Corrosion'.

The built-in silver and copper chips are also used to indicate the presence of SO_2, O_3, NO_2, Cl_2 and many other corrosive materials, which can cause deterioration of metals, cellulose and organic materials. These chips originally used only copper reactivity to establish environmental classifications. However, copper is not sufficiently sensitive to many of the pollutants ubiquitous to most urban environments, the same environments in which most museums, galleries, etc. are located. Furthermore, copper coupons cannot detect the presence of chlorine, a particularly dangerous contaminant to metals. With this in mind, Purafil Inc, developed built-in silver reactivity monitoring for the OnGuard™ 3000. Silver is sensitive to chlorine and, when used with copper reactivity monitoring, can be used to detect changes in the levels of gaseous pollutants in the ambient environment as small as 1 ppb. Silver can also be used to differentiate between different classes of contaminants (Purafil 2006).

There are two ways to view and save the OnGuard™ 3000 data. The first way is to use 'Capture Instant Data' and the second is to download the data that has already been logged. In both cases, the file is saved as a ".csv" text file, which can be read by Microsoft Excel for additional analysis. The data files are saved in the same directory as the application program unless another location has been specified (Purafil 2006).

6.5 Selected areas

To address, criticize and analyze the indoor air-quality and the indoor environments, of a two heritage preserved sites in Jordan; a comprehensive research was conducted with the aim of providing recommendations and suggestions. It is hoped that this information will enable senior officials of museums in Jordan, to address their preservation needs, improve and develop their conservation methods in order to portray an as excellent a historical image of Jordan as possible. Involved in the present study are the Department of Antiquities storage (DoAS) and the Museum of Jordanian heritage (MJH).

6.5.1 The Department of Antiquities main storage

The DoA storage in Amman, was built in 1996 and is situated near the main highway between Amman and Zarqa, which is the second -largest city in Jordan. As a result of its location, this road is always congested with traffic. The storage consists of three separate halls. The first is the main hall. In this hall mainly the findings from the archaeological excavations are kept. This main storage hall is a building with metal walls, which is not sealed against the outside atmosphere. It has windows on the upper side of each wall. The second hall is a rather smaller one, the only access to this hall is through the main big hall. It is somehow considered a small room within the big hall, in other words, it is a micro-room within the big hall. Moreover, the more vulnerable objects are kept in this second hall because it is well sealed and only the storage director has access to this room . The third hall is basically a cave located near the main storage area. Its access

Figure 6.7 The main hall at the DoAS storage.
Photo by: R. Alghazawi

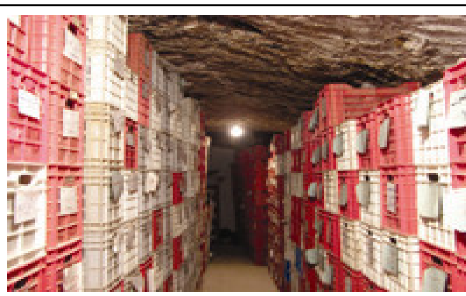

Figure 6.8 Objects stored in plastic boxes in the cave.
Photo by: R. Alghazawi

was closed, with a door, so that the cave could be used for storage. This cave has never been renovated (Alshami 2009). The DoAS storage is a prefabricated metal building, see Figure 6.7. This type of pre-engineered steel building is usually used for agricultural equipment and fodder, farms, pole barns, horses, workshops, residential homes and commercial buildings.

The use of metal buildings is rapidly becoming more popular in Jordan because they can be built very quickly and are extremely low in cost. They can easily be adapted to any number of external architectural treatments without restricting their interior floor planning.

6.5.2 Museum of Jordanian Heritage and Numismatics Museum

The Museum of Jordanian Heritage, part of the Faculty of Archaeology and Anthropology at Yarmouk University, Irbid, is a dynamic facility in a growing organization. The museum recounts the story of humankind from its earliest stages to today.

Figure 6.9 The main gallery at the MJH. Photo by: R. Alghazawi

The museum reflects the research and field projects conducted by the faculty, researchers and technicians of the faculty, whether independently or in cooperation with other local and foreign institutes.

The museum was established in 1988 and opened to the public in the same year. It offers a wide range of activities for the community, students, scholars and visitors, including exhibitions, lectures and excursions. The museum used to have the Numismatics Hall as part of its facilities, but recently this has become an independent museum, called the Numismatics Museum.

The main gallery of the Jordanian Heritage Museum consists of four rooms. The first room deals with Jordan's prehistory and includes features and exhibits on "Hunters, Gatherers and Food-Collectors", "Agricultural Evolution" and "Village Farming Communities". Jordan's early history is depicted in room two, through exhibits on "City-states and Development", "The development of Territorial States" and "Early Pastoralists and Bedouins". The third room is entitled "East and west" and puts special emphasis on the local population during the Roman and Byzantine periods. The main topics are "The Nabataeans", "Ethnic and Cultural Plurality in Classical Jordan" and "From Decapolis to *Jund al-Urdunn*". The exhibits of the fourth room, dealing with "Jordan as Part of the Islamic World", are arranged under the topics "Jordan under the Caliphate", "Ayyubid/Mamluk and Ottoman Jordan", "Land Tenure and Settlement in the Late Nineteenth Century" and "Jordan's Present and Future". Also it exhibit the "Shop of *attar* the traditional Druggist", reconstructions of a blacksmith's forge, a potter, woodcarver and treadle loom-weaver's workshops lead the visitor into the courtyard of the museum.

Figure 6.10 Courtyard of the museum. Photo by: R. Alghazawi

The courtyard features a rural house-complex from north Jordan displaying basic local architectural elements of the north part of Jordan citizens, such as cross-vaulted rooms, transversal arches and an arched façade. The visitor can enter the completely furnished living and guest rooms, a stable and a bread oven room.
A staircase leads to the second floor, giving access to the mezzanine floor. Here special topics related to the history of technology are displayed. These include "Stone-Implements and Rock-Art", "Metallurgy", "Basketry" and other "textile techniques", "Pottery and Pottery-making in Jordan" and "Glass". In addition, there are displays on numismatics, epigraphy and "Seals and Amulets".

6.6 Collection forecast and damage anticipation

6.6.1 Department of Antiquities main storage

The main reason for damage and deterioration of the collection in the DoA storage is due to the lack of standardisation of handling procedures and no safe environment for very fragile objects. The pre-engineered steel building provides an inadequate climate for employees and for the collection. It is cold in winter and hot in summer and so the employees have to open the windows to adjust the indoor climate in the summer. The cluttering of objects in the storage as seen in Figure 6.11 and the poor handling procedures were explained by the storage curator as a result of the vast quantity of items the storage holds.

Figure 6.11 The mass corrosion. Metal shelf infection
Photo by: R. Alghazawi

In addition, unsuitable environmental conditions lead objects that are more susceptible to deterioration. These objects in turn infect adjacent objects. The cluttering of metal objects on metal shelves has eventually led the metal shelves themselves to corrode.

6.6.2 Museum of Jordanian Heritage

The attractive design of the showcases has prompted considerable attention for a suitable preservation environment and the control of the ambient atmosphere at the MJH. Due to the large number of displayed objects and the complexity of the building's structure, as well as not taking advantage of the devices to reduce any deterioration and damage that might occur in the future which are existing already in the museum, it was necessary to visually assess the conditions of the displayed objects in the museum. From experience gained in visiting different types of international museums and from the available literature on the subject of museum conditions, one would expect a safe environment for the objects, but the reality was quite different.

Figure 6.12 A lead sarcophagus photo was taken in August 2009. Photo by: R. Alghazawi

The museum objects differ in their resistance to environmental factors. Through observation, two kinds of destruction have been noticed: human and natural (environmental). The human factor became clear while interviewing some of the museum employees. Every day actions, such as the way the employees handle and transfer objects from the museum to the storage area, the cluttered storage of objects even on a display shelf in the museum and the cleaning of the shelves in the museum all cause damage to the objects. Human handling can cause damage to objects like ceramics and sculptures that are otherwise relatively immune to environmental damage.

Figure 6.13 A lead sarcophagus photo was taken in February 2010. Photo by: R. Alghazawi

The environmental factor was evident in fragile objects and had caused fractures in wood, wear and tear of textiles, metal corrosion and brittleness of glass. The time period between the two photos in Figure 6.12 and 6.13 is only six months (August 2008 and February 2009), which is an extremely short period for such a change in the condition of the object. The same period also led a bronze spearhead to loose its front fore.

6.7 Results

The following results are based on an analysis of relative humidity and temperature data provided by a Meteorological station in Amman and Irbid, showing seasonal fluctuations. The monitoring period was one month in winter and another in summer in 2009, in both monitored locations of Amman and Irbid, where the two heritage-preserving sites are located. This data was used to compare the effect of the exterior climatic conditions on the conditions inside the museum and the storage area and to find correlations between the indoor climate and the exterior atmosphere. Data was recorded once every two hours, showing the actual maximum and minimum temperatures, RH and corrosion levels for both silver and copper.
The monitoring of temperature, RH and corrosion level period for the Museum of Jordanian heritage took place over two months in 2009. The first monitoring period was during March and the second period was in May. It is important to point out here that the first monitoring period of the Department of Antiquities' main storage was in February and the second monitoring period was in July. The measurements in the DoAS were taken by using the OnGuard^{TM} 3000 environmental reactivity-monitoring device.
The results are illustrated in three different graphs for each location and for each period. The first graph shows the fluctuation of temperature and RH compared to the previously mentioned 'Environmental guidelines for museums - Temperature and relative humidity' in the CCI standards. The second graph presents the corrosions levels of copper and silver compared to Muller's guidelines described in Table 6.4 and Table 6.5. The third graph demonstrates the monitored factors temperature, RH and the corrosion level combined in their correlation with the outside atmosphere.

6.7.1 Department of Antiquities main storage (winter monitoring)

Figure 6.14 shows the indoor measurements of temperature and RH in the wintertime in the Department of Antiquities main storage in Amman. These measurements, which were taken over a period of 28 days, were taken in the typical environment the storage usually provides for the objects throughout the wintertime. The RH results show continuous fluctuation through the whole monitoring period. The RH levels varied from 45% at the lowest point, which was recorded on February 9 2009, to 78% at its highest point, recorded on February 27 and 28. In addition, the readings of the temperature in the same graph shows fluctuation from 4 ?C, recorded on February 27 and 28 2009, to the highest point of 14 ?C, recorded on February 9, 2009. Figure 5.14 provides us with two important pieces of data: First, there is a fluctuation in both temperature and RH and second, the temperature and RH are directly correlated. The highest amount of RH was recorded on the same day as the lowest temperature, vice versa. This proves the Thomson (1986) hypothesis of the relation between RH and temperature.

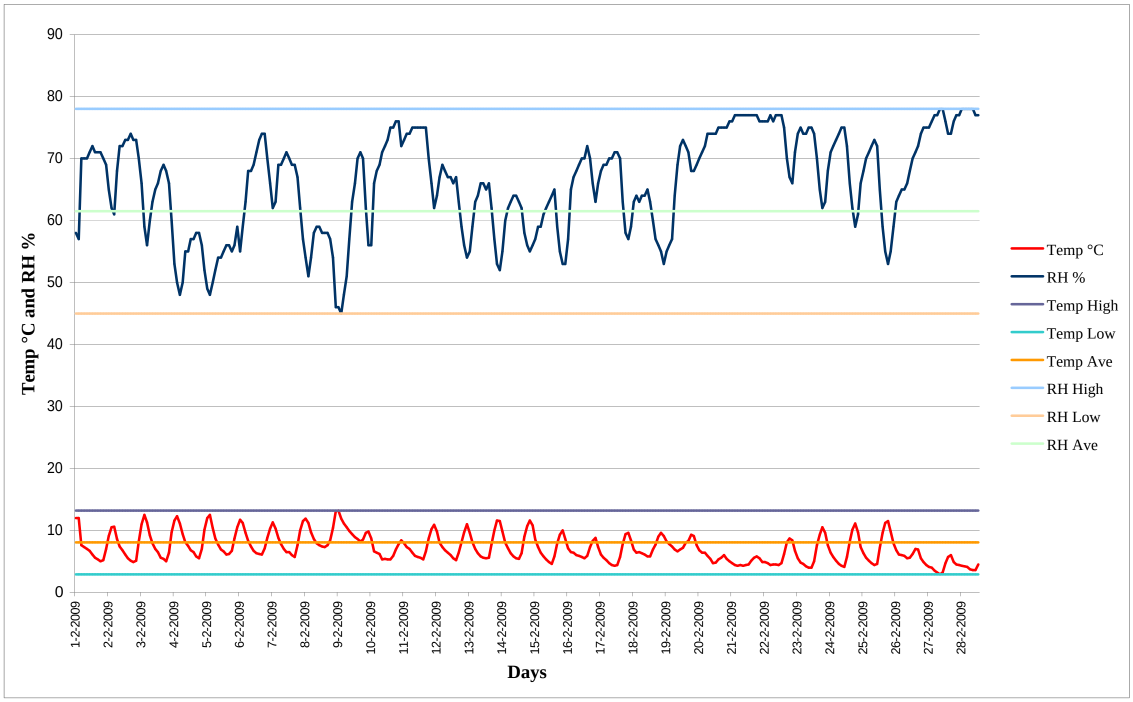

Figure 6.14 Fluctuations in temperature and relative humidity in the DoAS main storage in Amman. The monitoring period was during the winter.

The graph in Figure 6.15 indicates the corrosion levels in copper and silver in measured in ? . These measurements were taken in the DoAS in Amman. The results of monitoring were compared to the ISO standard EN-ISO 1184, the classification of the Canadian Conservation Institute standards and to the Muller's guidelines described in Table 6.4 and Table 6.5. Thus the classification S2/C2, i.e. for silver the maximum corrosion level should not exceed 100 ? / 30 days and for copper must not exceed 150 ? / 30 days for museum storage, was applied.

The monitoring period was in winter and took place from February 1, 2009 to February 28, 2009. During this period, there was a vast variation in the results of the incremental values of the corrosion levels. Sometimes the corrosion levels were at a level of zero values, while at other times the level reached 17 ? . When compared to the results in Figure 6.14, a direct correlation is seen between the fluctuation of RH and corrosion; whenever the RH rises, the rate of the corrosion level also rises. It was also noticed that the corrosion of silver and copper films were related to each other. The corrosion to the silver film is higher than the corrosion to the copper film due to high RH and this may indicate the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3). This issue is clarified further during the discussion section.

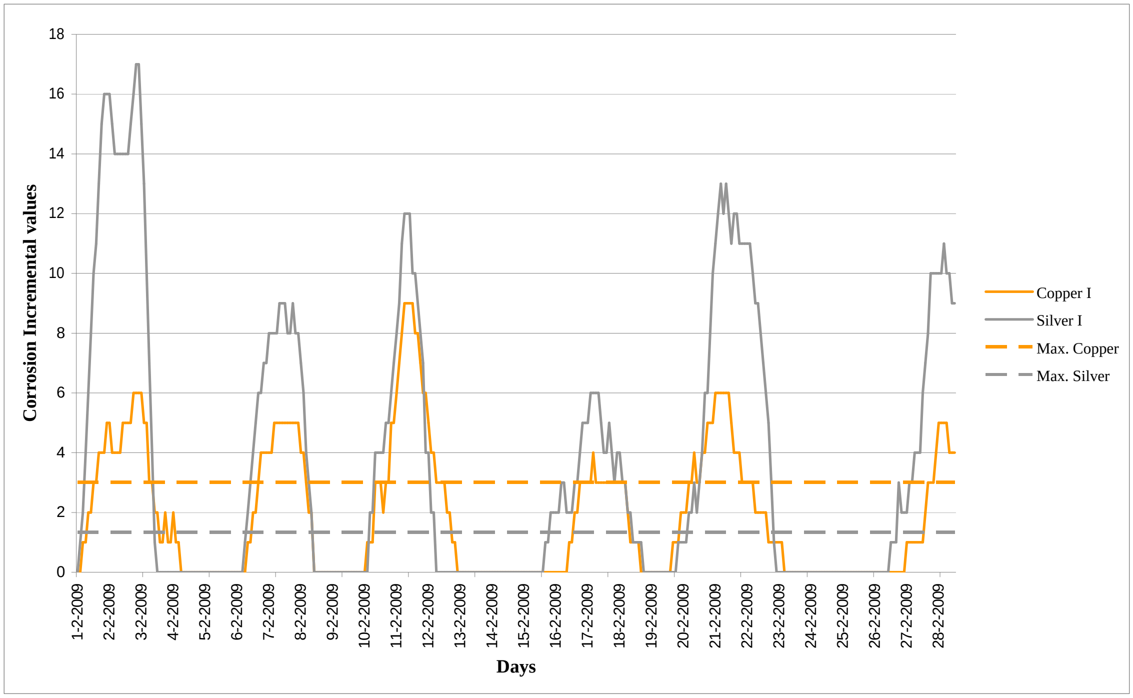

Figure 6.15 Corrosion levels in Copper and Silver in the DoAS main storage in Amman, compared to the Muller's guidelines described in Table 6.4 and Table 6.5. The monitoring period was during the winter. The recommended classification for Museums, Museum Storage, Libraries (Class S2/C2) is found in the graph as horizontal lines

The correlation between the fluctuations of the indoor and the outdoor climates in the DoAS in Amman and the relation to corrosion levels are all presented in Figure 6.16. The monitoring period was from February 1, 2009 until February 28, 2009. It is noticeable that there was a correlation between the outside and inside temperature, but they draw the same fluctuation line on the graph. On one hand, this graph shows the correlation between the outside and the inside atmosphere and on the other hand, it shows the relation between the fluctuation of the indoor RH and temperature and the rate of corrosion levels.

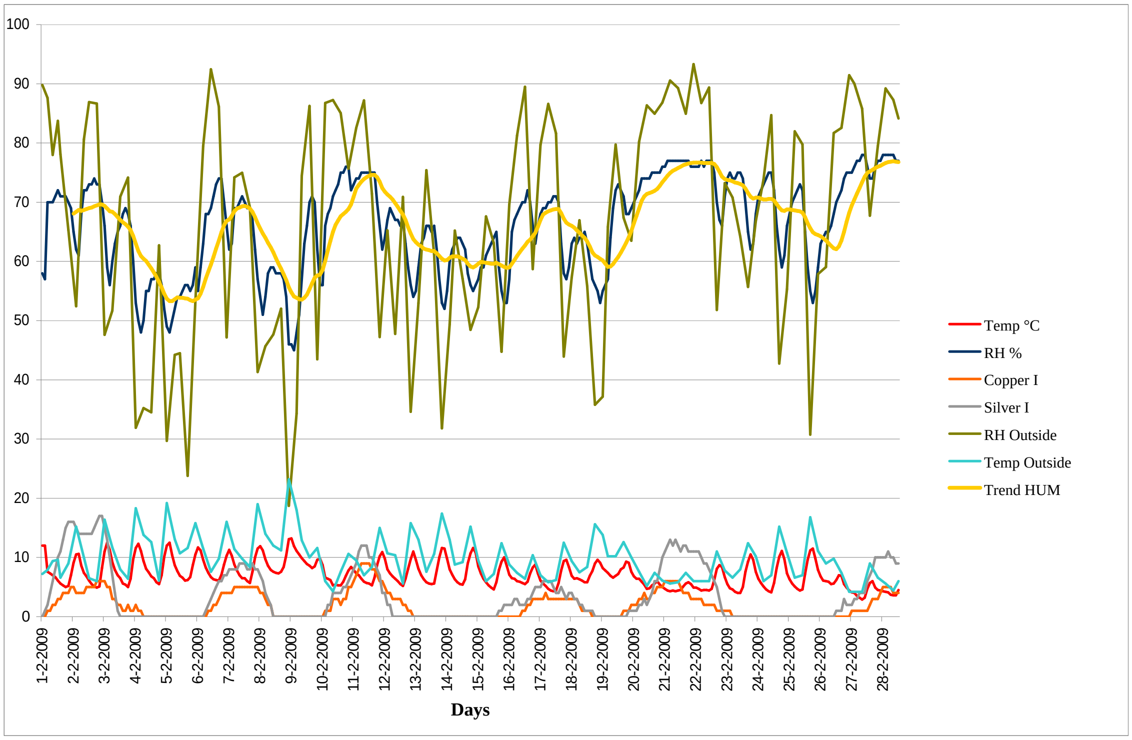

Figure 6.16 The correlation between the fluctuations of the indoor and the outdoor climates in the DoAS main storage in Amman and the relation to corrosion levels. The monitoring period was during the winter.

6.7.2 Department of Antiquities main storage (summer monitoring)

Figure 6.17 shows the indoor measurements of temperature and RH in the summer time in the Department of Antiquities main storage in Amman. These measurements were taken over a period of 30 days and the measurements were taken in the typical environment the storage usually provides for the collection throughout the summer season. It is obvious that there was a contrast in the results to those obtained in the wintertime. The average temperature in summer is 28 °C, while it was 8 °C in winter. As for RH results, the average in winter was 62% while it was in summer it was 47%. The difference between the average summer and winter readings can indicate a non-controlled environment inside the DoAS. The RH results show continuous fluctuation throughout the whole monitoring period. The reading of the RH level varied from 28% at the lowest point, recorded on June 30, 2009 and July 1, 2009, to 78% at its highest point, recorded on July 5, 2009. In addition, the readings for the temperature in the same graph show a fluctuation from 21 ?C, recorded on June 27 and 28, 2009, to the highest point of 34 ?C, recorded on July 1, 2009. This result provides an important piece of data: the highest temperature point was recorded on the same day as the lowest RH percentage was recorded and vice versa. In spite of this, the results are in contrast with the hypothesis of Thomson (1986) about the relation between RH and temperature. However, this can be explained by the particularly hot and dry summer in Jordan during the monitoring period and the direct correlation between the indoor and the outdoor atmospheres. In addition, graph 6.17 provides us with two other important pieces of data: there was a fluctuation in both temperature and RH; that temperature and RH are directly correlated.

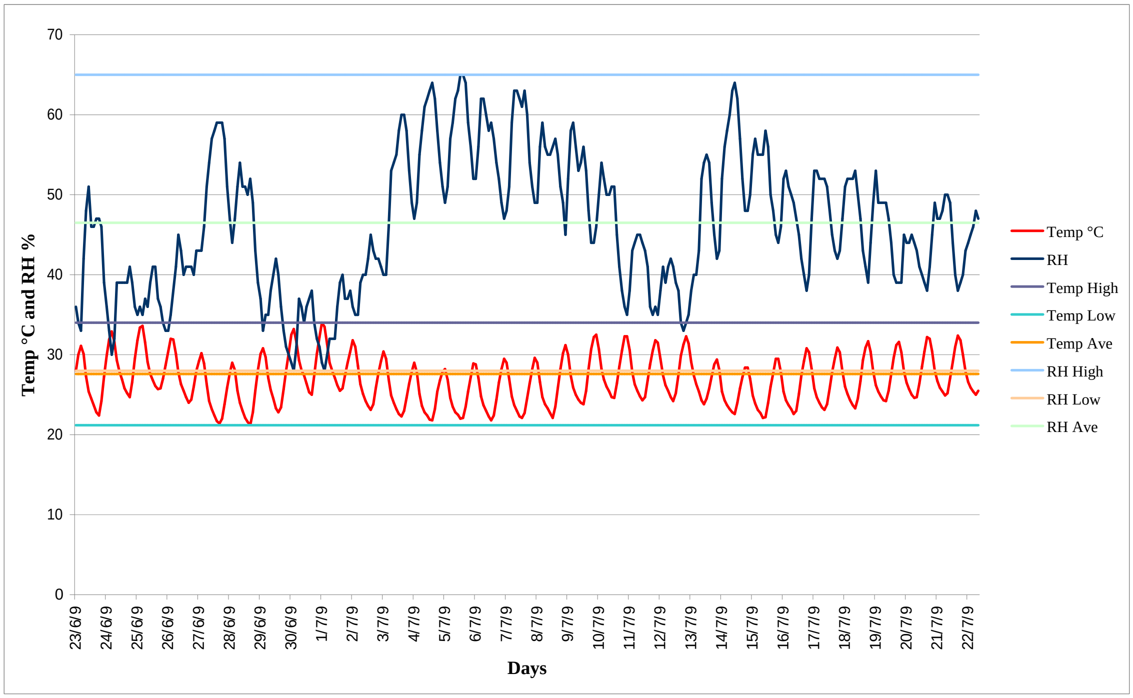

Figure 6.17 Fluctuations in temperature and relative humidity in the DoAS main storage in Amman. The monitoring period was during the summer.

Figure 6.18 indicates the corrosion levels in copper and silver, measured in ? . These measurements were taken in the DoAS in Amman. The results of monitoring were compared to Muller's guidelines described in Table 6.4 and Table 6.5. Thus the classification S2/C2, i.e. for silver the maximum corrosion level should not exceed 100 ? / 30 days and for copper must not exceed 150 ? / 30 days for museum storage, was applied. The monitoring period during the summer took place from June 23, 2009, to July 23, 2009. During this period, there was a vast variation in the incremental values results of the corrosion levels; some of the readings of the corrosion levels are at level zero value, whereas other readings reach 14 ?. When compared to these results in graph 6.15, it can be seen that whenever the DoAS had a high RH level, high corrosion levels are also recorded. In other words, high RH levels were recorded in the 4th, 5th and 15th of July 2009 and looking at Figure 6.18 we can see that the highest values of incremental values level of silver and copper corrosion were recorded on these same dates. Therefore, it can be assumed that there is a direct correlation between the presence of RH and corrosion levels. In addition (as was recorded in the results of the winter monitoring at the DoAS) it was noticed that the corrosion of silver and copper films were related to each other as well, but in different ratios. In other words, the corrosion on the silver film is higher than the corrosion on the copper film due to high RH and this may indicate the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3). This issue is clarified further during the discussion section.

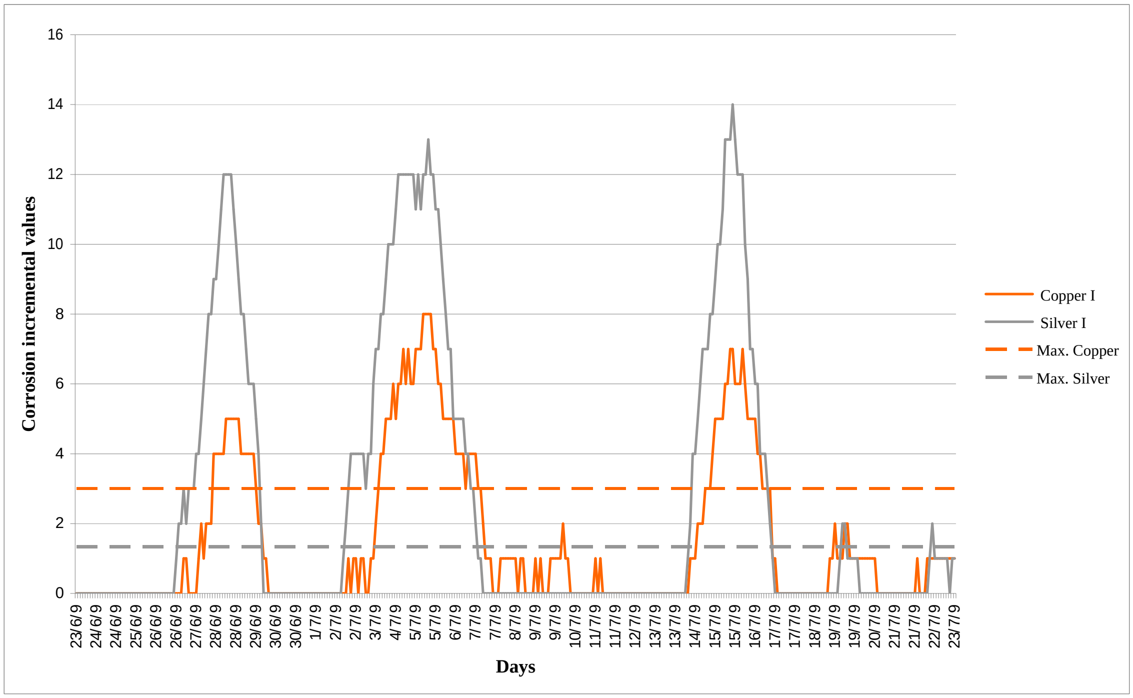

Figure 6.18 Corrosion levels in Copper and Silver in the DoAS main storage in Amman, compared to Muller's guidelines described in Table 6.4 and Table 6.5. The monitoring period was during the summer. The recommended classification for Museums, Museum Storage, Libraries (Class S2/C2) is found in the graph as horizontal lines.

The correlation between the fluctuations of the indoor and the outdoor climates in the DoAS in Amman and the relation to corrosion levels are all presented in Figure 6.19. The monitoring period was from June 23, 2009 to July 23, 2009. Figure 6.19 indicates several things: the joined trend of the indoor and the outdoor temperature line; the connection between the indoor and the outdoor RH; the presence of corrosion for both silver and copper films are related to the presence of RH. All these may lead us to conclude that there is no decisive separation between the indoor and the outside atmosphere.

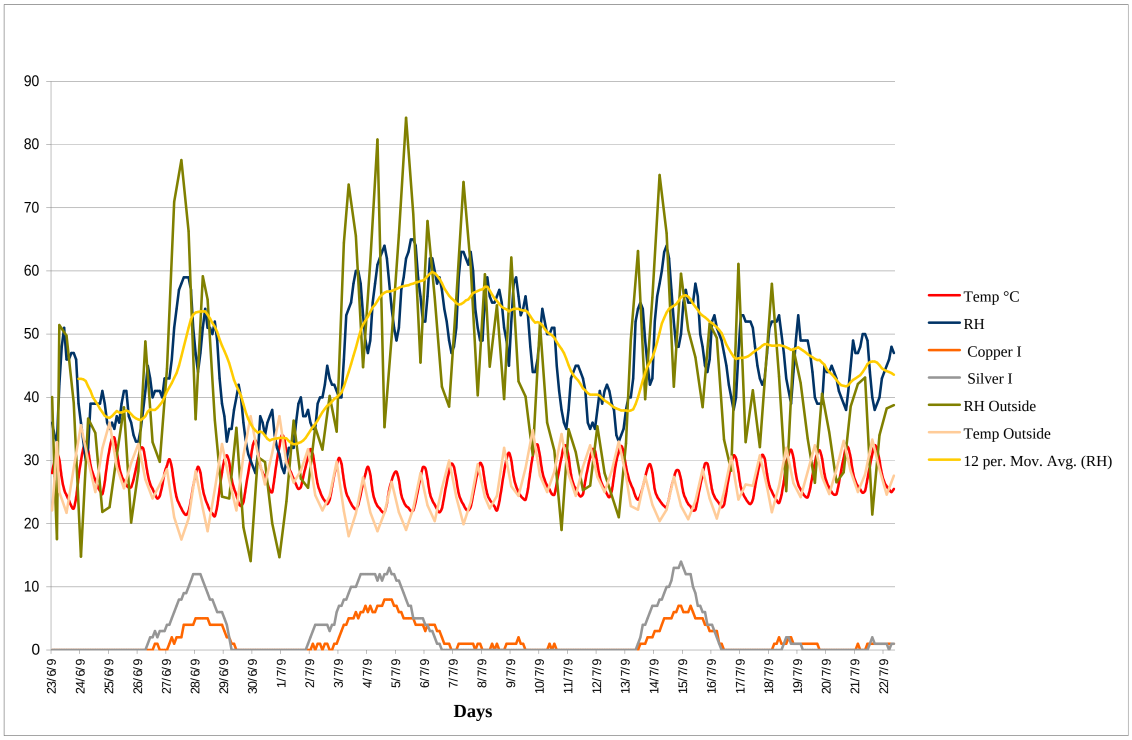

Figure 6.19 The correlation between the fluctuations of the indoor and the outdoor climates in the DoAS main storage in Amman and the relation to corrosion levels. The monitoring period was during the summer.

6.7.3 Museum of Jordanian heritage – Yarmouk University (winter monitoring)

Figure 6.20 shows the indoor measurements of temperature and RH in the wintertime in the Museum of Jordanian Heritage at Yarmouk University, Irbid. These measurements were taken over a period of 31 days. During this period, the museum was displaying its collection in the typical environment the museum usually provides throughout the winter season. Although the museum does not provide any climatic isolation systems, the readings for RH show a minor fluctuation throughout the monitoring period. The readings of the RH level varied from 54% at the lowest point, recorded on March 17, 2009, to 68% at its highest point, recorded on March 3, 2009. In addition, the readings for temperature in the same graph show fluctuation from 10 ?C, recorded on March 2 and 3, 2009, to the highest point of 16 ?C, recorded on March 8, 2009. This period is considered as being a transition phase between winter and spring in Jordan. Maybe this can explain the variation of the results compared to those in the DoAS, other than the different geographical locations of the museums.

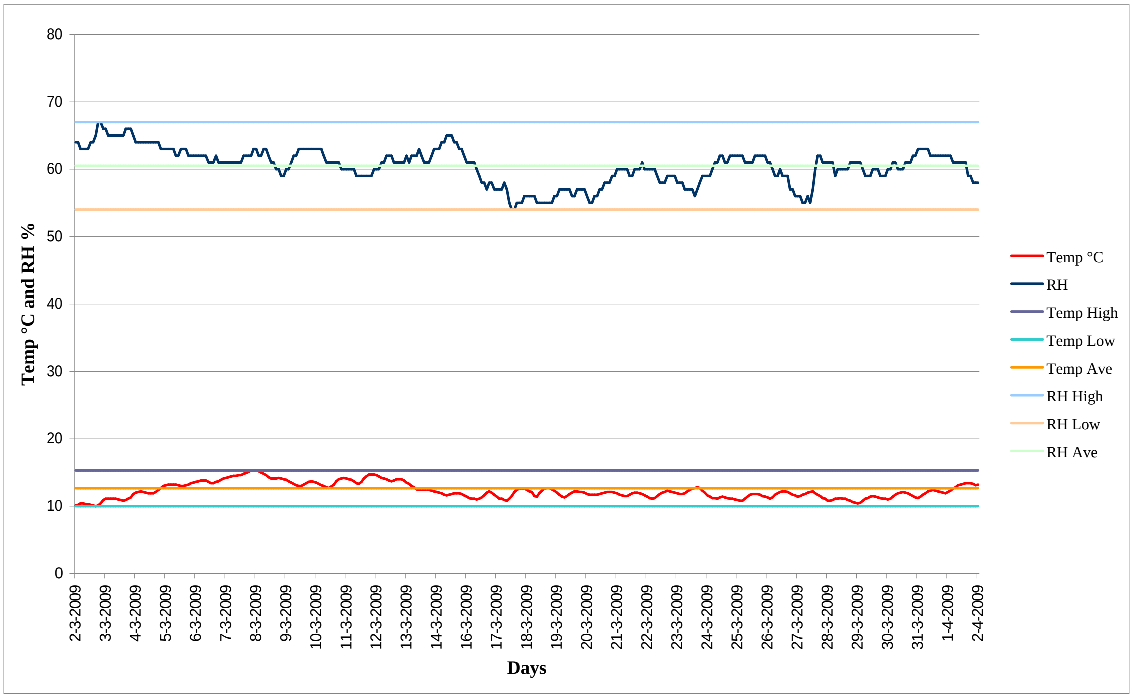

Figure 6.20 Fluctuations of temperature and relative humidity in the Jordanian Heritage Museum. The monitoring period was during the winter.

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Figure 6.21 shows the corrosion levels for copper and silver measured in ? . These measurements were taken in the MJH in Irbid. The results of this monitoring were compared to the Advisory guideline of air quality for archives of the Muller guidelines described in Table 6.4 and Table 6.5. Thus the classification S2/C2, *i.e*. for silver the maximum corrosion level should not exceed 100 ? / 30 days and for copper must not exceed 150 ? / 30 days for museum, was applied. The monitoring period was in wintertime and took place from February 2, 2009, to February 28, 2009. During this period, there was a vast variation in the results of the incremental values of the corrosion levels; sometimes the corrosion levels were at a level of zero values, while other times it reached 17 ? . When these results are compared to the results in Figure 6.20, a direct correlation is seen between the fluctuations of RH and the corrosion level, as whenever the RH raises the rate of the corrosion level also rises. It was also noticed that the corrosion of silver and copper films were related to each other as well but in different ratios. In other words, the presence of corrosion on the silver film is higher than the corrosion on the copper film due to high RH. This may indicate the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3). This issue is clarified further during the discussion section.

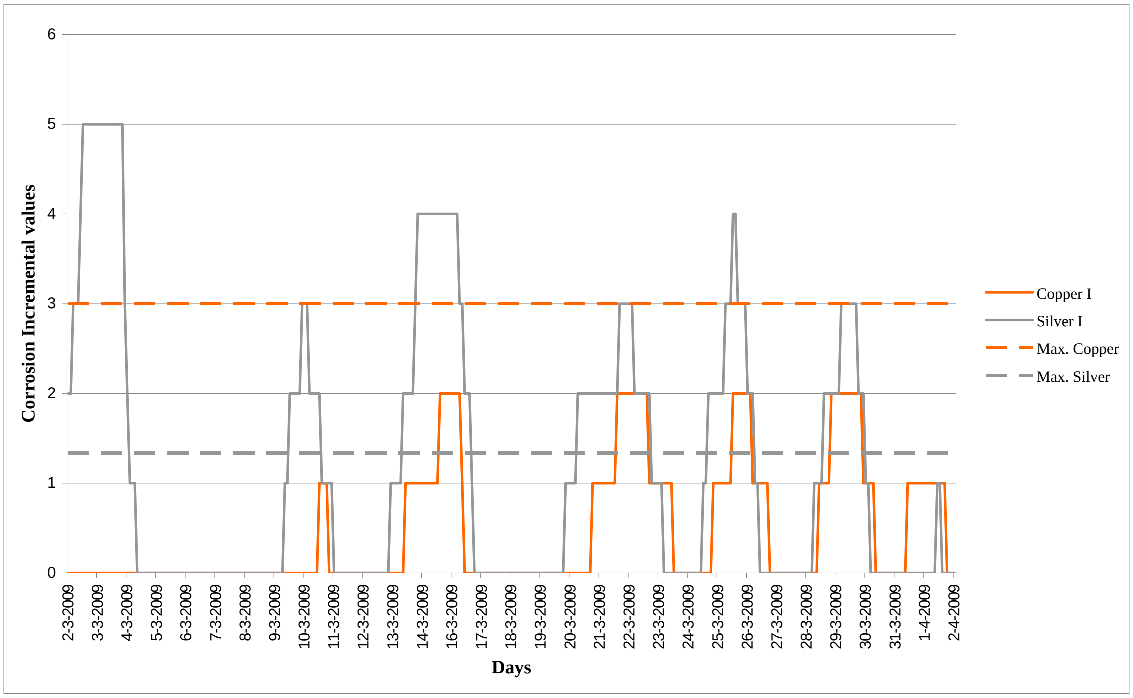

Figure 6.21 Corrosion levels in Copper and Silver in the in the Jordanian Heritage Museum, compared to the Muller's guidelines described in Table 6.4 and Table 6.5. The monitoring period was during the winter. The recommended classification for Museums, Museum Storage, Libraries (Class S2/C2) is found in the graph as horizontal lines.

The correlation between the fluctuations of the indoor and the outdoor climates in the MJH in Irbid and the relation to corrosion levels are presented in Figure 6.22. The monitoring period was from March 2, 2009, to April 2, 2009. Although there was a vast fluctuation in RH in the outside atmosphere in Irbid during this period, there was only a minor fluctuation in RH in the indoor environment of the Museum of Jordanian Heritage. This proves that the indoor and the outdoor climate are not related in any way, this is also obvious from the difference between the indoor and the outdoor temperatures.

On one hand this graph shows the correlation between the outside and the inside atmosphere. On the other hand, it shows the relation between the fluctuation of the indoor RH and temperature and the rate of corrosion levels, which were quite low for the copper film and higher for the silver film.

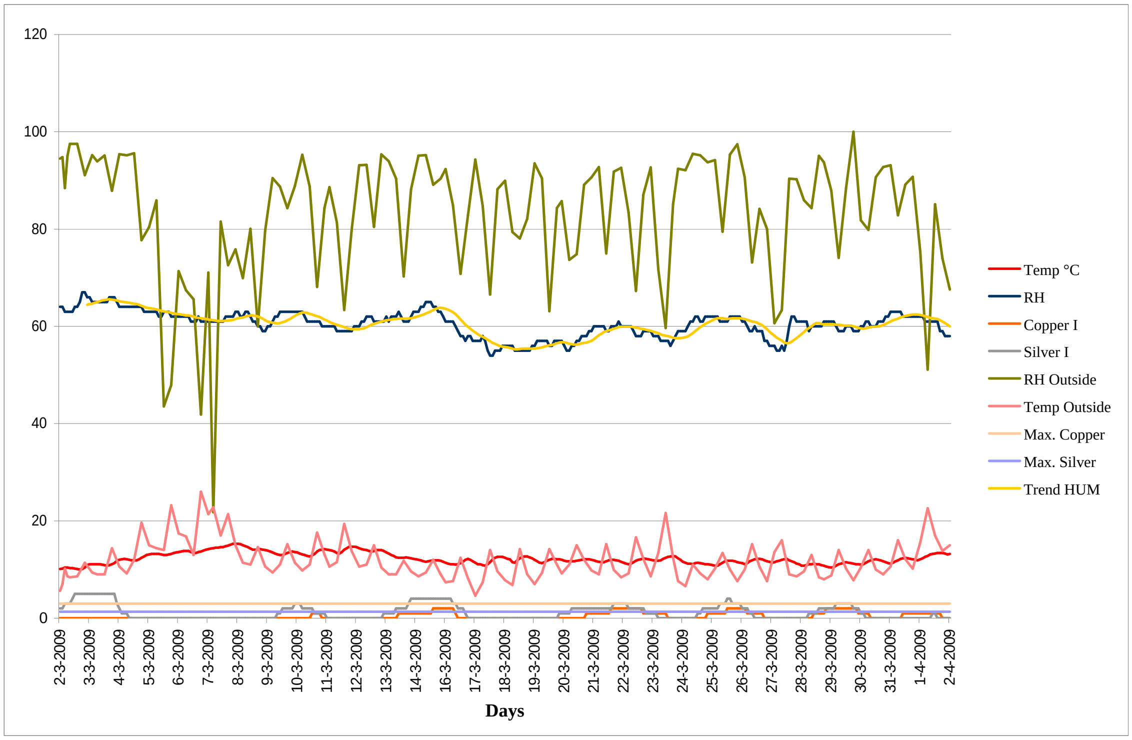

Figure 6.22 The correlation between the fluctuations in the indoor and outdoor climates at the Jordanian Heritage Museum in relation to corrosion levels. The monitoring period was during the winter.

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6.7.4 Museum of Jordanian heritage – Yarmouk University (Summer monitoring)

Figure 6.23 shows the indoor measurements of temperature and RH in the summer time in the Museum of Jordanian Heritage at Yarmouk University, Irbid. These measurements were taken over a period of 34 days and the monitoring period took place in the typical environment that the MJH usually provides throughout the summer season. It is obvious that temperature and RH were not constant at the monitored period, but as for the fluctuation rates, both were fairly low, as in the winter season readings. The average temperature in summer was 19 °C, while it was 12 °C in winter. As for the RH result, the average in winter was 61%, while it was in summer 56%. The difference between the average for the summer and winter readings can give an indication of a reasonable difference in both temperature and RH. The reading of the RH level varied from 56% at the lowest point, recorded on June 5, 2009, to 63% at its highest point, recorded on May 10, 2009. In addition, the readings for temperature in the same graph show a fluctuation from 16 ?C, recorded from May 5 to 10, 2009, to the highest point of 23 ?C, recorded on June 4 and 5, 2009. This result provides important data: the highest temperature point was recorded on the same day as the lowest RH percentage. In addition, Figure 6.23 provides us with two more important pieces of data: there is little fluctuation in both temperature and RH; temperature and RH are directly correlated, as the highest point of RH was recorded on the same day as the lowest point of temperature and vice versa.

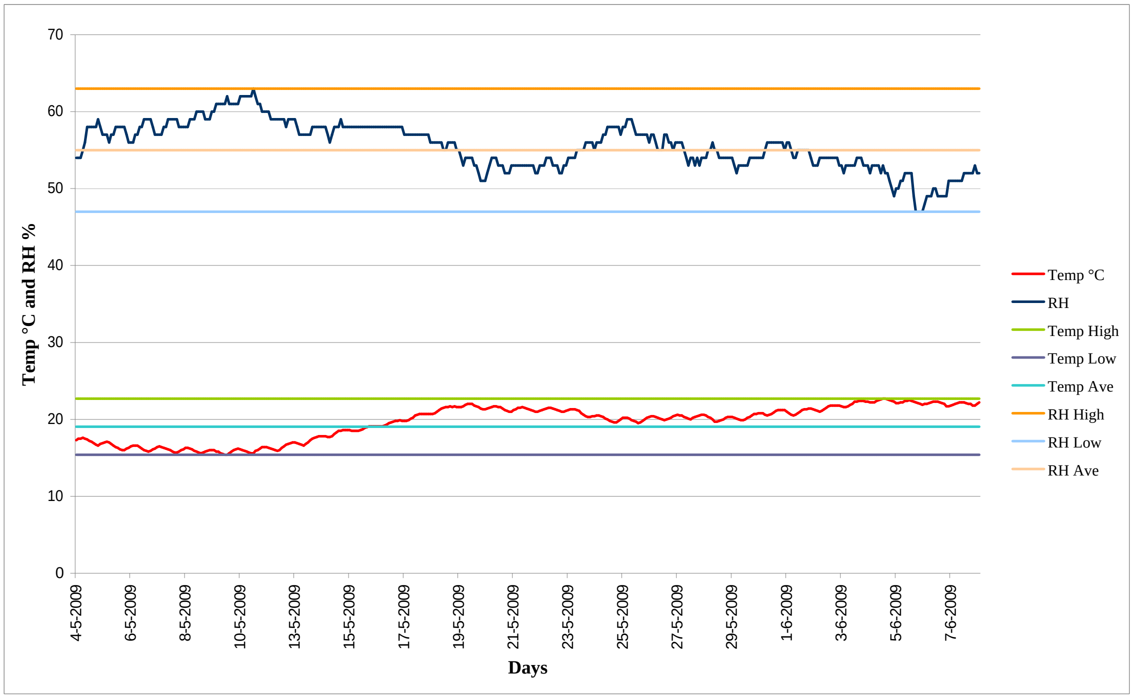

Figure 6.23 Fluctuations in temperature and relative humidity in the Jordanian Heritage Museum. The monitoring period was during the summer.

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The graph in Figure 6.24 indicates the corrosion levels in copper and silver, measured in ? . These measurements were taken at the MJH in Yarmouk University, Irbid. The results of this monitoring were compared to Muller's guidelines described in Table 6.4 and Table 6.5. Thus the classification S2/C2, *i.e*. for silver the maximum corrosion level should not exeed 100 ? / 30 days and for copper must not exceed 150 ? / 30 days for museum, was applied. The monitoring period was in wintertime and took place from May 4, 2009 to June 7, 2009. During this period, there were quite high rates in the incremental values in the results of the silver film corrosion levels. As for the corrosion levels of the copper film, this never exceeded the recommended levels, which is 3 ? / day. Some of the readings for the corrosion levels are at zero values, while others for the silver film corrosion levels reach 2 ? . The latter is in excess of the recommended level, which is 1.4 ? . When compared to the results in Figure 5.23, it can be seen that whenever the MJH had a high RH, high corrosion levels were recorded. Therefore, it is safe to suggest here a correlation between the presence of RH and the level of corrosion. Also as it was recorded at the results of winter monitoring at the MJH, it was noticed that the corrosion of silver and copper film was related to each other as well, but in different ratios. In other words, the presence of corrosion on the silver film is higher than the corrosion on the copper film due to high RH, which may indicate the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3). This issue is clarified further during the discussion section.

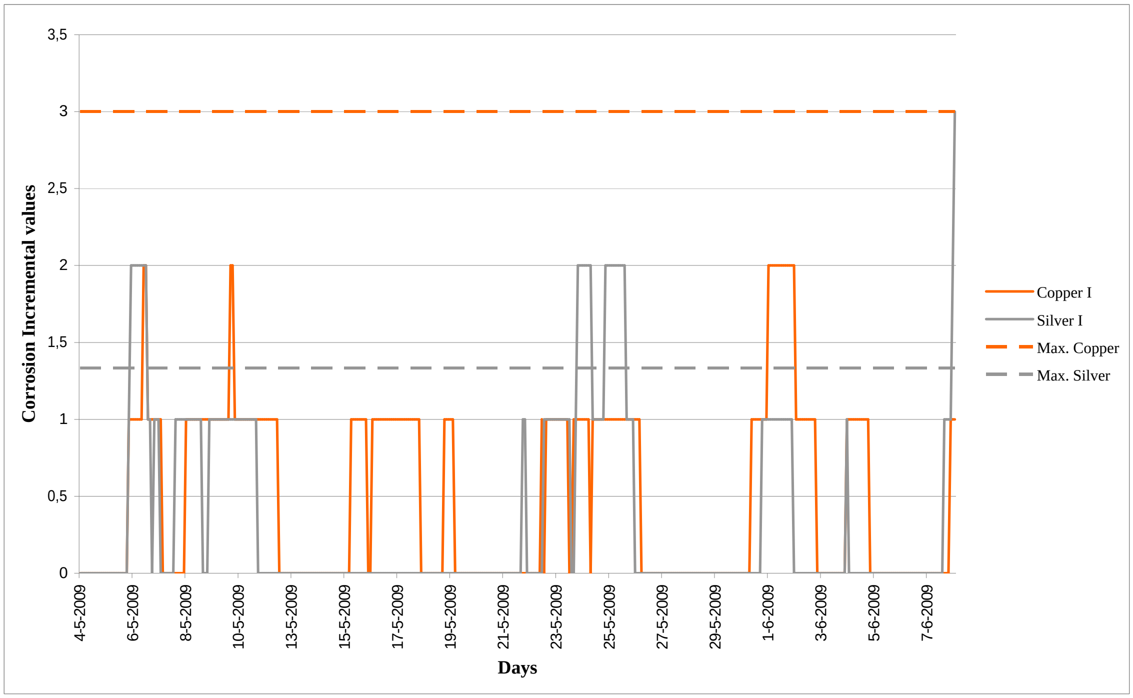

Figure 6.24 Corrosion levels in Copper and Silver in the Jordanian Heritage Museum compared to the Muller's guidelines described in Table 6.4 and Table 6.5. The monitoring period was during the summer. The recommended classification for Museums, Museum Storage, Libraries (Class S2/C2) is found in the graph as horizontal lines.

The correlation between the fluctuations in the indoor and the outdoor climates in the MJH at Yarmouk University, Irbid and the relation between this and the corrosion levels are all presented in Figure 6.25. The monitoring period was from May 4, 2009 to June 8, 2009. This graph indicates several important points, including the vast difference between the fluctuations of the outdoor RH and the indoor RH and the fact that the RH here seems to be stable. Figure 6.25 also shows the difference between the indoor and the outdoor temperatures. Finally, it indicates the relation between the presence of high RH and the corrosion levels, especially for the silver film. This leads to the conclusion that the museum has separate indoor and outdoor climatic conditions.

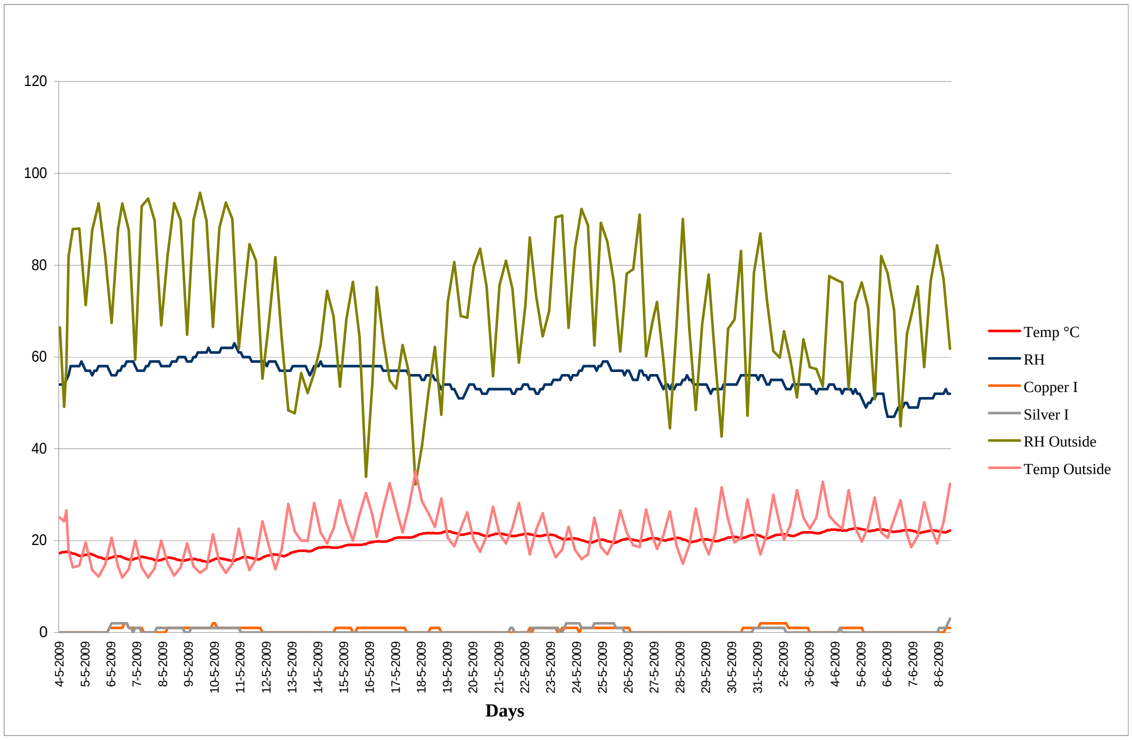

Figure 6.25 The correlation between fluctuations of the indoor and outdoor climates, in the Jordanian Heritage Museum and its' relation with the corrosion levels. The monitoring period was during the summer.

6.8 Discussion upon temperature and relative humidity
6.8.1 Department of Antiquities main storage – Amman

Figures 6.15 and 6.18 confirm the assumption that there is a direct correlation between the indoor climate and the outdoor atmosphere of the storage area, in the given winter and summer monitoring periods. The fluctuation rate of the outside atmosphere was rather more than that of inside the storage.

The same graphs show that the corrosion of copper and silver was only obvious once the relative humidity level exceeded 50%. It is clear that there was some corrosion in both monitored periods, despite the fact that the RH levels were slightly higher in winter than in summer.

When the results of the monitoring for the department of antiquities main storage were compared with Muller's guidelines described in Table 6.4 for the corrosion levels and compared with the international standards for temperature and RH. It was found that there was a fluctuation in temperature and RH through the whole monitoring period. Sometimes this fluctuation was above the international standards and other times it was below. Furthermore, the corrosion levels for both copper and silver exceeded the guidelines on many occasions.

This is the result of poor, or no, control of these parameters. The difference between the maximum and minimum temperature is considerably high, with fluctuation of ±9 ?C in February and almost ±13 ?C in July. Moreover, if the monitoring in winter is compared with the monitoring in the summer, we notice a difference of 19 degrees in the average temperature between February and July. The minimum and maximum levels of RH differs significantly more, with 34%,a fluctuation of ±16%, in February and 37%, a fluctuation of ±18%, in July. Additionally, there is a difference 15% in the average RH between February and July. According to the CCI classifications, these results classify the Department of Antiquities main storage as being class C and D.

6.8.2 Museum of Jordanian heritage – Yarmouk University

Figures 6.21 and 6.24 show the correlation of indoor and outdoor climate at the Museum of Jordanian heritage, in two monitoring periods "winter and summer monitoring". The fluctuations in the temperature and RH in this museum were much better than the results of the DoAS. Despite this, the RH sometimes reached 100% in the outside atmosphere, but never exceeded 68% inside the museum during both monitoring periods. As for temperature, outside a high of 36 ?C was reached in the summer and a low of 4 ?C was recorded in winter to inside the museum, however, the temperature remained between 18 ?C and 22 ?C in summer and between 10 ?C and 16 ?C in winter. This indicates that there is no correlation between the outside atmosphere and the indoor climate of the Museum of Jordanian heritage.
When the results of the monitoring for the museum of Jordanian heritage were compared with the Muller's guidelines described in Table 6.4 for corrosion levels and with the international standards for temperature and RH, it was found that the corrosion levels did not exceed the guidelines in any of the cases.
The comparison between the two indoor climate locations reveals that temperature and relative humidity at the MJH are better controlled than they are in the DoAS. This can be seen from the peak fluctuations in temperature and RH measures outside and the relatively constant temperature and RH measured inside with the OnGuard™ 3000. In addition, the difference between the maximum and minimum temperatures is only 4 ?C (a fluctuation of ± 2 ?C) in March and 6 ?C (fluctuation of ± 3 ?C) in May. The difference in the average temperature between March and May is less than seven ?C. The minimum and maximum RH differs more: 14% (fluctuation of ± 7%) in March and 16% (fluctuation of ± 8%) in May. There is also a difference of 5% in average RH between March and May. Therefore, the general situation of the museum of Jordanian heritage according to the CCI classifications can be classified A and B.

6.9 General discussion

The results confirm that there were fluctuations in relative humidity and temperature at the examined locations at the Museum of Jordanian Heritage (MJH) and the Jordanian Department of Antiquities main storage (DoAS). Based on the collected climatic data, it is quite evident that variations in the outside environment are reflected inside the MJH and DoAS, albeit to differing degrees. It is therefore apparent that there is absolutely no control or monitoring of the interior environments at the two locations.
On one hand, the museums are similar, as the indoor environments of both sites were not controlled, while on the other hand there was a vast contrast between the two locations in the results of the monitoring. This contrast between the results of the two monitored locations can be explained by several factors:

- The MJH has less side openings than the DoAS.
- The MJH building has thick side walls that are made of cement, while the DoAS is a pre-engineered steel building.
- The DoAS has a very high roof, which leads to a larger indoor climate, which is more difficult to control.
- The OnGuard™ 3000 was installed inside a showcase in the MJH, whereas in the DoAS it was placed on a bare shelf.

- The climatic and geographical locations of the two locations are different.

These factors may have led differences in the results. Environmental conditions affect objects in many ways. Some objects are vulnerable to conditions that may not affect other objects at all. Furthermore, the environments inside the MJH and the DoAS differ from one spot to another, depending on the number, size and location of the side openings of the halls.

Some attempts to improve conditions for an object might actually affect it adversely. For example, moving an object from a poor environment to a theoretically better one seems logical. However, despite the fact that this procedure may reduce the chemical and biological damage, it might also cause severe mechanical damage. There is no simple 'one-size-fits-all' pattern for good environmental control strategies, nor is there likely to be, no matter how good the heating, ventilation and air-conditioning (HVAC) systems engineering becomes. Providing a better indoor climate depends first on the climatic variability of a geographical region and on the components of the air pollution compounds in the ambient atmosphere. Thus, understanding how environmental factors affect collections helps conservators make consistently good choices.

When interpreting the analysis results for the individual corrosion films, the detection of a silver sulphide (Ag_2S) film without a corresponding copper sulphide (Cu_2S) film usually indicates the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3).

- Oxidized forms of sulphur are generated as combustion products of sulphur-bearing fossil fuels. Low parts per billion levels of sulphur oxides can passivate reactive metals and thus retard corrosion. At higher levels they attack certain types of masonry, metals, elastomers (synthetic rubbers) and plastics. The reaction with masonry and metals normally occurs when these gases dissolve in water to form sulphurous and sulphuric acid.
- The chief materials to suffer from sulphur dioxide pollution are calcium carbonate (marble, limestone, frescoes and alkaline sandstones), cellulose (paper, cotton, linen, wood veneers), silk, iron and steel. Leather, parchment and wool are also attacked. Many other materials, including certain bronze alloys, synthetic rubbers, dyes and textiles, may be affected.
- All cellulose, whether paper, cotton, or linen based materials, are attacked by sulphuric acid from sulphur dioxide. Light and even more, UV radiation, increases the damage. Poor quality paper deteriorates more quickly than rag paper, firstly because it contains more acid materials introduced during manufacturing and secondly because it absorbs acidic gaseous pollutants more strongly because of the lignin that is also present.
- A few modern dyes and pigments have been found to be specifically sensitive to sulphur dioxide. The elasticity of certain elastomers can be destroyed. Paints are affected.
- Iron is the chief metal to suffer from the presence of sulphur dioxide. Iron corrodes to rust electrolytically. This means that both moisture and an electrolyte must be present on the iron surface. All water-soluble salts, acids and alkalis form electrolytes. Those electrolytes that attract moisture, form soluble corrosion products and are non-volatile, are the most corrosive. Sulphuric acid and the ammonium sulphate to which it is often partly converted fulfil all these conditions.

When both films are detected, it more often than not indicates the presence of active sulphur compounds such as elemental sulphur, hydrogen sulphide (H_2S) and organic sulphur compounds (e.g. mercaptans). When both films are present and the amount of

Cu_2S is greater than 50% of the total corrosion, this is further evidence of the presence of active sulphur compounds in the subject's environment.

- Active sulphur compounds include hydrogen sulphide, elemental sulphur and organic sulphur compounds such as mercaptans. When present at low parts per billion levels, they rapidly attack copper, silver, aluminium and iron alloys. The presence of moisture and small amounts of inorganic chlorine compounds greatly accelerates sulphide corrosion. Note, however, that attack still occurs in low relative humidity environments. Active sulphurs rank with inorganic chlorides as the predominant cause of atmospheric corrosion.

Chloride corrosion (North and MacLeod) was not detected on any of the coupons reported here. Its presence would have indicated the presence of inorganic chlorine compounds, for example chlorine (Cl_2), chlorine dioxide (ClO_2), or hydrogen chloride (HCl). High levels of chloride (halogen) contamination can also serve to effectively mask any evidence of sulphur contamination on the corresponding copper coupons and can cause a large "unknown" copper corrosion film to appear.

- Chlorine contamination, whether as chlorine or hydrogen chloride, is a dangerous contaminant for metals. At elevated levels, many elastomers and some plastics are oxidized by exposure to chlorinated gases.
- Particular care must be given to materials that are exposed to environments containing chlorinated contaminants.

Looking back to Figures 6.11 to 6.22 it is clear that the fluctuations in temperature and RH differ enormously between the MJH and the DoAS. The DoAS is close to exceeding the recommended variation for both temperature and RH. Any rise in temperature or RH outside is reflected by a rise in temperature and RH inside, albeit to varying extents. There is, therefore, no temperature or RH control either at the MJH or at the DoAS.

Theoretically, silver should be less sensitive to fluctuations in humidity than copper (Abbott 1983; AICARR 1997). It may seem reasonable to expect then, that copper would react faster to high RH levels. Yet conversely, after analyzing the results data it was found that silver reacted faster than copper in both locations and in the two monitoring periods. When interpreting the analysis results for the individual corrosion films for both silver and copper, the rate of the corrosion levels for silver was higher than for copper in both monitored locations. A higher level of corrosion on the silver film than on the copper film at the same environment indicates the presence of oxidized forms of sulphur, such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3), which are mainly formed by combustion of coal and oil (e.g. automobile fuel).

Both Figures 6.24 and 6.25 show the thickness of the corrosion layer on both silver and copper films, after the monitored periods. The monitoring periods were approximately one month for each monitored period; once in winter and another in summer. The thicknesses of the corrosion layers were measured in Angstrom (?). Furthermore, the corrosion level was compared with the Environmental classifications for preservation environments presented earlier in Table 6.4.

Looking to the silver film corrosion rate, presented in both Figures 6.26 and 6.27, it seems that in monitored periods, winter and summer, the silver film corrosion level exceeded the S4 class on many occasions. These results mean that the indoor environment of the DoAS belongs to class S5 for silver corrosion, which is not an acceptable environment either for museums or for museum storage. The copper film corrosion exceeded the C3 class in winter and C2 in summer. For museums and museum storage, the corrosion level of copper film must be always below 150 ? / 30 days (C2 class). As the corrosion level for the silver film is higher than that of the copper film in the same environment, this indicates the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3), which are mainly formed by automobile fuel. Moreover, there were some days when the corrosion level was zero Ǻ. After checking the calendar of the year 2009, it appears that most of the days, which had a low corrosion level, were mainly weekends and holidays.

The location of the storage, adjacent to a main, busy highway (Amman-Zarqa highway), plays a significant role in the pollution of the indoor environment. It was evident that at the weekends the corrosion levels were lower, which indicates a relation to the traffic on the highway. Therefore, it is vital to pursue a further study in order to determine the impact of the traffic on the highway and the effects of the fuel gases on the indoor environment of the DoAS.

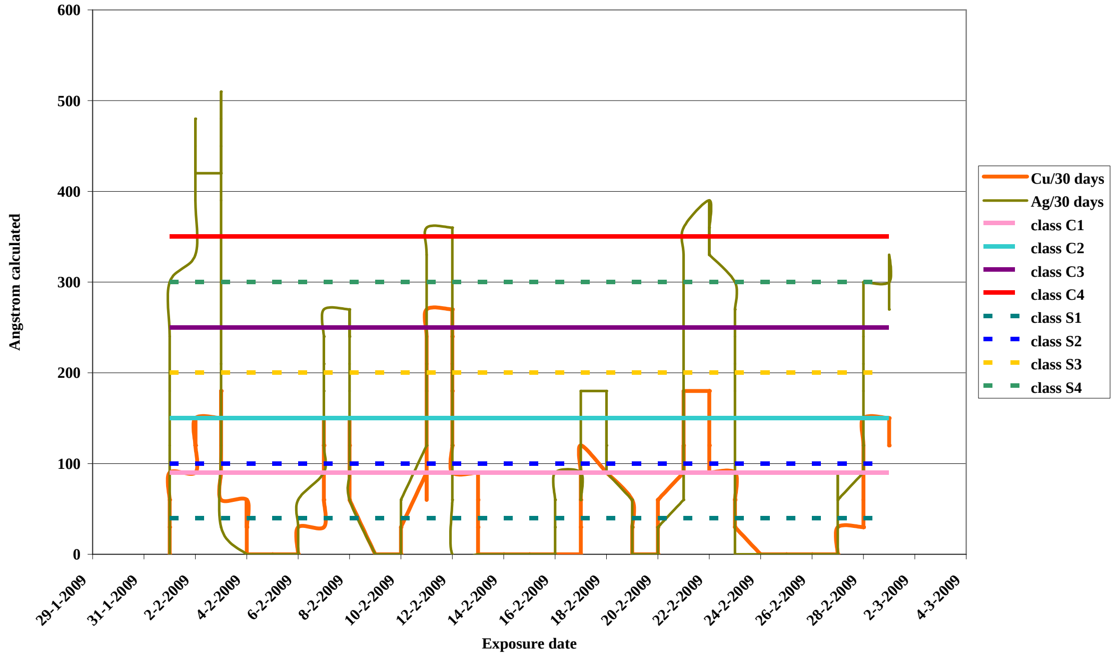

Figure 6.26 DoAS corrosion level compared to Muller's guidelines described in Table 6.4, (winter monitoring).

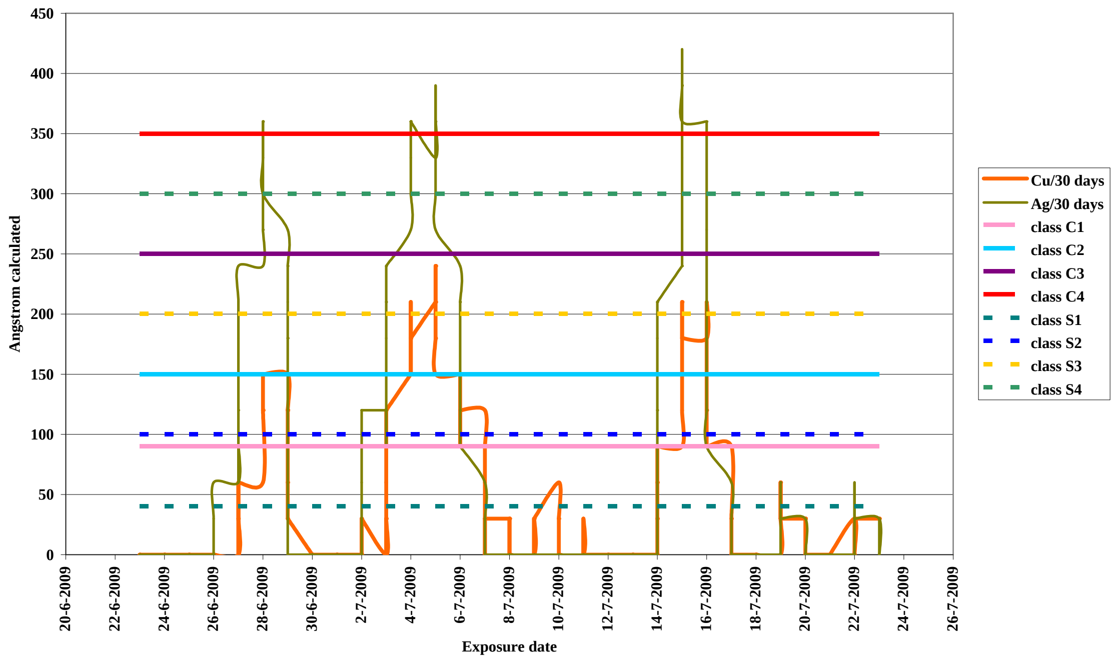

Figure 6.27 DoAS corrosion level compared to Muller's guidelines described in Table 6.4, (summer monitoring).

The corrosion levels on both copper and silver films are compared to the indoor RH for monitored periods, winter and summer, in Figures 6.28 and 6.29. The measurements of the indoor environment show that there was a continuous fluctuation in RH at the DoAS in winter and in summer. Moreover, Figures 6.28 and 6.29 present a clear relation between the fluctuation of RH and the corrosion levels. The corrosion level is directly correlated to RH; any rise in the outside RH is reflected by a rise in corrosion levels for both silver and copper films. In order to determine the indoor RH fluctuation, the indoor RH data was compared with the outdoor RH data obtained from the Meteorological Department in Jordan for the same period. The relation between the indoor and the outdoor RH and the relation of these to the corrosion levels are demonstrated in Figures 6.30 and 6.31 respectively.

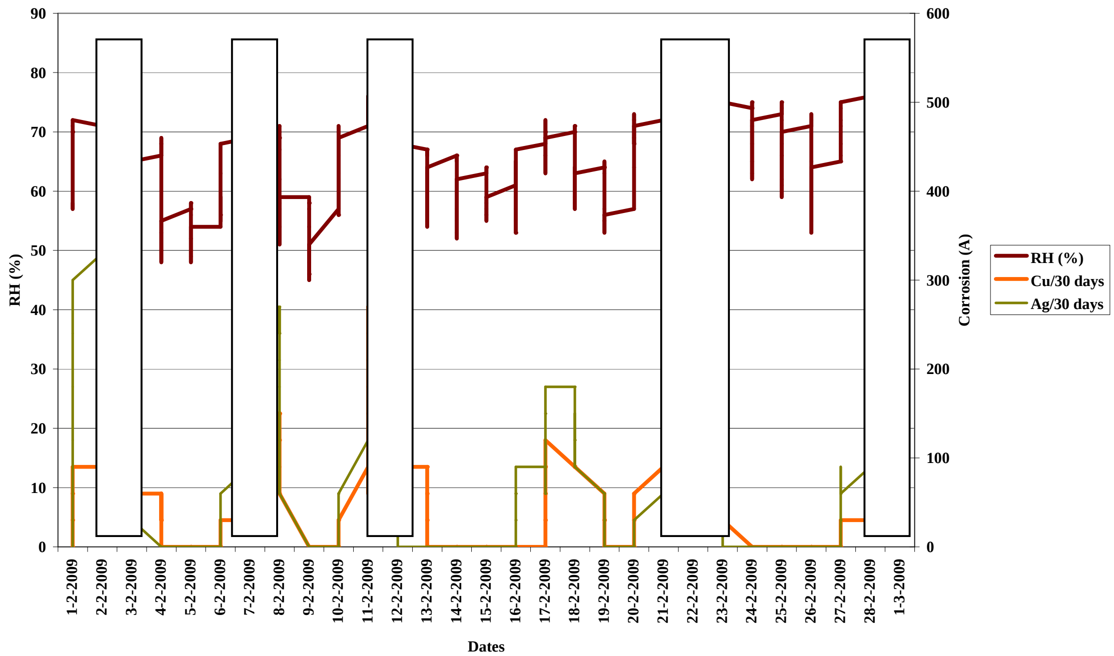

Figure 6.28 Corrosion level and RH ratio at the DoAS, (winter monitoring).

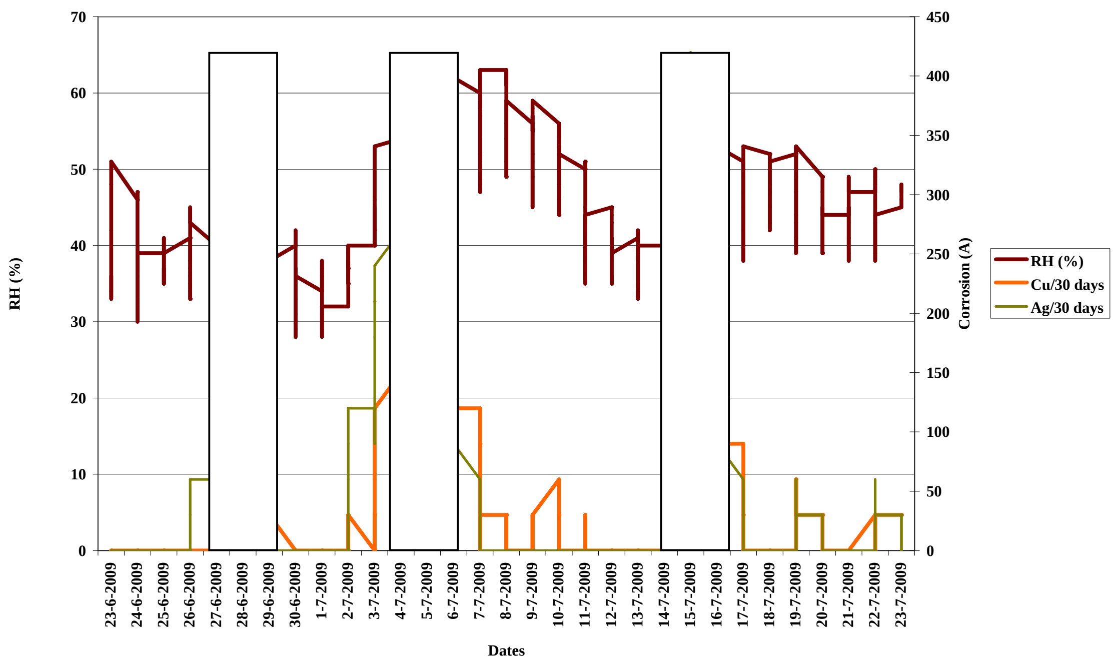

Figure 6.29 Corrosion level and RH ratio at the DoAS, (summer monitoring).

Temperature and RH inside and outside the DoAS were monitored and compared with each other, in order to determine whether the outdoor climate has an influence on the indoor climate. Temperature was measured in Celsius (°C) and the trend of the temperature line in Figures 6.30 and 6.31 suggest a direct bond between the indoor and the outdoor climate. As was mentioned previously, according to Figures 6.28 and 6.29 there is a direct correlation between the indoor and the outdoor RH. These bonds between the different environmental parameters do not appear to be haphazard. From the results of this study, it is safe to conclude here that the DoAS indoor environment is not separated from the outdoor environment. Furthermore, the relation between temperature and RH was also evident, as well as the relation of these to the corrosion levels in the same graphs. Therefore, temperature and RH must be controlled at the same time in the DoAS by installing suitable instruments and the side openings of the DoAS building must be sealed against the outdoor environment.

The connection between the mentioned environmental factors leads to a high corrosion rate in both winter and summer. Therefore, the building of the DoAS falls within the S5 and C3 classes, according to the Environmental Classifications for Preservation Environments presented earlier in Table 6.4. These classes are not suitable for the exhibition or storing of museum objects.

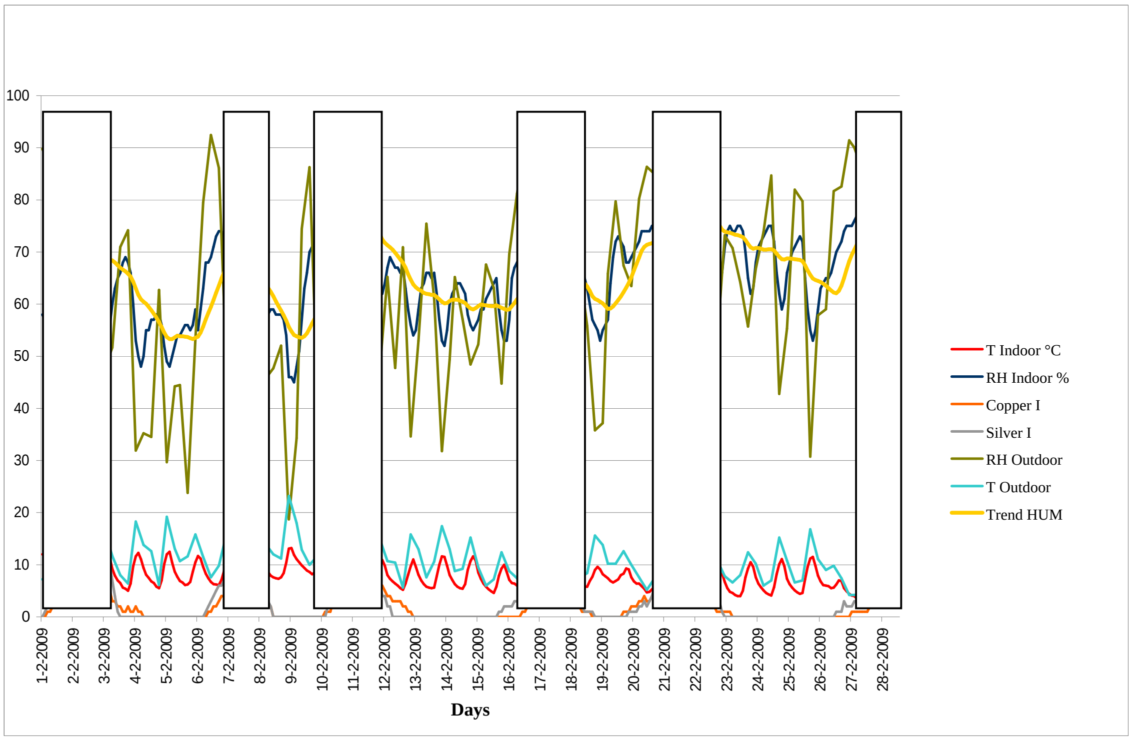

Figure 6.30 The relation between the indoor and outdoor environment compared to corrosion level at the DoAS, (winter monitoring).

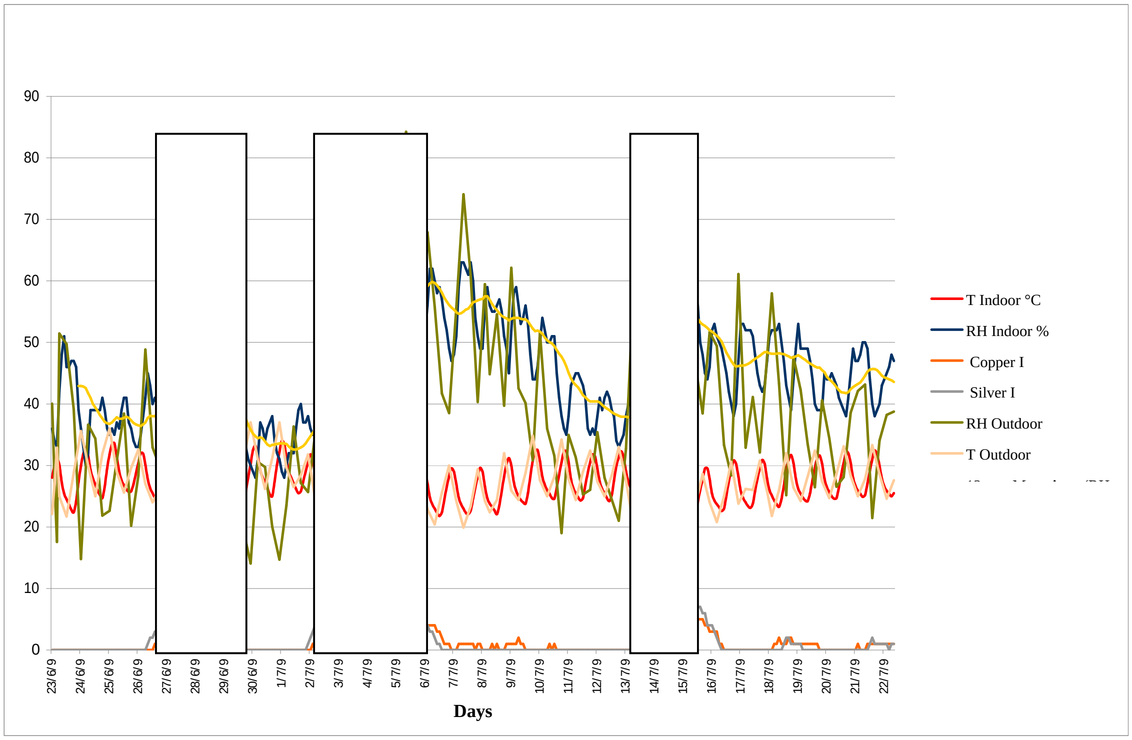

Figure 6.31 The relation between the indoor and outdoor environment compared to corrosion level at the DoAS, (summer monitoring).

The thickness of the corrosion layers on both silver and copper films after the monitoring periods is presented in Figures 6.32 and 6.33. The monitoring periods were approximately one month for each monitoring period; once in winter and another in summer. The thicknesses of the corrosion layers were measured in Angstrom (?). Furthermore, the corrosion level is compared with the Environmental Classifications for Preservation Environments presented earlier in Table 6.4.

In general, the environmental situation at the MJH seems to be better than at the DoAS. The corrosion level on copper film presented in Figures 6.32 and 6.33 did not exceed 90 ? / 30 days in either monitoring period. These results mean that the indoor environment at the MJH according to the CCI standards is class C1. As for the copper corrosion, this is an acceptable level for museums and for museum storage. The silver film exceeded 100 ? / 30 days in winter and 40 ? / 30 days in summer. These results categorize the MJH in class S3 in winter and class S2 in summer. For museums and museum storage the corrosion level of copper film must be always below 150 ? / 30 days (C2 class) and this was the case at the MJH. However, the corrosion levels for the silver film exceed the recommended 100 ? / 30 days (S2) several times, especially during the winter monitoring period. As the corrosion level for the silver film is higher than the corrosion level for the copper film at the same environment, this indicates the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3), which are mainly formed by automobile fuel. Moreover, there were days when the corrosion level was zero Å. After checking the calendar for the year 2009, it appears that the corrosion level was not related to the working days. In spite of the museum closing on Fridays and Saturdays, the corrosion level was not low on these days and the presence of oxidized forms of sulphur were detected inside the museum at the weekends, which raises an assumption that the museum is not immune to the outdoor environment, even when it is completely closed.

This museum is located within the Yarmouk University campus, which is adjacent to a main, busy highway (Shafiq Irshidat Street). This may be the main agent in polluting the indoor environment of the MJH. Therefore, it is recommended to pursue a further study to determine the source of the oxidized forms of sulphur and the relation with the traffic on the highway and the effects of the fuel gases on the indoor environment of the MJH.

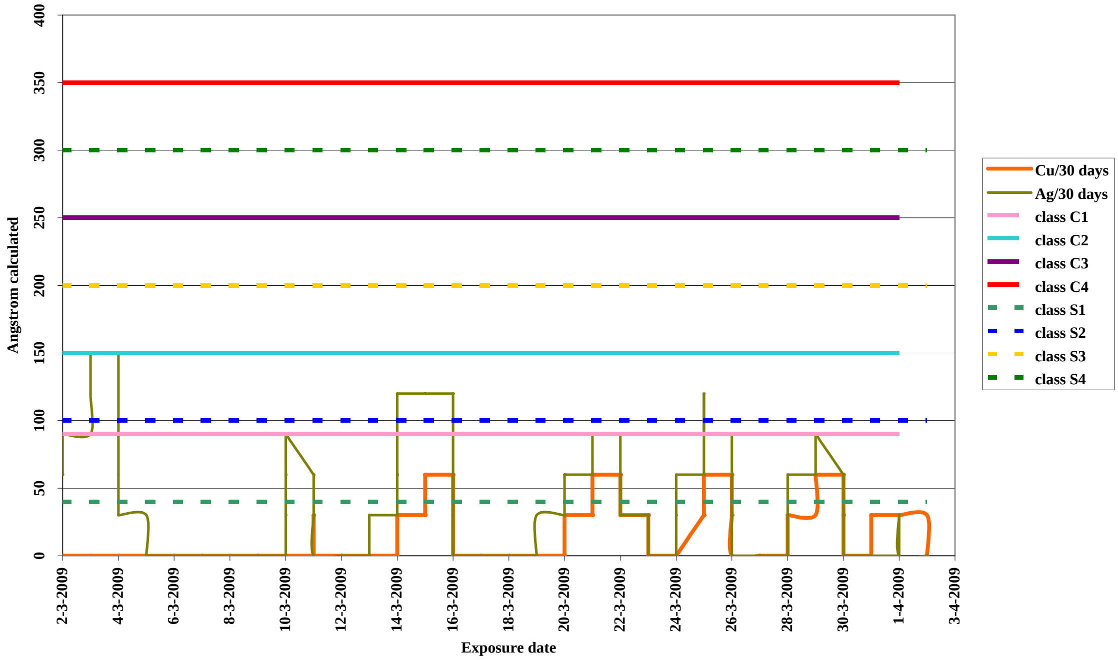

Figure 6.32 MJH corrosion level compared to Muller's guidelines described in Table 6.4, winter monitoring.

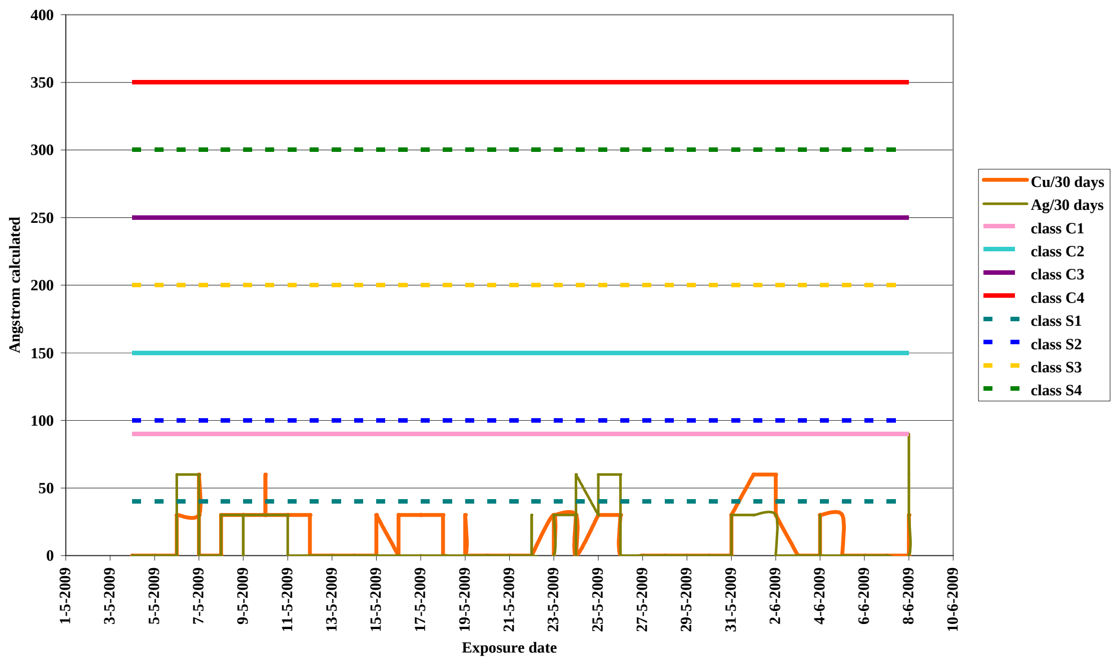

Figure 6.33 MJH corrosion level compared to Muller's guidelines described in Table 6.4, summer monitoring.

The corrosion levels for both copper and silver films are compared to the indoor RH for both monitored periods, winter and summer, in graphs 6.34 and 6.35. The measurements of the indoor environment show that there was a reasonable fluctuation in the amount of RH at the MJH in winter and in summer. The limited fluctuations in RH reflect a relation between the RH and the corrosion level. However, the relation is not clear in the presented graph.
In order to determine that the indoor RH is not related to the outdoor climate, the indoor RH was compared with the outdoor RH data obtained from the Meteorological Department in Jordan for the same period. The relation between the indoor and the outdoor RH and the relation of these with the corrosion level, are demonstrated in Figures 6.36 and 6.37 respectively.

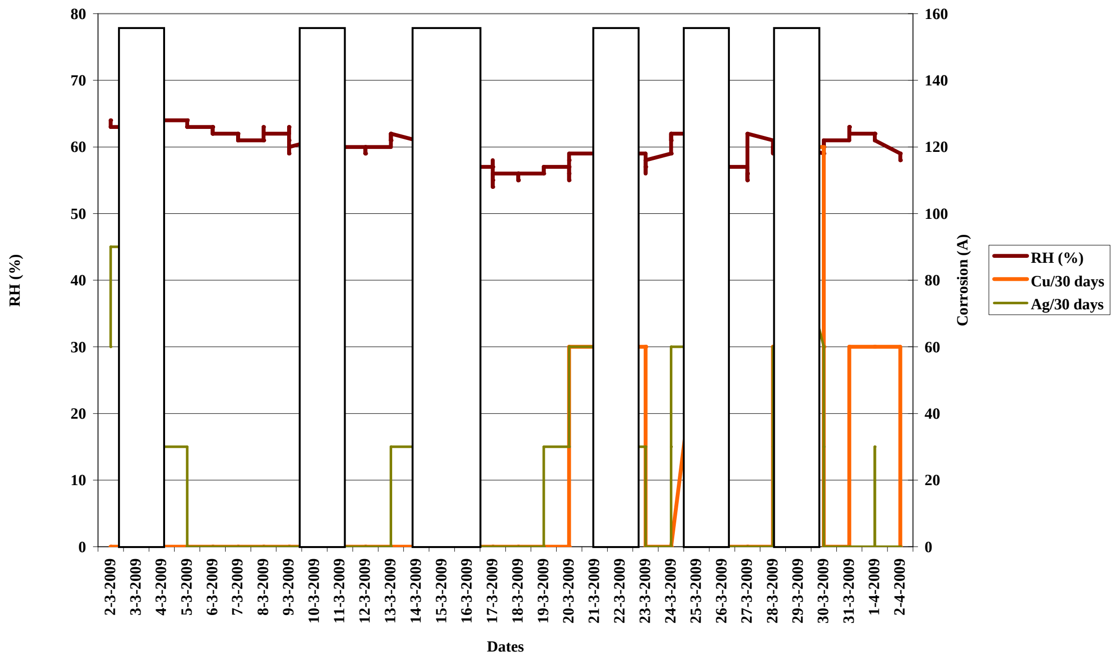

Figure 6.34 Corrosion level and RH at the MJH, winter monitoring

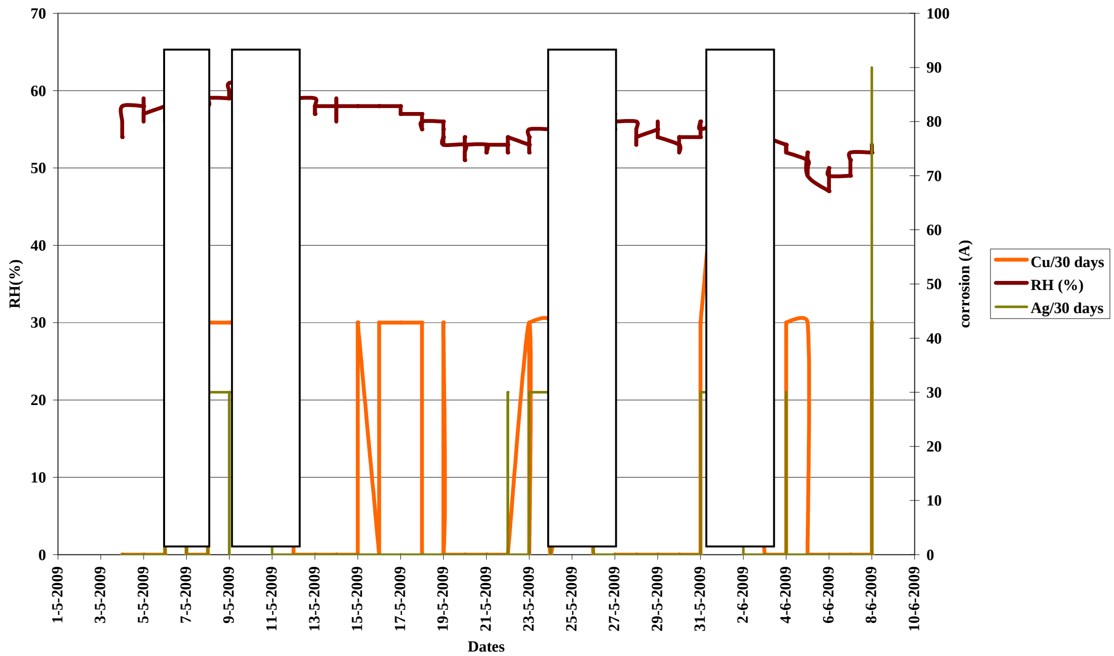

Figure 6.35 Corrosion level and RH at the MJH, summer monitoring

The temperature and RH inside the MJH and the data obtained from the Meteorological Department in Jordan for the outdoor climate were compared in order to determine whether the outdoor climate has an influence on the indoor climate. Temperature was measured in °C and the trend of the temperature line in Figures 6.36 and 6.37 indicates an independent indoor environment in the MJH, even though the museum does not have any instrument to control RH or temperature. In spite of the separated indoor environment, the monitoring results of the indoor environment of the MJH show a presence of high corrosion, especially on the silver film. Therefore, the building of the MJH falls within the S3 and C2 classes according to the Environmental classifications for preservation environments presented earlier in Table 6.4. On the one hand, the MJH falls in the S3 class, which is not suitable for museums. On the other hand, the C2 class is still an acceptable category for museums. Therefore, a future study is recommended to determine the source of the oxidized forms of sulphur, which were present in the indoor environment of the MJH.

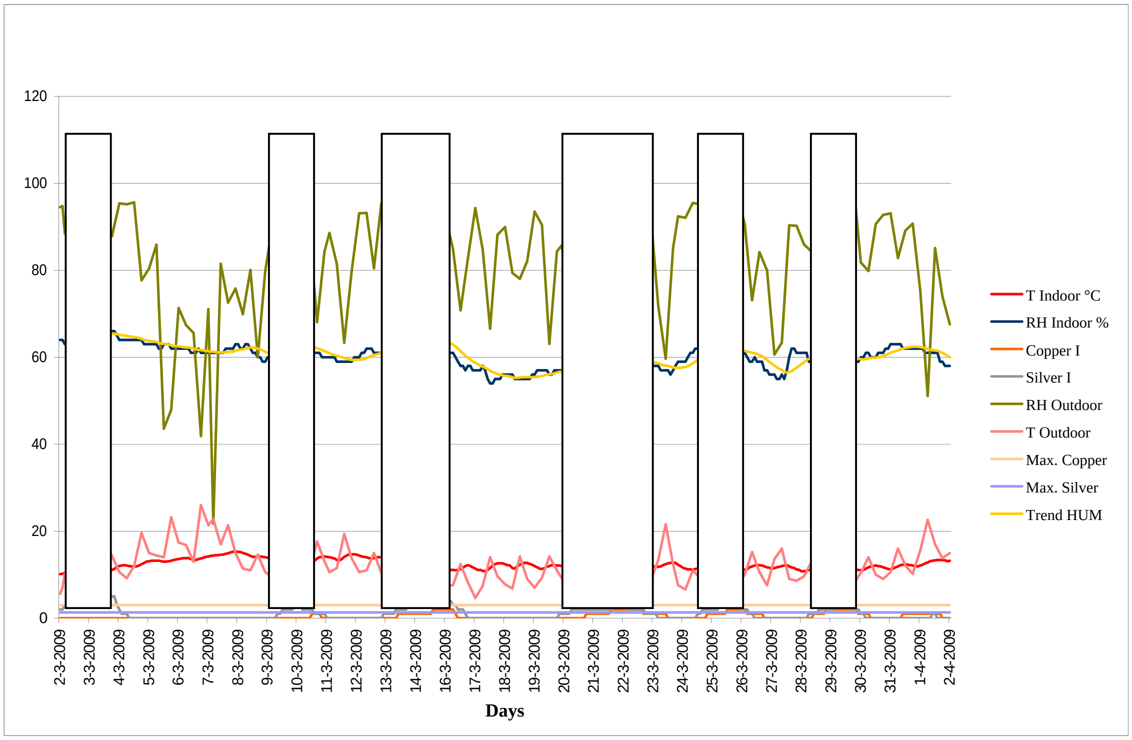

Figure 6.36 The relation between the indoor and outdoor environment compared to corrosion level at the MJH, in winter.

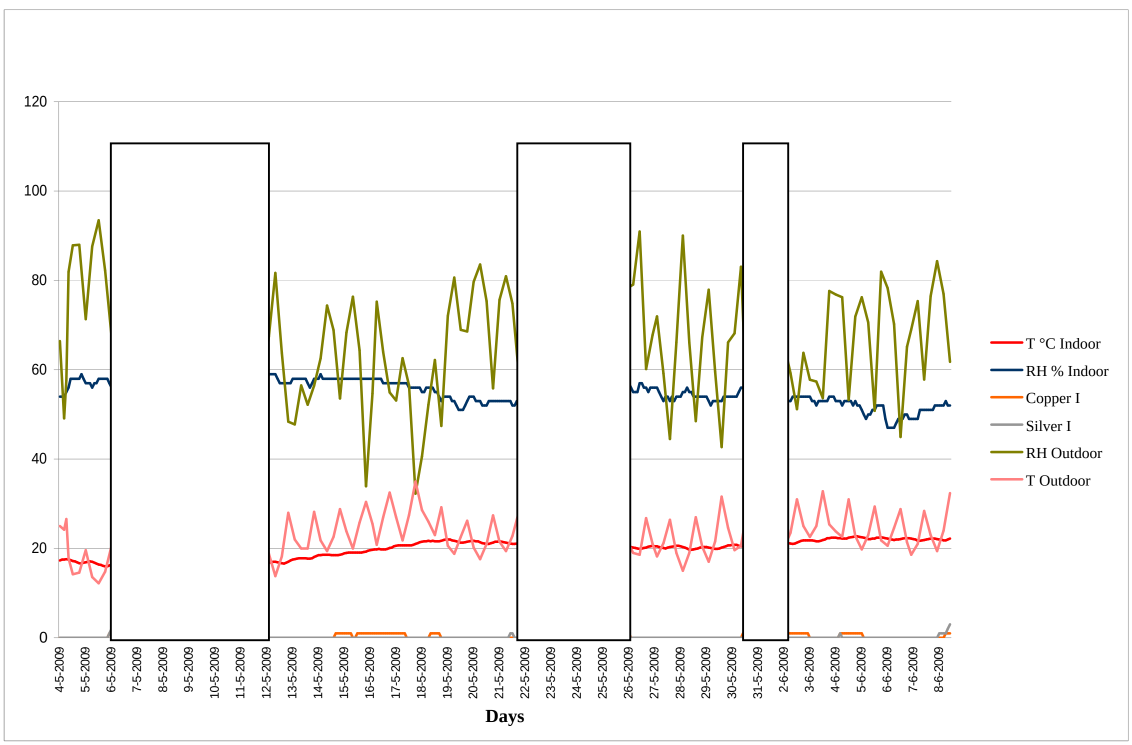

Figure 6.37 The relation between the indoor and outdoor environment compared to corrosion level at the MJH, in summer.

The OnGuard^{TM} 3000 Atmospheric Corrosion Monitor, Figure 6.6, measures corrosion on a continuous basis, which allows preventive action to be taken before serious damage has occurred. Appropriate reactivity and alarm levels for a particular application can be easily adjusted. The device can be operated independently with battery power and data logger, or wired directly into a central computer. The monitored data can be uploaded to a PC via USB for viewing or for creating graphs. By making use of the unit's ability to interface with computers, up-to-the-minute information on the levels of corrosive contaminants can be obtained. Environmental classification databases can be established and maintained to provide historical data. The OnGuard^{TM} 3000 is a multipurpose device, which any museum can benefit from. Besides measuring corrosion levels, it has the ability to monitor RH and temperature on a continuous basis. Furthermore, adjusting a high level of RH or temperature is applicable on demand, so that if the set temperature and RH levels are exceeded, the device will give a signal to warn the responsible personnel at the museum. Therefore, the use of the OnGuard^{TM} 3000 was utilitarian and convenient for the measurements and monitoring techniques this research demanded. Moreover, it can be recommended for further studies and fro environmental monitoring in museums.

Copper films cannot detect the presence of chlorine, a particularly dangerous contaminant for metals. Silver is sensitive to chlorine and, when used with copper reactivity monitoring, can be used to detect changes in the levels of gaseous pollutants in the ambient environment as small as one ppb and can differentiate between different classes of contaminants.

A previous study using the Environmental reactivity coupons (ERC), presented in this thesis in Chapter 5, confirms the hypothesis that the detection of a silver sulphide (Ag_2S) film without a corresponding copper sulphide (Cu_2S) film usually indicates the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3) (see the previous chapter).

Relative humidity in museums should be kept at a constant level of between 50% and 55%, but this fluctuation should not exceed 10% in order to preserve the museum's objects (Smith 1988).

Fluctuation of relative humidity may cause expansion and contraction of materials at different rates. It is evident from the results of the variations in RH and temperature that there is a vast difference between day and night time readings. Since the swings in humidity levels are linked to the outside air, it can be concluded here that pollution from outside enters the sites through unventilated side openings.

Interior RH and temperature should be kept constant, regardless of the outside climate. This is obviously not the case in the MJH and DoAS, leading to the sad conclusion that there is no interior control system. In fact, the interior temperatures and RH levels at the DoAS are almost on a parallel with exterior temperatures and RH.

It is clear from the results that there is a presence of corrosion contaminants in the ambient atmosphere, especially in the DoAS. It is vital, therefore, to determine the types of contaminants that are present, in order to be able to work towards either lessening their effects in the future, or isolating the susceptible objects from these corrosive materials. In addition, I recommend an extended study using the ERC to determine the type of contamination pollutants and the extent of the deterioration effects on the different types of objects hosted by the MJH and DoAS. Another study regarding the identification and quantification of the volatile organic compounds present in these sites is also recommended.

6.10 Conclusion

The intention of this research study is to investigate and evaluate the current indoor environment situation and the atmospheric corrosion levels at two selected Jordanian cultural heritage sites, with a view to protecting some of the most important and vulnerable, historical objects in Jordan. Air monitoring is central to any environmental control program for achieving and maintaining air-quality standards based on the presence, or absence, of gaseous air pollutants. The method of investigation of the indoor environment was through the application of the latest and most up to date, device regarding this issue: the OnGuard™ 3000 Atmospheric Corrosion Monitor (ACM). In addition to detecting air pollution, the ACM also has the ability to monitor RH and temperature. The data from the ACM can be transferred to a computer to be analyzed. Moreover and in addition to contamination control programs, air-monitoring data may be employed for:

- The evaluation of long-term air quality trends in a facility.
- Research studies designed to determine relationships, if any, between pollutant levels and possible damaging effects.

The preservation of museum collections depends upon the knowledge of how materials and objects in the collection behave and how environmental influences affect them. Some aspects of preservation are obvious; relative humidity, temperature and pollution will deteriorate or damage most collections.

The two selected locations for the monitoring using the OnGuard™ 3000 were the Museum of Jordanian Heritage (MJH) at Yarmouk University in Irbid and the Department of Antiquities main storage (DoAS) in Amman. These sites were chosen because of their importance as cultural heritage sites. The MJH was selected because it is the only museum in Jordan, which has the potential to be transformed into a better place for the safeguarding of objects between its walls (Alghazawi 2003). The DoAS was selected, as it is the first destination for objects, which come from excavations taking place in Jordan.

Humidity, temperature, air pollution and atmospheric corrosion were monitored in the MJH and the DoAS over a period of four weeks during the winter of 2009 and four weeks in the summer of the same year.

The OnGuard™ 3000 device (ACM) was installed in the MJH and in the DoAS for a period of one month in winter and another month in summer in 2009, in order to record hourly readings for RH and temperature. Moreover, the device recorded corrosion levels on silver and copper built-in films. The data was analyzed and compared first with the outdoor atmosphere, Muller's guidelines described in Table 6.4 and Table 6.5, the ISO standard EN-ISO 1184 and later with the international standards adopted from the classification of the Canadian Conservation Institute (CCI) standards for temperature and RH in museums, art galleries, libraries and archives.

The amount of corrosion that forms over any given period is a primary indicator of how well-controlled an environment may be. Depending on the quality of the indoor environment and the types of risks that the collections face at the selected sites, different categories were assigned to indicate the quality of the preservation at the given sites. An unsuitable environment inside a museum is harmful to the collection and may lead to deterioration and damage. The damage that might occur can be biological, chemical or mechanical and sometimes the three types are found combined. Therefore, it is important that all museums provide the proper indoor environment to safeguard their collections.

Fluctuations in temperature and RH in the MJH and DoAS were evident and from the results, we can conclude that the worse situation was in the DoAS. Moreover, a direct correlation between the indoor environment and the outside atmosphere is evident in both sites.

Controlling the climactic conditions within museums will solve the problem of corrosive gases coming from outside through side openings in the buildings. However, the gas concentrations in the MJH are lower than in the DoAS. It is therefore advised that temperature and relative humidity control apparatus such as air conditioning systems and humidistat, as well as gas phase filtration in the outside air conditioning units, be installed and used.

6.11 Recommendations

The total amount of corrosion measured in the outside air, which considered as the main source for the air make up in the the MJH and DoAS is much higher than the recommended levels. Moreover, the fact that the presence of sulphur oxides, active sulphur and in some cases chlorine has been confirmed at the two sites, means that the make-up air for these facilities should be treated, in order to remove the contaminants. Control mechanisms for relative humidity and temperature should be installed and a chemical filtration system should be able to specifically address the sulphur and chlorine contamination. The detection of sulphur or chlorine contamination is particularly problematic for metal collections, photographic images, various paper types and colorants. Chemical filtration should also be considered for the recirculation air handlers in order to prevent contaminants from being distributed throughout the facility.

It is further recommended that reactivity monitoring be continued, with either ERCs, the OnGuard ERM, or the OnGuard™ 3000 Atmospheric Corrosion Monitor, to provide a continuous environmental assessment of air quality. While information on individual contaminants can be obtained using the ERCs, real-time reactivity monitoring can provide a more accurate assessment of the total corrosion being formed due to the presence of chemical contaminants. Reactivity monitoring can also be used to measure the performance of chemical filter systems and can serve as a guide for media replacement.

Due to the elevated levels of sulphur contamination detected in the makeup air, it is recommended that additional sets of ERCs be placed in the makeup air handlers and inside the MJH and the DoAS to determine if and from where these contaminants are being distributed throughout the two buildings. Direct gas monitoring may also be helpful in order to determine the sources of the sulphur corrosion measured. This could help determine if these results were an anomaly, due to episodic events, or if there are some other gaseous contaminants present which may have synergistic effects and need to be accounted for. Indoor sources of contamination should also be investigated.

In order to prevent the occurrence of corrosion it is recommended that the relative humidity levels be kept stable and to within the recommended levels of 50%-55%.

CONCLUSION AND FURTHER RESEARCH

Conclusion and further research

7.1 Conclusion

The many different types of museum environmental research conducted throughout the years have provided the author with a reasonably good insight into and understanding of the mechanisms and techniques applied for measuring and monitoring research. The author's intention is to direct the managers of the Jordanian museums away from the horns of their dilemma and to indicate solutions for their delay in carrying out preservation activities. Moreover, it was of vital significance to analyse the available literature in the field in order to construct a fruitful and solid foundation for the study. Applying the outcome of these studies will ultimately result in appropriate guidelines and standards being defined.

The number of museums in Jordan is increasing constantly. They are fast becoming one of the main tourist destinations for local as well as international tourists. Despite this, no specialist researchers have so far demonstrated interest in evaluating the current status of Jordan's museums, neither locally nor at international level. Nor has such interest been expressed even by the museums' staff themselves.

Writing a theoretical background on the current situation of the museums in Jordan confronted the author with the lack of available published data concerning Jordanian museums in general. Therefore and in order to add to the literature on Jordanian museums, an initiation had to be made as a first step towards documenting the Jordanian museums. The current situation of the museums in Jordan was therefore described visually and evaluated. Moreover, the museums selected for evaluation in this thesis were visited periodically, interviews were conducted with their staff members and photographs were made of the museums. The brochures and leaflets issued by the museums themselves were reviewed as an additional source of information in order to develop a theory about the actual state of the Jordanian museums and in order to create a theoretical database on the museums, this being one of the primary concerns of this thesis.

The descriptive evaluation is mainly presented in the third chapter of this thesis. The standards to which I refer in this assessment include the International Council of Museums (ICOM) Ethics as well as the publication by Garry Thomson: *The Museum Environment* (1986). With the exception of the Jordan Archaeology Museum and the Museum of Jordanian Heritage, none of the other Jordanian museums in this study have been purpose-designed or constructed as a museum. All the remaining museums in this study were built using cement and natural stone, apart from the Karak Archaeology Museum, which is located within a historic castle. For this reason, the cement buildings are generally unable to provide a well-insulated indoor environment, so it can be concluded that they do not conform to international standards with respect to planning, architectural criteria or interior environmental control. Notwithstanding, it is possible for them to be upgraded following expert advice from conservation, preservation and museology consultants, so that they might fulfil their purpose as museums in a more efficient and effective manner.

The museums evaluated were sited in different types of physical locations. The Aqaba Archaeological Museum is located near the city centre, directly by the beach. This location on the one hand provides easy access for visitors and on the other hand it provides an ambient atmosphere with a high relative humidity. The museum therefore needs to install a humidistat as a precautionary measure to keep the indoor atmosphere of the museum display halls at a constant level of humidity throughout all its exhibition halls.

The Irbid Archaeology Museum is located in an appropriate location for a museum, in a quiet neighbourhood with limited traffic. The disadvantage is that it is hard to reach by public transport. The premises in which the museum is housed also accommodates other governmental institutions and private apartments inhabited by citizens. The museum, together with the Department of Antiquities, occupies the ground floor. The museum has limited and unqualified staff members and lacks any kind of safety provisions. Objects at this museum are exhibited randomly, cluttered either in the same showcase or on the floor. Explanation or interpretation of the exhibits is limited to descriptive panels.

The Jarash Archaeological Museum is an archaeological site museum, located within the Roman town of Decapolis, the “Jarash Archaeological site”. Access to the museum is quite difficult for able-bodied people and almost impossible for physically handicapped visitors, because of the poor state of the roads within the town of Decapolis. The museum is managed by a museum director, who has an archaeological background and a superintendent. Some of the Jarash museum objects are displayed in wooden showcases with panes of glass of various size and shapes and others are displayed on metal pillars or wooden stands or even directly on the floor, which obstructs the route taken by visitors through most of the main hall locations.

The Jordan Archaeological Museum is generally considered to be the main museum in Jordan and it is one of the few museums to have been purposely designed and built as a museum. However, the building does not comply with the museum’s mission, which is both to display and to preserve its collection simultaneously, since the museum does not have any form of environmental control equipment. In addition, the museum’s interior environment is always exposed to the outdoor atmosphere since its side openings are always open during working hours. The museum staff consists of a number of officers and employees of different specialities, which are unfortunately not related to the museum’s field or any field with the capability of supporting its mission. Objects are exhibited in cases of various shapes and sizes, made from a variety of materials. In addition, there is no defined route for the visitors.

The Karak Archaeological Museum is part of the historic castle of Karak. The museum was recently renovated and an exhibition room was added. The museum has small side openings, which are always open to the outdoor environment. This allows the outdoor environment access indoors. A curator and three superintendents are responsible for managing the museum. Objects are displayed in showcases of different sizes and shapes and in some cases are exhibited outside them.

The Madaba Archaeological Museum is situated in a unique location in the centre of Madaba city, away from the traffic, although, it is hard to reach because of the lack of signposts. The main problem that faces visitors to this museum is accessibility. The route between the exhibition rooms consists of different types of steps and facilities for handicapped visitors have not been taken into consideration. The museum is run by adequate but unqualified staff. The display showcases are locally made glass shelves and frames made of metal. Some of the objects are displayed on the floor. In spite of the valuable collection owned by the museum, the museum itself is in a shabby condition; the floor is always dirty, the paint on the walls is pale and greyish and a worn-out curtains hanging at the windows. All this leaves a poor impression on visitors.

The Petra museum is located in the middle of the Petra archaeological site in a desert environment. The museum is approximately three kilometres from the main entrance to the city and is accessible only on foot. This is by itself considered one of the main obstacles for visitors. The exhibition inside the museum is mainly displayed within showcases, which consist of a wooden base and aluminium frame with large panes of glass. Despite the rich harvest of archaeological objects excavated from the Petra archaeological site, the museum still exhibits an unpretentious collection that always disappoints the expectations of the museum's visitors.

The Salt Archaeology Museum is located on a main road in the city centre of Salt, which is always crowded with traffic. Air and noise pollution from the constant traffic make this location unsuitable for a museum. The Salt museum depends mainly on the curator and his assistant for decisions relating to the objects that should be displayed and the way they are exhibited. These two staff members sometimes escort groups of visitors to explain the exhibition method and to describe the objects displayed. The museum has recently been renovated with the assistance of the Royal Dutch Embassy in Amman. Despite this, the renovation work was apparently carried out without the advice of an expert in the field of museology, which was obvious, for instance, from the type of lighting lamps and the type of curtains installed.

The Museum of Archaeology is located within the campus of the University of Jordan. On the one hand, this location limits the type and number of visitors, because the university campus allows only students carrying valid student identification to enter the campus. On the other hand, this location provides the museum with a good ambient environment, since it is located away from any traffic and is surrounded with trees. A museum director and a museum curator who both have an archaeology background manage the museum's affairs. The collection is displayed in metal showcases with glass shelves. The museum has recently been renovated; the walls have been painted attractively and new flooring tiles have also been added.

The Museum of Jordanian Heritage is also located within a university campus - Yarmouk University - and its visitors are therefore also limited to students of the university. This museum is one of the two establishments researched for this thesis, which were purposefully designed and built as a museum. The museum management, that is subject to constant change, plays a significant role in the stabilization of the museum collection, through their major decisions relating to exhibition methods. For instance, the museum previously had a lighting system comprising UV-filtered tungsten lamps, until the unfortunate decision was made "by the responsible person by then" to change them into fluorescent lamps, the only reason for this modification being that the fluorescent lamps are brighter. This "enhancement" adds a further destructive element for the objects displayed, as well as hastening the decay process for the organically-based collection at the exhibition. All this is due to the limited knowledge and background of a responsible human element. The museum benefits from the expertise of the Faculty of Archaeology and of staff from other facilities, such as the conservation laboratories.

Successive visits to these museums show that their collections suffer from fluctuations in temperature and relative humidity, which correlate with the outside environmental conditions. Furthermore, this study has noted the deterioration and damage that the collections on display at these museums suffer on a daily basis, as was illustrated by the lead sarcophagus case in section 6.6.2 of this study. The collections displayed in these museums suffer continuously from deterioration and damage, especially paintings, drawings and pictures, which are particularly vulnerable to harmful indoor environmental conditions. Interventionist conservation of these objects will be of no use later since they will be ruined if the staff responsible does not take immediate action to prevent them from suffering the worst possible scenario. The current priority should therefore be to address the stabilisation of environmental conditions and thereby prevent further deterioration.

This thesis also aimed to examine the extent to which Jordanian museums conform to recommended conditions and international standards for housing collections, so that they can provide a safe environment for the display and preservation of artefacts. The research also aims to evaluate whether the monitoring and control systems within the museums are adequate for maintaining temperature and humidity within the required ranges, taking into consideration the fact that the museums are located in different climatic zones.

The first step towards achieving a safe environment for the collection at the Jordanian museums, either displayed in the museums or kept in storage, is to identify the most appropriate climate control to suit the museums. As part of this process, light, humidity, temperature and air pollution were monitored over a specific period, using modern monitoring methods and measuring devices (OnGuard^{TM} 3000, Atmospheric corrosion monitoring coupons and the ELSEC 764 environmental monitor). Additionally, the variations in humidity, light, temperature and air pollution inside the museums were also compared with the variations in these factors in the exterior atmosphere, to assess the degree of consequential fluctuations of these values inside the museums. The previous measurements were also compared to international standards in order to determine to what extent Jordanian museums conform to international norms.

Light is an agent of long-term deterioration to exhibition objects. A museum audience expects to be able see the objects exhibited in a collection clearly. Therefore, it is the dual role of the museum administration to meet the visitor’s expectations and at the same time to protect the objects from deterioration that might result from unsuitable lighting. Since all museum objects are opaque to light, the major effect is damage and deterioration on the surface of materials. Moreover, all organic materials - “the term ‘organic material’ includes all things that originate from animals or plants” (Thomson 1986) - as well as some inorganic materials, such as plastics, are at risk of damage when exposed to light. Light can cause not only colour change but also strength change, as in the weakening of textiles.

It was therefore of vital significance to set up a study to assess the light efficiency at Jordanian museums and to seek to reduce as far as possible the potential damage caused by inappropriate lighting in the country’s museums, within the available capabilities of the museums selected. Hence, it is vital to reduce to a minimum the light damage to objects.

Consequently, fourteen museums in Jordan were examined. The museums selected varied in terms of their locations, collections and building types. The ELSEC 764 environmental monitor was used to monitor visible light and ultraviolet (UV) radiation at the fourteen Jordanian museums that formed the object of this study. The resulting data from the ELSEC 764 device were compared to the current recommended international guidelines for museum lighting (Thomson 1986). A further comparison was made between the different museums monitored, depending on the susceptibility of their collections to exposure to unsuitable illumination. Finally, the available light sources in each museum were investigated, in order to determine the optimum type of lighting, depending on the availability of the lighting equipment on the local market in Jordan and the budgets of museums.

All museums were monitored using the same ELSEC 764 device and the same process. In addition, the light measuring process was carried out in each museum at the same time of day, from 10 a.m. until 2 p.m. From the fieldwork study it was found that there were four different light sources in the museums monitored: daylight, fluorescent lamps, incandescent lamps and filtered spotlights. These four sources were found to be

combined in some of the museums, while at others, only some of these sources were used.
Regarding the lighting efficiency at the museums investigated, it can be concluded that light efficiency needs urgent improvement in most of the museums monitored. The results reveal inadequate lighting intensity in most of the locations investigated within the museums that form part of this study. UV light intensity exceeded the recommended levels in 62% of the locations examined within all the museums investigated, while visible light exceeded the recommended level in 35% of the locations among all the locations examined. Therefore, it is safe to assume here that museums in Jordan do not provide the kind of special lighting system that should be installed in museums appropriate for ensuring the safety of their assets. Our findings also pointed out the detrimental levels of unfiltered daylight and UV radiation through the available light sources either by poorly-designed doors and windows, or by the artificial lighting lamps installed at most of the museums selected.
Jordanian museums, repository areas and archives contain distinguished collections that require a certain environment to ensure preservation of the objects and to restrict the deterioration process to a minimum. In the absence of environmental control, the collections of these museums are under threat of damage and decay. The museums are therefore required to provide the facilities needed for the protection of their collections.
All objects suffer decay and deterioration. Museums, however, must plan to slow down the rate of decay by reducing the negative impact of certain factors that affect objects. The environmental conditions inside a museum are among the most significant of these factors.
In preservation environments there are a number of environmental factors that can cause degradation of materials and artefacts. Among these are temperature, humidity, particulates and gaseous pollutants. Of the factors mentioned, gaseous pollutants are considered to be the most destructive element.
Although gaseous pollutants are of major worldwide environmental concern, the sources of gaseous pollutants, their introduction and migration through museums and their interactions with artefacts are the least studied and least understood areas of concern within preservation environments. General reviews of pollutant sources and object vulnerabilities and information and guidelines for gaseous pollutants were scarce until the 1990s.
In this thesis, eleven heritage preservation institutions, including nine museums, the main repository of the Department of Antiquities (DoA) and the main archive of the DoA were selected to be environmentally monitored. The passive environmental reactivity coupon (ERC) monitors that were offered by Purafil Inc., were adopted in this research to be applied on the selected Jordanian museums. The ERCs were typically exposed to the environment for a period of 30-90 days. The coupons were then sent to the Purafil Inc. headquarters to be analysed in order to determine the thickness and type of corrosion that has formed. This technique can provide cumulative reactivity rates, an assessment of average environmental conditions over time and can give an indication of the types and relative levels of corrosive gaseous pollutants. ERCs may be used to indicate the presence of SO_2, O_3, NO_2, Cl_2 and many other corrosive agents, which can cause deterioration of metals, cellulose and organic materials. Due to the ease of use and reliability of these ERCs, it can be concluded that the ERCs were extremely useful in assessing the indoor air quality of the museums . They can be applied at different locations within the same museum. For outdoor air quality control, it can be concluded that the use of ERCs are not so useful, because the corrosion occurs much faster than inside buildings.

Furthermore, the resulting data were compared to the international standards of museum environment and air purification (ISA standard S71.04-1985 "Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants"- ISA, 1986), the ISO standard EN-ISO 1184 and to the Purafil Inc, Environmental classifications for preservation environments carried out by Chris Muller (Muller 1996). The analysis of ERCs was made using the electronic cathodic reduction method (ISO 2004).

In spite of the importance of the effects of air pollution on a museum's collection, this present study seems to be the first research detecting and determining environmental gaseous air pollution in Jordan.

The findings revealed that the indoor air is in direct contact with the outdoor air in most of the Jordanian museums investigated. Therefore, where there are non-sealed windows, open showcases or open doors, it can be concluded that there is a serious contamination of the indoor environment by the outdoor air. As a result, there will be an inevitable deterioration of the collection exhibited. Moreover, based on measurements at several locations within each museum, the influence of the geographical location of each museum on its indoor environment was noticed.

Based on the results of the indoor air quality measurements, the indoor air quality can be considered as clean in some of the museums monitored. However, there are a few exceptions. In one museum and some exhibition halls in other museums, the air quality can be considered as poor. There is some evidence that the source of the active sulphur contamination observed as the Cu_2S layer on certain ERCs is also found in the outside ambient air of the museums.

Referring back to the Purafil environmental classifications for preservation environments in Table 5.6, most of the museums monitored were classified as S1 C1 criteria, which means that the environments of the museums are suitable for hosting most vulnerable materials. However, particular spots in some museums were classified as S3 C3 and S5 C5, indicating that these areas are not suitable for the museums' collections. Therefore, the vulnerable collections displayed at these spots must be moved to another location within the museum, more suitable place for safeguarding the collection.

It should be noted that the amount of copper corrosion observed in the outdoor air from Umm Qeis (ERC UQM1) was so high that a reliable analysis was not possible. The active sulphur contamination levels were so high that the copper layer was totally stripped from the coupon. The unknown copper products that were found in Umm Qeis in the two sculpture halls (UQM2 and UQM3) are further evidence that the inorganic chlorine levels are far in excess of what would be considered acceptable for this type of environment. Chlorine gas revealed itself on copper as a resulted unknown copper compound.

It is concluded, that most of the museums monitored should improve their management of a good indoor environment. When comparing the results of the current environmental conditions based on the work of Muller, most of the museums monitored were classified as medium criteria in their indoor environment as was shown in Table 5.20. This means that most of the Jordanian museums require modifications to their indoor environmental conditions.

Here it can be assumed that the main pollutants observed at the museums monitored are inorganic chlorine and active sulphur compounds and it can be supposed that their sources originate from outside the buildings. Purification of the incoming exterior air might result in a cleaner interior air with, of course, less corrosive components that deteriorate metal objects. It is worth noting that this work does not take into account seasonal influences. It would therefore be appropriate to study this effect in the near future.

As most of the measurements were taken inside the buildings, the actual outdoor composition was not fully analysed and is therefore unknown. Information on the outdoor composition can be crucial in order to establish needs in preventive conservation. It should be mentioned that the average of the exterior and interior relative humidity level during this study was lower in summer periods than it is in the winter periods.

It is therefore concluded that environmental management at each Jordanian museum should take immediate action to prevent the undesirable outdoor pollutants from combining with the indoor environment in order to prevent the effect of these pollutants damaging the collection. In addition, actions should be taken in the near future to achieve a suitable and isolated indoor environment for all museums.

The preservation of museum collections depends upon the available knowledge of how materials and objects in the collection behave and how environmental influences affect them. Some aspects of preservation are obvious; relative humidity, temperature and pollution will deteriorate or damage most collections. It is also obvious that such threats should be controlled or minimized and this can be considered as one of main tasks of museums.

Consequently and in order to determine the correlation between the indoor climate and the outdoor climate and to evaluate the indoor environment, a further research project presenting real-time measurements of relative humidity, temperature and corrosion levels of two Jordanian cultural heritage sites took place in 2009, using the latest developed device OnGuard™ 3000 Atmospheric Corrosion Monitor (ACM). The OnGuard™ 3000 Atmospheric Corrosion Monitor measures corrosion on a continuous basis, thus allowing preventive action to be taken before serious damage has occurred. Appropriate reactivity and alarm levels for a particular application can easily be adjusted.

The first location was the Museum of Jordanian Heritage (MJH); this museum was selected because it is the only museum in Jordan that has the potential to be transformed into a better place for safeguarding objects within its walls and also because it was designed and built as a museum. The second selected heritage preservation institution was the main storage area of the Department of Antiquities (DoAS). This storage area is currently being considered as the first destination for objects coming from excavations that are taking place throughout Jordan.

Humidity, temperature, air pollution and atmospheric corrosion were monitored in the MJH and the DoAS over a period of four weeks during the winter of 2009 and four weeks in the summer of the same year, using the OnGuard™ 3000 (ACM), which was borrowed from the company Twin Filter Inc. in the Netherlands. In addition to detecting air pollution, the ACM also has the ability to monitor relative humidity and temperature. This followed a specific period of observation, investigation and monitoring of approximately one month in each semester. The silver and copper corrosion data obtained were then processed and compared to the work by Chris Muller (Purafil Inc.) (Muller 1996) and to the ISO standard EN-ISO 1184, whereas, the relative humidity and temperature data were compared to the Canadian Conservation Institute standards and guidelines for temperature and relative humidity in museums, art galleries, libraries and archives. Furthermore, the results of the indoor environment were compared to results from outdoors, in order to determine any correlation between the two atmospheric zones.

The amount of corrosion that forms over any given period is a primary indicator of how well-controlled an environment may be. Depending on the quality of the indoor environment and the types of risks that the collections face at the institutions selected, different categories were assigned to indicate the quality of the preservation at the given locations.

Environmental conditions affect objects in many ways. Some objects are vulnerable to conditions that may not affect other objects at all. Furthermore, the environments inside the MJH and the DoAS differ from one spot to another, depending on the number, size and location of the side openings of the exhibition halls.

The findings confirm that there were fluctuations in relative humidity and temperature at the locations examined at the MJH and the DoAS. Based on the climatic data collected, it was quite evident that variations in the outside environment are reflected inside the MJH and DoAS, albeit to differing degrees. It is therefore apparent that there is absolutely no control or monitoring of the interior environments at the two locations.

While investigating the indoor environment at the DoAS, it was discovered that there is a direct correlation between the indoor climate and the outdoor atmosphere of the storage area, in the given winter and summer monitoring period. The corrosion of copper and silver at the DoAS was only obvious once the relative humidity level exceeded 50%. Also, it was noticed that there was some corrosion in both periods monitored, in spite of the fact that the relative humidity levels were slightly higher in winter than in summer.

When the results of the monitoring for the DoAS were compared with Muller's guidelines described in Table 6.4 for the corrosion levels and compared with the international standards for temperature and relative humidity, it was found that there was a fluctuation in temperature and RH through the whole monitoring period. Sometimes this fluctuation was above international standards and at other times it was below them. Furthermore, the corrosion levels for both copper and silver exceeded the guidelines on many occasions.

In the case of DoAS monitoring, the difference between the maximum and minimum temperature is considerably high, with a fluctuation of ±9 ?C in February and almost ±13 ?C in July. Moreover, if the monitoring in winter is compared with the monitoring in summer, a difference of 19 degrees in the average temperature between February and July was seen.

In addition, the minimum and maximum levels of RH differ significantly more, with 34%, a fluctuation of ±16%, in February and 37%, a fluctuation of ±18%, in July. Thus, there is a difference 15% in the average RH between February and July. According to the CCI classifications, these results identify the main storage area of the Department of Antiquities as being class C and D, as it was described in Table 6.6, which is not acceptable for museum storage.

When discussing the investigation of the air purification at the DoAS, it seems that in the periods monitored, both winter and summer, the silver film corrosion level exceeded the S4 class on many occasions. These results mean that the indoor environment of the DoAS conforms to class S5 for silver corrosion, which is not an acceptable environment either for museums or for museum storage, as was described in Table 6.4. The copper film corrosion exceeded the C3 class in winter and C2 in summer. For museums and museum storage, the corrosion level of copper film must be always below 150 ? / 30 days (C2 class). As the corrosion level for the silver film is higher than that for the copper film in the same environment, this indicates the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3), which are mainly formed by automobile fuel. Moreover, there were some days when the corrosion level was zero Å. After checking the calendar of the year 2009, it appears that most of the days with a low corrosion level were weekends and holidays.

The location of the storage, adjacent to a main, busy highway (Amman-Zarqa highway), plays a significant role in the pollution of the indoor environment. It was evident that at the weekends the corrosion levels were lower, which indicates a relation to the traffic on the highway. Therefore, it is vital to pursue a further study in order to determine the impact from the traffic on the highway and the effects of the fuel gases on the indoor environment of the DoAS.

In general, the environmental situation at the MJH seems to be better than at the DoAS. The correlation of indoor and outdoor climate at the MJH was also monitored in two monitoring periods - winter and summer. The fluctuations in the temperature and relative humidity in this museum were much better than the results of the DoAS. Despite this, the relative humidity sometimes reached 100% in the outside atmosphere, but never exceeded 68% inside the museum during both monitoring periods. As regards temperature, a high of 36 ?C was reached outside in the summer and a low of 4 ?C was recorded in winter inside the museum. However, the temperature remained between 18 ?C and 22 ?C in summer and between 10 ?C and 16 ?C in winter. This indicates that there is no correlation between the outside atmosphere and the indoor climate of the Museum of Jordanian Heritage.

When the results of the monitoring for the museum of Jordanian heritage were compared with Muller's guidelines described in Table 6.4 for corrosion levels and with the international standards for temperature and relative humidity, it was found that the corrosion levels did not exceed the guidelines in any of the cases. The comparison between the two indoor climate locations reveals that temperature and relative humidity at the MJH are better controlled than they are in the DoAS. This can be seen from the peak fluctuations in temperature and relative humidity measures outside and the relatively constant temperature and relative humidity measured inside with the OnGuard^{TM} 3000. In addition, the difference between the maximum and minimum temperatures was only 4 ?C (a fluctuation of ± 2 ?C) in March and 6 ?C (fluctuation of ± 3 ?C) in May. The difference in the average temperature between March and May is less than 7 ?C, while the minimum and maximum relative humidity differs more, about 14% (fluctuation of ± 7%) in March and 16% (fluctuation of ± 8%) in May. There is also a difference of 5% in average relative humidity between March and May. Therefore, the general situation of the Museum of Jordanian Heritage according to the CCI classifications can be categorized as A and B as seen in Table 6.6.

When discussing the investigation of air purification at the MJH, the measurements of the copper corrosion did not exceed 90 ? / 30 days in either monitoring period. These results mean that the indoor environment at the MJH according to Muller's work described in Table 6.4 is class C1. As regards copper corrosion, this is an acceptable level for museums and for museum storage, while the silver film exceeded 100 ? / 30 days in winter and 40 ? / 30 days in summer. These results categorize the MJH as class S3 in winter and class S2 in summer. For museums and museum storage the corrosion level of copper film must be always below 150 ? / 30 days (C2 class), which was the case at the MJH. However, the corrosion levels for the silver film exceed the recommended 100 ? / 30 days (S2) several times, especially during the winter monitoring period. As the corrosion level for the silver film is higher than the corrosion level for the copper film in the same environment, this indicates the presence of oxidized forms of sulphur such as sulphur dioxide (SO_2) and sulphur trioxide (SO_3), which are mainly formed by automobile fuel. Moreover, as at the DoAS, there were days when the corrosion level was zero Å. After checking the calendar for the year

2009, it appears that the corrosion level was not related to the working days. In spite of fact that the museum closes on Fridays and Saturdays, the corrosion level was not low on these days and the presence of oxidized forms of sulphur was detected inside the museum at the weekends, which raises the assumption that the museum is not immune to the outdoor environment, even when it is completely closed.

In general, fluctuations in temperature and relative humidity in the MJH and DoAS were evident. Discussing the results, we can, however, conclude that the worst situation was found at the DoAS. Moreover, a direct correlation between the indoor environment and the outside atmosphere is evident in both sites, but with differing rates.

Controlling the climatic conditions within these cultural heritage institutions will resolve the problem of corrosive gases coming from outside through side openings in the buildings. However, the gas concentrations in the MJH are lower than in the DoAS. Given the importance of environmental control, it is therefore recommended that temperature and relative humidity control apparatus such as air conditioning systems and humidistats, as well as gas phase filtration in the outside air conditioning units, should be installed and used.

As a general conclusion, it is safe to assume that the cost of making the necessary improvements to the museums selected would be high in monetary terms, but it is equally certain that it would be a small price to pay for the proper preservation of the Jordanian national heritage. Time is of the essence in implementing a comprehensive programme of improvements in these museums to meet international standards for museums. Training programs for museum staff are of prime importance, in order to educate all those who work in museums, in terms of respect for and appreciation of this historical legacy and taking pride in being responsible for its preservation.

Action needs to be taken soon before artefacts are damaged beyond repair. This is our duty, to the generation of the past, the present and the future.

7.2 Further research

This thesis sheds new light on the subject of museum environments regarding museums in Jordan. Since the purpose of any scientific study is to explore and not to prove, this thesis plays a major role in exploring the current environmental situation at the Jordanian museums. The focus of this work is to identify and as far as possible to institute a suitable environment for the objects displayed in the museums monitored. Museums in Jordan in general are in need of environmental control systems, new lighting systems and air filtration units. Hence, this research was limited in some aspects; for instance, the availability of the monitoring devices and the ability and willingness of the Jordanian museum directors to investigate their museum's indoor environment; some of these individuals refused to allow me to monitor and investigate the environmental conditions in the museum under their authority. It may be that they were not overly concerned about the conditions in their museums as long as they are able to keep their positions. In addition, this research was limited in terms of the investigation period.

There are a number of possible avenues for further exploration. The main ones are:

- Since the availability of the measurement devices was limited, this also caused a limitation in the numbers of institutions monitored. The apparatuses used (OnGuard™ 3000 and ELSEC 764 environmental monitor) were found to be adequate and efficient for the requirements of the research. It is recommended that a similar study should be pursued using these devices to evaluate Jordanian museums not covered by this present research.
- The environmental reactivity coupons (ERCs) used particularly in chapter five were very useful and not expensive to use and are able to provide a complete evaluation of the indoor environment and pollutant gaseous. A further study is therefore recommended that applies this method to assess the environmental conditions in the remaining museums in Jordan that for various reasons were not covered by this study.
- It was noticed from the frequent visits to some of the Jordanian museums that a number of objects are suffering from deterioration on daily basis. The extent of deterioration of some of these objects was clearly evident within a short period, as for instance in the case of the Museum of Jordanian Heritage as discussed in section 6.6, which even today remains unaddressed. A research study is therefore recommended that will analyse samples of the deteriorating objects, in order to determine whether the presence of adjacent objects in the same showcase or even the showcase itself are contributing to the decay or deterioration of these objects.
- The number of archaeological excavations in Jordan is increasing constantly, which means in turn that the amount of the material excavated is also increasing. I would propose here to start a study that might be able to assist the responsible personnel in Jordan to determine the environmental situation of objects in their original soil context in order to determine the preferred environment for preserving these objects in their current condition for a longer period.

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ANNEX 1

Terms and abbreviations used

Table A1.1 List of terms abbreviations used

Term or abbreviation	**Explanation**
µA/cm²	Micro ampere per square centimetre.
µW/lm	Micro watt per lumen.
?	Angstrom.
a.m.	Ante meridiem, before midday.
ACM	Atmospheric Corrosion Monitor.
AD	Anno Domini.
Ag	Silver.
Ag_2O	Silver oxide.
Ag_2S	Silver sulphide.
AgCl	Silver chloride.
Air pollutants	Substances present in the air that pollute the environment.
ASHRAE	American Societies of Heating, Refrigeratingand Air-conditioning Engineers
Badia	Arid, desert environment, where there is little or no permanent vegetation, infrequent precipitation and intermittent surface water
BC	Before christ
Brightness	An attribute of visual perception in which a source appears to be radiating or reflecting light or reflecting light, a measure of the lightness/whiteness etc.
$CaCO_3$	Calcium carbonate
$CaSO_4$	Calcium sulphate
CCI	Canadian Conservation Institute
CH_3COOH	Acetic acid
Cl_2	Chlorine
Climatization	To acclimate to a new environment.
CO_2	Carbon dioxide
COST	European cooperation in science and technology.
CTI	Comitato Termotechnical Italiano
Cu_2O	Copper oxide (Cuprite).
Cu_2S	Copper sulphide
Decapolis	A group of ten cities on the eastern frontier of the Roman Empire.
Delta plan Cultuurbehoud	Delta Plan for Culture Preservation in the Netherlands
Deterioration	A change for the worse in one or more characteristics of material.
DoAS	Department of Antiquities main storage
Dust	Solid particles with diameters, particles in the atmosphere arise from various sources such as soil dust lifted up by wind, volcanic eruptionsand pollution.
'E	East
ELSEC	Littlemore scientific engineering
Embrittlement	Loss of ductility of a material
ERC	Environmental Reactivity Coupons
Erfgoedinspectie	Cultural Heritage Inspectorate
Term or abbreviation	**Explanation**

F	Farady’s constant, 96 485 C/mol.
Fading	Gradual change in colour.
$Fe(OH)_2$	Ferrous hydroxide.
$Fe(OH)_3$	Ferric hydroxide.
Fe	Iron.
$FeCl_2$	Ferrous chloride.
$FeCl_3$	Ferric chloride.
Fluorescent lamp	A gas-discharge lamp that uses electricity to excite mercury vapor.
H_2CO_3	Carbonic acid.
H_2O	Water / water vapour.
H_2S	Hydrogen sulphide.
H_2SO_4	Sulphuric acid.
HCHO	Formaldehyde.
HCl	Hydrochloric acid, (Hydrogen chloride).
HF	Hydrogen fluoride.
HVAC	Heating, Ventilation and Air-Conditioning systems.
i	The current density, in mA/m^2.
i.e	In example.
Incandescent lamps	An electric current passes through a thin filament, heating it to a temperature that produces light.
IR	Infrared.
ISA	Institute Society of America.
ISO	International organization for standarization.
JICA	Japanese international cooperation agency.
K_2O	Potassium oxide.
KCl	Potassium chloride.
Km	Kilometer.
km^2	Square kilometer.
Lumen	The SI (International System of Units) unit of luminous flux.
$lumen/m^2$	Lumen per square meter.
Lux	The SI unit of illuminance.
M (Faradays law)	The relative molecular mass.
M (Concentration)	Molar concentration (e.g. 0.1 M KCL).
m	Meter.
m.s.l	Mean sea level.
Mechanical damage	Change in size and shape.
M_{film}	The relative molecular mass of the corrosion film.
$mg/(m^2t)$	Milligram per square meter per time.
MJH	Museum of Jordanian Heritage.
mW/m^2	Milliwatts per square meter.
n	The valance state.
'N	North.
Na_2O	Sodium oxide.
NaCl	Sodium chloride (Natural Salt).
$NaNO_3$	Sodium nitrate.
NH_3	Ammonia.
Nm	Nanometer.
Term or abbreviation	**Explanation**

NO_2	Nitrogen dioxide.
NO_x	Oxides of nitrogen, here the sum of the concentration of NO and NO_2.
O_3	Ozone.
?C	Centigrade (Degree Celsius).
PM	Particles micros.
p.m.	Post meridiem, after midday.
Pb	Lead.
PC	Computer.
ppb	part per billion.
r_{corr}	The corrosion rate, in mg/m^2t.
RH	Relative Humidity.
S	Sulphur.
SiO_2	Silica oxide.
SO_2	Sulphur dioxide.
SO_3	Sulphur trioxide.
t	The exposure time, in years.
T	Temperature.
t_f	The thickness of the corrosion film in nm (10^{-9}m).
t_{red}	The total time for reduction of corrosion products, in seconds.
VOC	Volatile organic compound.
UNESCO	United Nations Educational, Scientific and Cultural Organization.
USB	Universal Serial Bus, flash drive.
UV	Ultra Violet.
Ventilation	The process of "changing" or replacing air in any space.
Vis	Visible light.
Vision	The ability to interpret information and surroundings from the effects of visible light reaching the eye.
σ_{film}	The density of the corrosion film in g/cm3.

ANNEX 2

Analyzing and monitoring data

Table A2.1A Literature reviewed articles sorted by the subject by type of effect at museum objects (chapter 2).

Articles	Year	Natural light	Artificial light	UV	Micro organisms	Pests	Dust	Material aging	Polluted outdoor air	Polluted indoor air
Chicora foundation	1994									
Bouwmeester	1996					Pests				
Anonymous report	1997					Pests	Dust			
Dirksen	1997							Leather		
Brysbaert	1998							Bronze		
Toledo and Price	1998									
Padfield *et al*	2002							Glazed picture		
Korenberg	2003							Polyester fabrics		
Roberts	2004	Analyzing					Analyzing			
Havermans	2004									Purified air
Havermans and Steemers,	2004									
Cigic *et al*	2004									Volatile organic compounds
Cornelissen and De Jong	2004									
Bradley	2005									
Connors-Rowe *et al*	2005	Watercolour fading								
Kang *et al*	2005				Fungi	Pesticides				
Kaplan *et al*	2005									
Muething *et al*	2005					Pests				
UNESCO	2006									
Blazik *et al*	2007							Paper		
Bratasz *et al*	2007									
Broecke	2007									
Brokerhof	2007	Measuring						Dose-effect		
Child	2007				Insect					
Costa and Dubus	2007							Metal Artefacts		
Coxon	2007									
Druzik	2007		Colour Fading							
Erthardt at al	2007									
Fry *et al*	2007									
Hackney	2007		Framing							
Huber	2007	Window								
Knight	2007									
Krus	2007				Mould					
Larsen	2007									
Ligterink and Giovanna	2007									
Lithgow	2007									
Lloyd *et al*	2007						Libraries			Wood
Maekawa	2007									
Mecklenburg	2007							Painting		
Ntanos and Bell	2007									
Odlyha *et al*	2007									
Olstad and Anneka	2007							Wood		
Padfield	2007									
Padfield *et al*	2007									
Rasmussen	2007									
Reilly *et al*	2007									

Articles	Year	Natural light	Artificial light	UV	Micro organisms	Pests	Dust	Material aging	Polluted outdoor air	Polluted indoor air
Richard	2007				Silica gel					
Ryhl-Syendsen	2007									
Schieweck *et al*	2007				Airborne polutants					
Shiner	2007									
Strlic	2007							Paper		
Thicket *et al*	2007									
Thicket and Lambarth	2007								Gases	
Toledo *et al*	2007									
Watts *et al*	2007									

Table A2.1B Literature reviewed articles sorted by the subject by type of effect at museum objects (chapter 2).

Articles	Year	High humidity	Humidity fluctuation	Passive air conditioning	Micro climates	Temperature	Storage	General evaluation	Ventilation
Chicora foundation	1994					Adjusting		Managing	Measuring
Bouwmeester	1996	Measurin g				Measuring		Control	
Anonymous report	1997						Paper		
Dirksen	1997								
Brysbaert	1998								
Toledo and Price	1998		Monitoring			Monitoring			
Padfield *et al*	2002								
Korenberg	2003								
Roberts	2004	Analyzin g				Analyzing			
Havermans	2004								
Havermans and Steemers,	2004								Presence of NOx and SO2
Cigic *et al*	2004								
Cornelissen and De Jong	2004								Pollutants concentratio n
Bradley	2005		Control				Control		
Connors-Rowe *et al*	2005								
Kang *et al*	2005								
Kaplan *et al*	2005						Rehousin g	Rehousing	
Muething *et al*	2005							Risk assessment	
UNESCO	2006							Evaluation	
Blazik et al	2007								
Bratasz *et al*	2007				Microc limates				
Broecke	2007	Microcli mates		Case study					
Brokerhof	2007								Outcome climate
Child	2007					Effect on insects			
Costa and Dubus	2007								

Articles	Year	High humidity	Humidity fluctuation	Passive air conditioning	Micro climates	Temperature	Storage	General evaluation	Ventilation
Coxon	2007							Ventilation	
Druzik	2007								
Erthardt at al	2007							Specifications	
Fry *et al*	2007							Risk assessment	
Hackney	2007								
Huber	2007								
Knight	2007		Wood						
Krus	2007								
Larsen	2007							Church	
Ligterink and Giovanna	2007		Paintings on walls						
Lithgow	2007							Environment managing	
Lloyd *et al*	2007								
Maekawa	2007	Visitors						Visitors	
Mecklenburg	2007								
Ntanos and Bell	2007							Evaluation	
Odlyha *et al*	2007							Dosimeter	
Olstad and Anneka	2007								
Padfield	2007							Climate records	
Padfield *et al*	2007		Natural stability	Air conditioning					
Rasmussen	2007			Storage			evaluation		
Reilly *et al*	2007						Assessment		
Richard	2007	Silica gel							
Ryhl-Syendsen	2007							Air exchange	Air exchange
Schieweck *et al*	2007				Airborne pollutants				
Shiner	2007				Display cases				
Strlic	2007								
Thicket *et al*	2007		Air exchange						
Thicket and Lambarth	2007							Libraries and archives	
Toledo *et al*	2007				Glass boxes				
Watts *et al*	2007				Cases				

Table A2.2 Literature reviewed articles sorted by the subject by type of objects (chapter 2).

Articles	Year	Stone	Pottery	Metals	Glass	Bone, ivory	Wood	Textile	Leather	Paints	Glow	Others
Chicora foundation	1994											
Bouwmeester	1996			Metals								
Anonymous report	1997											
Dirksen	1997								Degradation			

Articles	Year	Stone	Pottery	Metals	Glass	Bone, ivory	Wood	Textile	Leather	Paints	Glow	Others
Brysbaert	1998			Sickle			Sickle					
Toledo and Price	1998											
Padfield *et al*	2002				Frames					Pictures		
Korenberg	2003							Polyester fabrics				
Roberts	2004											
Havermans	2004											
Havermans and Steemers,	2004											
Cigic *et al*	2004											Paper
Cornelissen and De Jong	2004											
Bradley	2005			Copper, silver	Weeping	Ivory, bone						
Connors-Rowe *et al*	2005									Water colours		
Kang *et al*	2005						Pesticides					
Kaplan *et al*	2005											
Muething *et al*	2005											
UNESCO	2006											
Blazic *et al*	2007											Paper
Bratasz *et al*	2007											
Broecke	2007											
Brokerhof	2007											
Child	2007											
Costa and Dubus	2007			Environment impact								
Coxon	2007											
Druzik	2007											
Erthardt at al	2007											
Fry *et al*	2007											
Hackney	2007						framing				Framing	
Huber	2007											
Knight	2007						Response to humidity					
Krus	2007	historic building										
Larsen	2007	Building stone										
Ligterink and Giovanna	2007									Canvas humidity		
Lithgow	2007	Decorated surfaces										
Lloyd *et al*	2007											Paper
Maekawa	2007											

Articles	**Year**	**Stone**	**Pottery**	**Metals**	**Glass**	**Bone, ivory**	**Wood**	**Textile**	**Leather**	**Paints**	**Glow**	**Others**
Mecklenburg	2007									Humidity		
Ntanos and Bell	2007											
Odlyha *et al*	2007											
Olstad and Anneka	2007						Climate change					
Padfield	2007											Paper
Padfield *et al*	2007											
Rasmussen	2007											
Reilly *et al*	2007											Paper
Richard	2007											
Ryhl-Syendsen	2007									Silica gel		
Schieweck *et al*	2007											
Shiner	2007											
Strlic	2007											Infrared on paper
Thicket *et al*	2007											
Thicket and Lambarth	2007											
Toledo *et al*	2007				Boxes					In glass		
Watts *et al*	2007											

Table A2.3 Results for ELSIC light measuring in the Jordanian museums (chapter 4)

Location Room/Case	Date	Objects type	Light source	Visible light lux		UV μW/lm	
				10:00 AM	8:00 PM	10:00 AM	8:00 PM
Ajloun museum							
first hall Facing ceiling	4/10/2009	Coins, glass, Accessories	Tungsten lamps & Natural light	23		832	
first hall under light	4/10/2009	idem	Tungsten lamps	71		98	
First hall facing window	4/10/2009	idem	Natural light	158		576	
Second hall facing ceiling	4/10/2009	Pottery, mosaics	Tungsten lamps & Natural lights	31		0	
Second hall facing window	4/10/2009	idem	Natural light	158		1197	
Second hall facing inside showcase	4/10/2009	idem	Tungsten lamps	115		117	
Archaeology museum/ University of Jordan							
First hall	6/9/2009	Pottery, bones	Natural light	498		480	
First hall	6/9/2009	idem	Tungsten lamps & Natural light	217		114	
Second hall	6/9/2009	Accessories, glass, pottery	Natural light	300		420	
Interior hall	6/9/2009	idem	Natural light	86		331	
Corridor ?	6/9/2009	Pottery, stone	Natural light	211		135	
Entrance hall	6/9/2009	idem	Natural light	791		648	
Against window	6/9/2009	idem	Natural light	500		1169	
Aqaba museum							
First hall faceing ceiling	7/10/2009	Pottery, ceramics	Tungsten lamps & Natural light	104		112	
First hall facing window	7/10/2009	idem	Natural light	143		273	
First hall facing door	7/10/2009	idem	Natural light	508		274	
Second hall under light	7/10/2009	Glass,pottery	Tungsten spot light	49		31	
Second hall facing display area	7/10/2009	idem	Tungsten lamps & Natural light	15		98	
Third hall facing window	7/10/2009	idem	Natural light	67		677	
Third hall facing ceiling	7/10/2009	idem	Tungsten lamps & Natural light	22		281	
Fourth hall under light	7/10/2009	Wood, parchment, accessories	Tungsten spot light	236		52	
Fourth hall against wall	7/10/2009	idem	Tungsten lamps & Natural light	27		0	
Archaeology museum/ University of Jordan							
First hall	6/9/2009	Pottery, bones	Natural light	498		480	
First hall	6/9/2009	Tungsten lamps & Natural lights		217		114	
Second hall	6/9/2009	Accesories, glass, pottery	Natural light	300		420	
Interior hall	6/9/2009	idem	Natural light	86		331	
Corridor ?	6/9/2009	Pottery, stone	Natural light	211		135	
Entrance hall	6/9/2009	idem	Natural light	791		648	
Against window	6/9/2009	idem	Natural light	500		1169	
Dar alsaraya museum							
Anceint periods hall	2/9/2009	Bone, metal, accessories, pottery	Tungsten lamps	10		164	
Anceint periods hall	2/9/2009	idem	Tungsten lamps	17		99	
Inside showcase	2/9/2009	idem	Fluorescent lamp	156		159	
Ancient priods hall	2/9/2009	idem	Natural lights & Tungsten lamps	261		69	
Calssical periods hall	2/9/2009	Fresco, ivory, glass, coins	Ntural lights & Tungsten lamps	75		439	
Calssical periods hall	2/9/2009	idem	Natural light	178		1020	
Inside showcase	2/9/2009	idem	Tungsten spot light	50		67	
Folklore museum							
First hall facing door	7/9/2009	Textile, furniture	Tungsten lamps	190		1100	
First hall facing ceiling	7/9/2009	idem	Tungsten lamps	63		715	
First hall facing window	7/9/2009	idem	Natural light	61		364	
First hall facing tungsten light	7/9/2009	idem	Tungsten spot light	212		88	

Location Room/Case	Date	Objects type	Light source	Visible light lux		UV μW/lm	
Second hall facing ceiling	7/9/2009	idem	Tungsten spot light	20		0	
Second hall facing door	7/9/2009	idem	Natural light	82		568	
Third hall facing ceiling	7/9/2009	Tent	Tungsten spot light	165		1200	
Jarash museum							
Main hall Facing ceiling	4/10/2009	Coins, bones, glass, pottery	Tungsten lamps & Natural lights	55		75	
Main hall inside show case	4/10/2009	idem	Tungsten lamps	201		70	
Main hall facing window	4/10/2009	idem	Natural light	144		289	
Jordanian national gallery of fine arts/first building							
Ground floor/first hall	7/9/2009	Paintings & drawings	Tungsten spot light	61		0	
Ground floor/first hall facing ceiling	7/9/2009	idem	Tungsten spot light	210		11	
Entrance hall	7/9/2009	idem	Tungsten spot light & Natural light	266		15	
First floor/facing ceiling	7/9/2009	idem	Tungsten spot light	154		0	
First floor far corner	7/9/2009	idem	Tungsten spot light	175		0	
Jordan gallery of fine arts 2nd building							
Entrance hall facing main door	7/9/2009	Paintings & drawings	Natural light	236		200	
First hall facing window	7/9/2009	idem	Natural light	257		185	
First hall facing ceiling	7/9/2009	idem	Natural light & Tungsten lamps	232		52	
First hall facing spot light	7/9/2009	idem	Tungsten spot light	1000		63	
Second hall facing ceiling	7/9/2009	idem	Tungsten spot light	37		0	
First floor facing ceiling	7/9/2009	idem	Tungsten spot light	198		0	
First floor beside window	7/9/2009	idem	Natural light & spot light	423		194	
First floor facing window	7/9/2009	idem	Natural light	481		373	
Middle hall facing ceiling	7/9/2009	idem	Tungsten spot light	173		8	
First floor middle hall facing ceiling	7/9/2009	idem	Tungsten spot light	68		11	
First floor interior hall facing ceiling	7/9/2009	idem	Tungsten spot light	66		25	
Jordan museum of popular traditions							
First hall inside showcase	7/9/2009	Textile & accessories	Fluorescent lamp	208		216	
First hall facing ceiling	7/9/2009	idem	Tungsten lamps	30		46	
First hall facing incandescent light	7/9/2009	idem	Tungsten spot light	248		107	
Second hall facing ceiling	7/9/2009	Cloth	Tungsten spot light	23		0	
Second hall facing door	7/9/2009	idem	Natural light	85		349	
Third hall facing artificial light	7/9/2009	Wood, mosaics	Tungsten spot light	47		63	
Third hall facing ceiling	7/9/2009	idem	Tungsten spot light	8		0	
Museum of Jordanian Heritage							
First hall, inside showcase	31/8/2009	Pottery, bone	Tungsten lamps	45		41	
First hall, inside showcase	31/8/2009	idem	Fluorescent lamp	110		212	
Entrance	31/8/2009	Maps, pictures	Natural	132		120	
Middle Hall	31/8/2009	Pottery, metal, glass	Tungsten lamps	160		93	
Peasant house	31/8/2009	Textile tent	Tungsten lamps	980		81	
Second hall	31/8/2009	Led, metal, accessories	Natural light & Tungsten lamps	29		143	
Court yard	31/8/2009	Wood	Natural	4980		30	
Peasant house	31/8/2009	Textile, furniture	Natural	132		87	
Museum of popular heritage / Jordan University							
Main hall under incandescent light	6/9/2009	Textile, basketry furniture, clothes	Fluorescent lamp	375		110	
Main hall facing ceiling	6/9/2009	idem	Natural & Fluorescent lamp	175		74	
Towards display hall	6/9/2009	idem	Natural & Fluorescent lamp	106		26	

Location Room/Case	Date	Objects type	Light source	Visible light lux		UV µW/lm	
Main hall against window	6/9/2009	idem	Natural light	118		381	
Main hall under lamp	6/9/2009	idem	Tungsten lamps	297		82	
Natural history museum/ Yarmouk University							
First hall	1/9/2009	Stuffed animals	Natural light	496		171	
Second Hall	1/9/2009	idem	Fluorescent lamp	152		150	
Inside showcase	1/9/2009	idem	Fluorescent lamp	362		1000	
Petra Archaeology museum							
First hall facing ceiling	5/10/2009	Stone objects, pottery	Tungsten lamps & Natural lights	60		27	
First hall facing window	5/10/2009	idem	Natural light	131		141	
First hall under light	5/10/2009	idem	Tungsten lamp & Natural light	205		66	
Second hall facing ceiling	5/10/2009	Bones, pottery, coins	Tungsten lamps & Natural lights	86		50	
Second hall facing display area	5/10/2009	idem	Tungsten lamps & Natural lights	161		171	
Second hall facing display area	5/10/2009	idem	Tungsten lamps & Natural lights	186		123	
Second hall under light	5/10/2009	idem	Tungsten spot light	76		0	
Third hall facing ceiling	5/10/2009	idem	Tungsten lamps & Natural lights	227		124	
Third hall facing light	5/10/2009	idem	Fluorescent lamp	674		202	
Salt museum							
GF. First hall facing ceiling	8/9/2009	Pottery	Tungsten lamps & Natural lights	71		27	
GF. First hall facing window	8/9/2009	idem	Natural light	70		93	
GF. First hall facing yellow light	8/9/2009	idem	Tungsten spot light	213		28	
GF. Second hall facing ceiling	8/9/2009	Stone objects, potter, bronze accessories	Tungsten lamps	146		28	
GF. Second hall facing window	8/9/2009	idem	Natural light	135		311	
GF. Second hall facing window	8/9/2009	idem	Natural light	93		0	
GF. Third hall facing yellow light	8/9/2009	idem	Tungsten spot light	456		57	
1stF.. Fist hall facing south window	8/9/2009	Pottery, glass, coins	Natural light	169		291	
1stF. First hall facing west window	8/9/2009	idem	Natural light	377		117	
1stF. First hall facing ceiling	8/9/2009	idem	Tungsten lamps	162		42	
1stF. First hall under light	8/9/2009	idem	Tungsten spot light	225		85	
1stF. Second hall facing east window	8/9/2009	accessories	Natural light	392		199	
1stF. Second hall facing ceiling	8/9/2009	idem	Tungsten lamps	149		100	
1stF. Second hall under light	8/9/2009	idem	Tungsten spot light	231		56	
Umm Qeis museum							
Sculptures hall, facing main door	3/9/2009	Stone objects, pottery, accessories	Natural light	313		337	
Inside hall, towards artificial light	3/9/2009	idem	Fluorescent lamp	111		167	
First hall, against closed door and artificial light	3/9/2009	idem	Fluorescent lamp & Natural light	349		278	
Second hall, facing display hall	3/9/2009	idem	Natural light	89		148	

Table A2. 4 The ERC corrosion results at the selected Jordanian museums in chapter 5.

ERC Panel #	Location * = outside air	Silver Corrosion					Copper Corrosion				
		AgCl	Ag_2S	Ag-Unk.	Total	Class	Cu_2S	Cu_2O	Cu-Unk.	Total	Class
	Dar Alaraya Museum										
P54414	Mosaic Hall DSM 6	0	31	0	31	S1	0	85	0	85	C1
P54553	Ancient Period Hall DSM 1	0	28	0	28	S1	337	29	0	366	C5
P54555	Islamic Period Hall inside case (glass case) DSM 4	0	19	0	19	S1	0	46	0	46	C1
P54556	Metallurgy room inside case DSM2	0	17	0	17	S1	0	33	0	33	C1
P54603	Inside case DSM 7	0	17	0	17	S1	0	37	0	37	C1
P54415	Outdoor DSM 8	0	18	0	18	S1	0	30	0	30	C1
P54557	Classical periods hall DSM3	0	18	0	18	S1	0	47	0	47	C1
P54412	Sculptures Hall DSM 5	0	17	0	17	S1	0	34	0	34	C1
	Department of Antiquities										
P54438	Main storage-exit DAS 5	0	105	0	105	S3	0	68	0	68	C1
P54469	Storage no. 1 DAS 2	0	102	0	102	S3	0	63	0	63	C1
P54442	The Cave-inside DAS 7	0	49	0	49	S2	0	63	0	63	C1
P54577	Main storage, Entrance DAS 3	0	53	0	53	S2	0	61	0	61	C1
P54443	The Care-Entrance DAS 6	0	60	0	60	S2	0	59	0	59	C1
P54576	Main storage, back DAS 4	0	45	0	45	S2	0	58	0	58	C1
P54411	Archive Drawers DAA 2	0	13	0	13	S1	0	30	0	30	C1
P54468	Storage DAS 1	0	14	0	14	S1	0	29	0	29	C1
P54416	Archive DAA 1	0	13	0	13	S1	0	32	0	32	C1
P54558	Archive Closet DAA3	0	25	0	25	S1	0	42	0	42	C1
	Karak Museum										
P54543	Main Hall entrance KM1	0	26	0	26	S1	52	24	0	76	C1
P54491	Entrance KM4	0	15	0	15	S1	60	27	0	87	C1
P54517	Main Hall back side KM3	0	20	0	20	S1	51	24	0	75	C1
P54480	Entrance KM5	0	15	0	15	S1	56	29	0	85	C1
P54515	Main Hall inside closet KM2	0	15	0	15	S1	0	60	0	60	C1
	Madaba Archeology Museum										
P54479	MM6	0	17	0	17	S1	76	24	0	100	C2
P54545	Second show room MM5	0	15	0	15	S1	0	52	0	52	C1
P54478	In show room case MM7	0	14	0	14	S1	0	29	0	29	C1
P54490	Main show room MM4	0	14	0	14	S1	0	48	0	48	C1
	Madaba Folkore Museum										
P54470	Main Hall MM1	7	28	0	35	S1	106	38	0	144	C2
P54471	Textile Hall MM2	0	30	0	30	S1	0	62	0	62	C1
P54441	Main Hall Entrance MM3	0	29	0	29	S1	0	60	0	60	C1
	Museum of Jordanian Heritage										
P47908	Inside show case Lead Sarcophagus MJH 7	0	18	0	18	S1	84	37	0	121	C2

ERC Panel #	Location	Silver Corrosion					Copper Corrosion				
	* = outside air	AgCl	Ag_2S	Ag-Unk.	Total	Class	Cu_2S	Cu_2O	Cu-Unk.	Total	Class
P47913	Baet Refe (village house) MJH 9	0	25	0	25	S1	105	35	0	140	C2
P47936	Warehouse (storage) MJH 10	0	18	0	18	S1	81	34	0	115	C2
P47914	Inside show case MJH6	0	17	0	17	S1	78	30	0	108	C2
P47937	Entrance MJH 5	0	13	0	13	S1	0	62	0	62	C1
P47928	Fourth hall Isamic period objects MJH 8	0	20	0	20	S1	0	58	0	58	C1
P56417	W Outside Airco-Inlet*	459	633	0	1092	S5	412	60	422	894	C5
P56413	SW Outside Airco Inlet*	98	422	0	520	S5	20000	0	0	20000	C5
P56420	E Outside Window*	0	211	0	211	S4	349	45		394	C5
	Numismatics Museum										
P47918	Outside air Yarmouk MJH 4*	20000	0	0	20000	S5	0	20000	0	20000	C5
P47917	Main Hall Yarmouk Entrance MJH1	0	18	0	18	S1	0	54	0	54	C1
P47915	Main Hall Yarmouk far corner from entrance MJH2	0	15	0	15	S1	0	56	0	56	C1
P47916	Main Hall Yarmouk Out coming air from AC MJH3	0	13	0	13	S1	0	53	0	53	C1
	Petra Museum										
P54559	Second Hall PM 2	0	17	0	17	S1	72	22	0	94	C2
P54560	First Hall PM1	0	16	0	16	S1	70	25	0	95	C2
	Salt Archaeology Museum										
P54606	Entrance SM4	0	24	0	24	S1	0	42	0	42	C1
P54605	Late Bronze Age Hall SM3	0	25	0	25	S1	0	33	0	33	C1
P54410	Hellenistic - early Islamic Hall	0	24	0	24	S1	0	46	0	46	C1
P54422	The Rual Landscape Middle Islamic SM1	0	19	0	19	S1	0	60	0	60	C1
	Umm Qeis Museum										
P47911	Outside air VQM1*	224	179	0	403	S5	20000	0	0	20000	C5
P47909	Main Hall VQM4	0	69	0	69	S2	192	51	0	243	C3
P47910	Sculpture Hall VQM2	13	47	0	60	S2	113	21	40	174	C3
P47912	Sculptures Hall VQM3	12	46	0	58	S2	103	35	38	176	C3
P56421	Courtyard Mid-SE Cypress tree*	131	676	0	807	S5	20000	0	0	20000	C5
P33177	Courtyard - Side Vault*	59	300	0	359	S5	628	210	0	838	C5
P56418	Courtyard South Ikozai Gallery*	59	300	0	359	S5	174	90	274	538	C5

Table A2.5 Amman weather forecast, Relative humidity % data (February) (chapter 6).

Date	0000GMT	0600GMT	1200GMT	1800GMT
2009-02-01	90	88	78	84
2009-02-02	78	65	52	81
2009-02-03	87	87	48	52
2009-02-04	71	74	32	35
2009-02-05	35	63	30	44
2009-02-06	44	24	53	79
2009-02-07	92	86	47	74
2009-02-08	75	69	41	46
2009-02-09	48	52	19	34
2009-02-10	74	86	43	87
2009-02-11	87	85	76	83
2009-02-12	87	71	47	65
2009-02-13	48	71	35	53
2009-02-14	75	61	32	49
2009-02-15	65	57	48	52
2009-02-16	68	63	45	70
2009-02-17	81	89	59	80
2009-02-18	87	82	44	57
2009-02-19	67	56	36	37
2009-02-20	66	80	67	63
2009-02-21	80	86	85	87
2009-02-22	91	89	85	93
2009-02-23	87	89	52	73
2009-02-24	71	64	56	67
2009-02-25	74	85	43	55
2009-02-26	82	80	31	58
2009-02-27	59	82	83	91
2009-02-28	90	86	68	79
2009-03-01	89	87	84	87

Table A2.6 Amman weather forecast, Dry Bulb Temperature °C data (February) (chapter 6).

Date	0000GMT	0600GMT	1200GMT	1800GMT
2009-02-01	7,2	7,9	9,4	9,6
2009-02-02	6,6	9,0	15,2	10,0
2009-02-03	6,5	6,0	16,4	11,7
2009-02-04	8,0	6,4	18,3	13,8
2009-02-05	12,6	6,1	19,2	13,1
2009-02-06	10,7	11,6	15,8	11,5
2009-02-07	7,6	9,8	16,0	11,4
2009-02-08	9,8	8,4	19,0	14,0
2009-02-09	12,0	11,2	23,2	18,0
2009-02-10	12,9	10,0	11,6	6,0
2009-02-11	4,3	7,6	10,6	9,5
2009-02-12	7,0	8,4	15,0	10,7
2009-02-13	10,4	5,6	15,8	13,0
2009-02-14	7,6	10,6	17,4	13,0
2009-02-15	8,8	9,2	15,2	9,5
2009-02-16	6,0	7,2	12,4	8,8
2009-02-17	7,4	6,4	10,4	7,0
Date	0000GMT	0600GMT	1200GMT	1800GMT

2009-02-18	5,8	6,2	12,5	9,4
2009-02-19	7,5	8,4	15,6	13,8
2009-02-20	10,2	10,2	12,6	10,0
2009-02-21	7,6	5,2	7,4	6,1
2009-02-22	5,6	5,8	7,4	6,0
2009-02-23	6,0	6,0	11,0	7,8
2009-02-24	6,6	8,0	12,4	10,2
2009-02-25	6,0	7,0	15,2	10,8
2009-02-26	6,6	7,0	16,8	11,1
2009-02-27	9,0	9,8	7,4	4,2
2009-02-28	4,2	4,2	9,0	6,6
2009-03-01	5,6	4,4	6,0	5,8

Table A2.7 Amman weather forecast, Relative humidity % data (June-July) (chapter 6).

Date	0000GMT	0600GMT	1200GMT	1800GMT
2009-06-23	40	27	18	51
2009-06-24	50	39	15	37
2009-06-25	34	22	23	31
2009-06-26	38	20	28	49
2009-06-27	33	30	45	71
2009-06-28	78	66	37	59
2009-06-29	55	36	24	24
2009-06-30	35	19	14	31
2009-07-01	30	20	15	24
2009-07-02	36	27	26	35
2009-07-03	32	40	35	64
2009-07-04	74	66	45	61
2009-07-05	81	35	50	66
2009-07-06	84	69	45	68
2009-07-07	56	42	39	56
2009-07-08	74	61	40	59
2009-07-09	45	55	40	62
2009-07-10	43	40	31	52
2009-07-11	36	32	19	35
2009-07-12	31	25	26	35
2009-07-13	28	24	21	33
2009-07-14	49	63	40	56
2009-07-15	75	66	42	60
2009-07-16	51	46	38	52
2009-07-17	49	33	28	61
2009-07-18	33	41	32	48
2009-07-19	58	43	25	48
2009-07-20	42	33	26	41
2009-07-21	34	27	28	39
2009-07-22	42	43	21	34
2009-07-23	38	39	26	42

Table A2.8 Amman weather forecast, Dry Bulb Temperature °C data (June-July) (chapter 6).

Date	0000GMT	0600GMT	1200GMT	1800GMT
2009-06-23	22,1	27	32,9	25
2009-06-24	21,7	28,8	35,6	30
2009-06-25	25	31,9	36	29
2009-06-26	25,6	29,6	32,6	27
2009-06-27	24	26,2	28,6	21
2009-06-28	17,5	20,8	28,3	22,4
2009-06-29	18,8	25,4	32,6	26,9
2009-06-30	22,1	30,8	37	31
2009-07-01	26,2	31,2	37	29,6
2009-07-02	26,5	28,4	31,8	24,5
2009-07-03	22,1	24,4	29,8	22
2009-07-04	18	21,6	27,3	21,8
2009-07-05	18,8	21,7	26,6	21,8
2009-07-06	19	22,4	28	22,9
2009-07-07	20,4	25,6	30	24,2
2009-07-08	19,9	23,4	29,4	24,2
2009-07-09	22,4	24,4	32	25,9
2009-07-10	24,4	28,8	34,8	27,6
2009-07-11	25	28,2	34,2	27,8
2009-07-12	24,4	29	32,4	27,4
2009-07-13	25	28,4	33	27,6
2009-07-14	22,8	22,2	27,5	23
2009-07-15	20,4	22,2	27,4	22,8
2009-07-16	20,7	23,6	28,6	24
2009-07-17	20,8	25	30,6	23,8
2009-07-18	26,2	26	30,8	25,8
2009-07-19	21,8	26	32	26,4
2009-07-20	24,2	28,2	32,4	27,4
2009-07-21	24,7	28,6	33,1	28,3
2009-07-22	25	27,8	33,3	28,6
2009-07-23	24,6	27,6	32,6	26,7

Table A2.9 Irbid weather forecast, Relative humidity % data (March) (chapter 6).

Date	0000GMT	0600GMT	1200GMT	1800GMT
2009-03-01	97	92	88	95
2009-03-02	94	95	88	95
2009-03-03	98	98	91	95
2009-03-04	94	95	88	95
2009-03-05	95	96	78	80
2009-03-06	86	44	48	71
2009-03-07	67	66	42	71
2009-03-08	22	82	73	76
2009-03-09	70	80	60	80
2009-03-10	90	89	84	89
2009-03-11	95	89	68	84
2009-03-12	89	81	63	80
2009-03-13	93	93	80	95
2009-03-14	94	90	70	88
2009-03-15	95	95	89	90
Date	**0000GMT**	**0600GMT**	**1200GMT**	**1800GMT**

2009-03-16	92	85	71	83
2009-03-17	94	85	67	88
2009-03-18	90	79	78	82
2009-03-19	93	90	63	84
2009-03-20	86	74	75	89
2009-03-21	91	93	75	92
2009-03-22	93	83	67	87
2009-03-23	93	72	60	85
2009-03-24	92	92	95	95
2009-03-25	94	94	79	95
2009-03-26	97	91	73	84
2009-03-27	80	61	63	90
2009-03-28	90	86	84	95
2009-03-29	94	88	74	88
2009-03-30	100	82	80	91
2009-03-31	93	93	83	89
2009-04-01	91	75	51	85
2009-04-02	74	68	46	66

Table A2.10 Irbid weather forecast, Dry Bulb Temperature °C data (March) (chapter 6).

Date	0000GMT	0600GMT	1200GMT	1800GMT
2009-03-01	4,8	5,8	9,2	6,8
2009-03-02	5,6	7,0	10,2	8,6
2009-03-03	8,4	8,6	11,4	9,4
2009-03-04	9,0	9,0	14,4	10,6
2009-03-05	9,2	12,0	19,6	15,0
2009-03-06	14,4	14,0	23,2	17,4
2009-03-07	16,8	13,0	26,0	21,4
2009-03-08	22,8	17,0	21,4	15,0
2009-03-09	11,4	11,0	14,6	10,6
2009-03-10	9,4	11,0	15,2	11,4
2009-03-11	9,8	11,0	17,6	13,1
2009-03-12	10,6	11,5	19,4	13,8
2009-03-13	10,6	11,0	15,0	10,4
2009-03-14	9,0	9,0	11,8	9,6
2009-03-15	8,6	9,4	12,0	9,0
2009-03-16	7,4	7,6	12,4	8,2
2009-03-17	4,6	7,4	14,0	9,6
2009-03-18	7,8	6,8	14,2	9,0
2009-03-19	7,0	9,3	14,2	11,0
2009-03-20	9,2	11,0	15,0	12,0
2009-03-21	9,8	9,0	15,2	9,9
2009-03-22	8,4	9,2	16,6	12,2
2009-03-23	8,6	13,4	21,6	12,4
2009-03-24	7,6	6,6	11,0	9,2
2009-03-25	8,0	10,2	13,4	10,0
2009-03-26	7,6	10,0	15,2	10,6
2009-03-27	7,6	13,6	16,0	9,0
2009-03-28	8,6	9,6	13,0	8,4
2009-03-29	8,0	8,8	14,0	10,2
Date	**0000GMT**	**0600GMT**	**1200GMT**	**1800GMT**
2009-03-30	7,8	10,4	14,0	10,0

2009-03-31	9,0	10,6	16,0	12,1
2009-04-01	10,2	15,6	22,6	17,0
2009-04-02	13,8	15,0	26,0	19,0

Table A2.11 Irbid weather forecast, Relative humidity % data (April) (chapter 6).

Date	0000GMT	0600GMT	1200GMT	1800GMT
2009-05-04	66	49	58	82
2009-05-05	88	88	71	88
2009-05-06	93	82	67	88
2009-05-07	93	88	59	93
2009-05-08	95	90	67	82
2009-05-09	93	90	65	90
2009-05-10	96	90	67	88
2009-05-11	94	90	62	76
2009-05-12	85	81	55	68
2009-05-13	82	64	48	48
2009-05-14	56	52	56	63
2009-05-15	74	69	54	68
2009-05-16	76	64	34	55
2009-05-17	75	64	55	53
2009-05-18	63	56	32	41
2009-05-19	52	62	47	72
2009-05-20	81	69	69	80
2009-05-21	84	75	56	76
2009-05-22	81	75	59	71
2009-05-23	86	73	65	70
2009-05-24	90	91	66	84
2009-05-25	92	89	63	89
2009-05-26	85	76	61	78
2009-05-27	79	91	60	68
2009-05-28	72	59	45	66
2009-05-29	90	66	48	67
2009-05-30	78	59	43	66
2009-05-31	68	83	47	78
2009-06-01	87	73	61	60
2009-06-02	66	59	51	64
2009-06-03	58	57	54	78
2009-06-04	77	76	53	72
2009-06-05	76	71	51	82
2009-06-06	78	70	45	65
2009-06-07	69	75	58	76
2009-06-08	84	77	62	76

Table A2.12 Irbid weather forecast, Dry Bulb Temperature °C data (May) (chapter 6).

Date	0000GMT	0600GMT	1200GMT	1800GMT
2009-05-04	25,0	24,2	26,6	17,8
2009-05-05	14,2	14,6	19,6	13,6
2009-05-06	12,2	14,8	20,6	14,4
2009-05-07	12,0	13,8	20,0	14,2
Date	**0000GMT**	**0600GMT**	**1200GMT**	**1800GMT**
2009-05-08	12,0	14,0	20,0	15,0
2009-05-09	12,4	14,2	19,4	14,4

2009-05-10	13,0	14,0	21,4	15,2
2009-05-11	13,0	15,0	22,6	16,4
2009-05-12	13,6	16,0	24,2	18,8
2009-05-13	13,8	18,2	28,0	22,0
2009-05-14	20,0	20,0	28,2	21,8
2009-05-15	19,4	22,6	28,8	23,8
2009-05-16	20,0	25,8	30,4	25,5
2009-05-17	20,8	27,0	32,5	27,0
2009-05-18	21,8	27,5	35,0	28,6
2009-05-19	26,0	23,0	29,2	20,6
2009-05-20	18,8	22,6	26,2	20,2
2009-05-21	17,6	21,0	27,4	21,5
2009-05-22	19,4	22,8	28,2	21,6
2009-05-23	17,0	22,4	26,0	20,0
2009-05-24	16,4	18,0	23,0	18,0
2009-05-25	16,0	17,0	25,0	18,6
2009-05-26	17,0	20,0	26,6	21,8
2009-05-27	19,0	18,6	26,8	21,0
2009-05-28	18,2	21,2	26,4	19,0
2009-05-29	15,0	19,0	27,0	20,4
2009-05-30	17,0	21,6	31,6	24,6
2009-05-31	19,6	20,6	29,0	22,3
2009-06-01	17,0	21,4	30,0	23,4
2009-06-02	20,2	23,5	31,0	25,0
2009-06-03	22,6	25,0	32,8	25,4
2009-06-04	23,8	22,6	31,0	22,8
2009-06-05	19,8	23,0	29,4	21,8
2009-06-06	20,6	24,6	28,8	21,4
2009-06-07	18,6	21,0	28,4	23,0
2009-06-08	19,4	24,0	32,4	27,0

Figure A2.1 Results of analysis of a water sample collected from *Alshonah Al-shamaliyah* hot spring.

Royal Scientific Society
Environmental Research Center

الجمعية العلمية الملكية
مركز بحوث البيئة

(442 / 09) تقرير فحص رقم

JAS
Jordanian Accreditation System
نظام الاعتماد الأردني

Test – 015

Division: Water Quality Studies Division **Lab.:Water Testing Laboratory**

Client Name : Mr. Raed Al-Ghzawi
Client Address : Amman
Date of Receiving : July, 2nd, 2009
No. of Samples : (1)
Your Ref. : ---------------
Date : -- / --- / ---

Sample Designation No. : 17/09/275
Worksheet and Cost & Date : 10467 dated 7 /7/2009
No. of Pages : (1)
Source of Samples : AL- Shunah al Shamaliyah
Our Ref. No. : (17) 330/55/1/ 17377
Date : 7 / 7 / 2009

Following are the results of analysis of a water sample collected and delivered by your representative on July, 2nd, 2009. Tests were carried out upon your request.

Parameter	Unit	Results	Test Method No. & Date*
NO_3	mg/L	<0.1	4110 – B
SO_4	mg/L	96.5	4110 – B
Cl	mg/L	141	4500 – Cl, D

* : Standard Methods for the Examination of Water and Wastewater, Online.

Notes: ------------

Royal Scientific Society
Environmental Research Centre

Head of Chemical Testing Unit : Eman Ta'an **Division Head: Dr.Nisreen Al- Hmoud**

Eman Nisreen Al-Hmoud

P.O. Box 1438, P.C., Amman – Jordan. Telephone (962 6) 5344701 Cable: ERRAMAH – AMMAN. Telex 21276 RAMAH JO. Fax 5340373

Form No. RSSPMP 1302 | REV. (1)

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ANNEX 3

Museums overview in chapter five

Research area in chapter five, museums overview

1. The Dar Alsaraya Museum

The Saraya Castle was built in 1886, as a residence for the Ottoman governor. Later it was used as a local prison for the Jordanian police until 1994. After that date the Saraya castle was taken over by the Jordanian Department of Antiquities to be restored and used as The Dar Alsaraya Museum.
The museum consists of two storeys. The ground floor represents the museum halls and the second floor the administration offices. The museum contains three major display hallsand four small halls. The objects in the museum are displayed in chronological order in each hall. The first hall, entitled “Irbid hall”, displays archaeological artefacts that has been excavated in Jordan and gives a historical introduction to Irbid City. It leads to the other halls of the museum. The other hall, named Ancient Period Hall, displays archaeological objects belonging to the period 1600-1200 BC. The last main hall, named the Metallurgy Room, displays in its showcases metallic objects belonging to the period 4500-2200 BC. The other halls display mosaics and Islamic pottery.

2. The Department of antiquities

A- Department of antiquities (Archive)

The Department of antiquities archive, located in the Third Circle area of Amman (the capital), this area is considered to be the middle of the old city centre of Amman. The archive is part of the main building of the DoA, which consists of three floors. It was built in two phases: the DoA's current building was built (the two lower floors) during the 1970s, the upper two floors in 1994.

B- Department of Antiquities (Storage)

The DoA's storage which was built in 1996, is located at the main highway between Amman and Zarqa (the second biggest city in Jordan), which means that this road is always congested with traffic. The storage consists of three separate halls; the first one is the main hall. In this hall mainly the findings from the archaeological excavations are kept. The second room is a small one, but it is part of the main hall; in this hall the more vulnerable objects are kept.
The third hall basically is a cave located near by the storage; this cave has never been renovated; a door was built and it was locked to be used as storage. The main storage hall is a building with metal wallsand it is not sealed against the outside atmosphere; it also has windows on the upper side of each wall.

3. The Karak Museum

The museum was established within the ancient Castle of Karak, which was built in the first decade BC. It was renovated and rehabilitated in 1142 and it was used for military purposes until 1921. In 1980 the museum was established as a Part of the castle. The museum underwent its first restoration and rehabilitation in 2001. The museum consists of two main halls, which were used in the middle ages (Mamlouk period) as a military repository. The museum also includes storage among its facilities, located on the basement floor. The museum collections vary in their date and shape, starting from stone tools from the Stone Age (8000-6000 BC) to the Late Islamic period. Most of these objects were collected in excavations in cooperation with the

Jordanian Department of Antiquities in the surrounding areas of Karak. In addition, the museum hosts Byzantine glassware and inscriptionsand a Roman collection.

4. Madaba archaeological museum

Building a museum requires an adequate budgetand prioritization within the governmental annual program, so when the Jordanian Department of Antiquities decided to establish a museum in the city of Madaba, the only choice was to do so in houses that already belonged to the Department. These adjoining houses with mosaic ground floors represented the core of the archaeological museum in the city, which was established in 1978.

Madaba museum consists of three separate rooms with a separate hall representing a separate museum called the Folk museum. The Madaba museum also has its own storage area. In the middle of these halls there is an open square which contains most of the mosaic objects, which have been brought from the surrounding archaeological sites. The museum also contains forms of columns, altars and different shapes of ionic column crowns, minutely engraved.

There is also a collection of Islamic pottery and bronze ware which have been found in an excavation at Umm Alwaleed palace (Umayyad palace). This collection was transferred to Geneva for conservation treatment; and afterward brought back to Madaba Archaeological Museum to be displayed. The museum also hosts a numismatics collection. Here we should mention that this museum also includes one of the biggest mosaics of the world in its collection.

5. The Museum of Jordanian Heritage and Numismatics Museum

The Museum of Jordanian Heritage, part of the Faculty of Archaeology and Anthropology at Yarmouk University, is a dynamic facility in a growing organization. The museum recounts the story of mankind from its earliest stages until today. The museum reflects the research and field projects conducted by the faculty, researchers and technicians of the faculty, whether independently or in cooperation with other local and foreign institutes. The museum was established in 1988 and it was opened to the public in the same year. It offers a wide range of activities for the community, students, scholars and visitors, including exhibitions, lectures and excursions. The museum used to have the Numismatics Hall as part of its facilities, but recently it reverted being an independent museum, named the Numismatics Museum. The main gallery of the Jordanian Heritage Museum consists of four Rooms. Room One, dealing with Jordan’s prehistory, features exhibits on “Hunters, Gatherers and Food-Collectors”, “Agricultural Evolution” and “Village Farming Communities”. Jordan’s early history, in Room Two, is depicted through exhibits on “City-states and Development”, “The development of Territorial States”and “Early Pastoralists and Bedouins”.

Room three is entitled “East and West” and puts special emphasis on the local population during the Roman and Byzantine periods. The main topics are “The Nabataeans”, “Ethnic and Cultural Plurality in Classical Jordan” and “From Decapolis to Jund al-Urdunn”. The exhibits in Room Four, dealing with “Jordan as Part of the Islamic World”, are arranged under the topics “Jordan under the Caliphate”, “Ayyubid /Mamluk and Ottoman Jordan”, “Land Tenure and Settlement in the Late Nineteenth Century” and “Jordan’s present and Future”. The “Shop of an attar - the traditional Druggist”and reconstructions of "the Workshops of a Potter”, the “Forge of a

Blacksmith", a "Woodcarver" and a "Treadleloom-Weaver" lead the visitor into the courtyard.
The courtyard features a rural house-complex from north Jordan, displaying basic local architectural elements, such as cross-vaulted rooms, transversal arches and an arched façade. The visitor enters completely furnished living and guest rooms, a stable and a bread oven room.
A staircase leads to the second floor, giving access to the mezzanine floor. Here special topics relating to the history of technology are displayed. These include "Stone-Implements and Rock-Art", "Metallurgy", "Basketry"and other textile techniques", "Pottery and Pottery-making in Jordan" and "Glass". In addition there are displays on numismatics, epigraphy and "Seals and Amules".
Near the entrance to the museum, a special hall accommodates temporary exhibitions. The Numismatics Museum consists mainly of one room. This hall displays a specialized exhibition of numismatics based on historical sequences: The Lydian, Hellenistic, Nabataean, Roman, Byzantine, Umayyad, Abbasid, Ayyubid, Mamluk, Ottoman and Hashemite periods. The display contains a reconstruction of a minting place, melting furnace and striking tools that were used during the Islamic periods.

6. The Petra Museum

Petra is one of the Seven Wonders of the World and one of the UNESCO world heritage preserved sites. Petra museum is located in the middle of the city, approximately 1500m from the Siq entrance of Petra. It was established in 1994, consists of two main halls and an entrance hall.
The entrance hall presents an introduction to the Nabataean kingdom and the geological facts about Petra. The second hall represents the excavated objects in Petra, displayed in chronological order. It also deals with the historical earthquakes that occurred in Petra. The third hall contains a pottery collection, bronze statues, ceramic wares, jewellery and a numismatics collection.

7. The Salt Museum

The Salt Museum which was established in 1986 is located in the middle of the new city centre of Salt, which experiences constant daily traffic jams. The museum consists of two storeys, each with two main halls. The main hall of the first floor contains a pottery collection, excavated in Tlelat Alghasool and belonging to the period 4500-3300 BC. The other hall on the same floor hosts a collection of Bronze Age (3300-2200 BC) pottery wares used for storing water and lanterns. Most of these objects were excavated in Alsalalem area. This hall also includes pottery objects belonging to the period 2200-539 BC, excavated in Tell Der Alla. The second floor consists of two main halls. The first one displays Byzantine period (324-636) objects in its showcases. These objects include pottery, copper objects, bronze bracelets and a collection of numismatics. The second hall in the same storey, which is the smallest in the museum, contains a glass collection excavated in Balqa'a governorate and a mosaic brought to the museum from Southern Shouna.

8. The Umm Qeis museum

The Department of Antiquities in Jordan renovated one of the houses at the Umm Qies archaeological site in 1987 and it has been used as a museum since then. The museum consists of two separate halls, the first of which has three showcases. One, displaying the pottery collection, belongs to the Hellenistic period – Islamic period. The other showcase displays what has been excavated at the site of Umm Qeis. The last showcase in that room displays stone and flint tools. The second hall is assigned to display statues and stone sculptures, which belong to the Roman - Byzantine period. The museum has its own courtyard, in which are basalt sarcophagi and tombstones, plus mosaics. The city of Umm Qeis has a unique geographical setting which explains its importance during the historical periods, when it became famous as a member of the Decapolis league. These cities were located along major trade routes and within a rich agricultural belt. Transit trade and industry provided the city's wealth until the crisis of the third century.

Despite most of the old city of Umm Qeis being occupied by the local citizens, the Jordanian Department of Antiquities managed to possess the entire archaeological site of Umm Qeis. From that day onward there has been a continuous process of conservation and restoration work on the entire site, as well as an annual excavation. Objects yielded from these excavations become the property of the Umm Qeis museum.

ANNEX 4

ICOM Code of Ethics for Museums

(International Council of Museums (ICOM), Code of Professional Ethics in 1986:
"http://icom.museum/fileadmin/user_upload/pdf/Codes/code2006_eng.pdf")

The status of the ICOM Code of Ethics for Museums

The ICOM Code of Ethics for Museums has been prepared by the International Council of Museums. It is the statement of ethics for museums referred to in the ICOM Statutes. The Code reflects principles generally accepted by the international museum community. Membership in ICOM and the payment of the annual subscription to ICOM are an affirmation of the ICOM Code of Ethics for Museums.

A Minimum Standard for Museums

The ICOM Code represents a minimum standard for museums. It is presented as a series of principles supported by guidelines for desirable professional practice. In some countries, certain minimum standards are defined by law or government regulation. In others, guidance on and assessment of minimum professional standards may be available in the form of 'Accreditation', 'Registration', or similar evaluative schemes. Where such standards are not defined, guidance can be obtained through the ICOM Secretariat, a relevant National Committee of ICOM, or the appropriate International Committee of ICOM. It is also intended that individual nations and the specialized subject organizations connected with museums should use this Code as a basis for developing additional standards.

Translations of the ICOM Code of Ethics for Museums

The ICOM Code of Ethics for Museums is published in the three official languages of the organization: English, French and Spanish. ICOM welcomes the translation of the Code into other languages. However, a translation will be regarded as "official" only if it is endorsed by at least one National Committee of a country in which the language is spoken, normally as the first language. Where the language is spoken in more than one country, it is preferable that the National Committees of these countries also be consulted. Attention is drawn to the need for linguistic as well as professional museum expertise in providing official translations. The language version used for a translation and the names of the National Committees involved should be indicated. These conditions do not restrict translations of the Code, or parts of it, for use in educational work or for study purposes. .

1. Museums preserve, interpret and promote the natural and cultural inheritance of humanity.

Principle: Museums are responsible for the tangible and intangible natural and cultural heritage. Governing bodies and those concerned with the strategic direction and oversight of museums have a primary responsibility to protect and promote this heritage as well as the human, physical and financial resources made available for that purpose.

Institutional standing

1.1 Enabling documentation
The governing body should ensure that the museum has a written and published constitution, statute or other public document, in accordance with national laws which clearly states the museum's legal status, mission, permanence and non-profit nature.

1.2 Statement of the Mission, Objectives and Policies
The governing body should prepare, publicize and be guided by a statement of the mission, objectives and policies of the museum and of the role and composition of the governing body.

Physical resources

1.3 Premises
The governing body should ensure adequate premises with a suitable environment for the museum to fulfill the basic functions defined in its mission.

1.4 Access
The governing body should ensure that the museum and its collections are available to all during reasonable hours and for regular periods. Particular regard should be given to those persons with special needs.

1.5 Health and Safety
The governing body should ensure that institutional standards of health, safety and accessibility apply to its personnel and visitors.

1.6 Protection Against Disasters
The governing body should develop and maintain policies to protect the public and personnel, the collections and other resources, against natural and human-made disasters.

1.7 Security Requirements
The governing body should ensure appropriate security to protect collections against theft or damage in displays, exhibitions, working or storage areas and while in transit.

1.8 Insurance and Indemnity
Where commercial insurance is used for collections, the governing body should ensure that such cover is adequate and includes objects in transit or on loan and other items that are the responsibility of the museum. When an indemnity scheme is in use, it is necessary that material not in the ownership of the museum is adequately covered.

Financial resources

1.9 Funding
The governing body should ensure that there are sufficient funds to carry out and develop the activities of the museum. All funds must be accounted for in a professional manner.

1.10 Income-generating Policy
The governing body should have a written policy regarding sources of income that it may generate through its activities or accept from outside sources. Regardless of funding source, museums should maintain control of the content and integrity of their programmes, exhibitions and activities. Income-generating activities should not compromise the standards of the institution or its public (See 6.6).

Personnel

1.11 Employment Policy
The governing body should ensure that all action concerning personnel is taken in accordance with the policies of the museum as well as the proper and legal procedures.

1.12 Appointment of the Director or Head
The director or head of the museum is a key post and when making an appointment, governing bodies should have regard for the knowledge and skills required to fill the post effectively. These qualities should include adequate intellectual ability and professional knowledge, complemented by a high standard of ethical conduct.

1.13 Access to Governing Bodies
The director or head of a museum should be directly responsible and have direct access, to the relevant governing bodies.

1.14 Competence of Museum Personnel
The employment of qualified personnel with the expertise required to meet all responsibilities is necessary. (See also 2.18; 2.24).

1.15 Training of Personnel
Adequate opportunities for the continuing education and professional development of all museum personnel should be arranged to maintain an effective workforce.

1.16 Ethical Conflict
The governing body should never require museum personnel to act in a way that could be considered to conflict with the provisions of this Code of Ethics, or any national law or specialist code of ethics.

1.17 Museum Personnel and Volunteers
The governing body should have a written policy on volunteer work which promotes a positive relationship between volunteers and members of the museum profession.

1.18 Volunteers and Ethics
The governing body should ensure that volunteers, when conducting museum and personal activities, are fully conversant with the ICOM Code of Ethics for Museums and other applicable codes and laws.

2. Museums that maintain collections hold them in trust for the benefit of society and its development.

Principle: Museums have the duty to acquire, preserve and promote their collections as a contribution to safeguarding the natural, cultural and scientific heritage. Their collections are a significant public inheritance, have a special position in law and are protected by international legislation. Inherent in this public trust is the notion of stewardship that includes rightful ownership, permanence, documentation, accessibility and responsible disposal.

Acquiring collections

2.1 Collections Policy

The governing body for each museum should adopt and publish a written collections policy that addresses the acquisition, care and use of collections. The policy should clarify the position of any material that will not be catalogued, conserved, or exhibited (See 2.7; 2.8).

2.2 Valid Title

No object or specimen should be acquired by purchase, gift, loan, bequest, or exchange unless the acquiring museum is satisfied that a valid title is held. Evidence of lawful ownership in a country is not necessarily valid title.

2.3 Provenance and Due Diligence

Every effort must be made before acquisition to ensure that any object or specimen offered for purchase, gift, loan, bequest, or exchange has not been illegally obtained in or exported from, its country of origin or any intermediate country in which it might have been owned legally (including the museum's own country). Due diligence in this regard should establish the full history of the item from discovery or production.

2.4 Objects and Specimens from Unauthorized or Unscientific Fieldwork

Museums should not acquire objects where there is reasonable cause to believe their recovery involved the unauthorized, unscientific, or intentional destruction or damage of monuments, archaeological or geological sites, or species and natural habitats. In the same way, acquisition should not occur if there has been a failure to disclose the finds to the owner or occupier of the land, or to the proper legal or governmental authorities.

2.5 Culturally Sensitive Material

Collections of human remains and material of sacred significance should be acquired only if they can be housed securely and cared for respectfully. This must be accomplished in a manner consistent with professional standards and the interests and beliefs of members of the community, ethnic or religious groups from which the objects originated, where these are known (See also 3.7; 4.3).

2.6 Protected Biological or Geological Specimens

Museums should not acquire biological or geological specimens that have been collected, sold, or otherwise transferred in contravention of local, national, regional or international law or treaty relating to wildlife protection or natural history conservation.

2.7 Living Collections

When the collections include live botanical and zoological specimens, special considerations should be made for the natural and social environment from which they are derived as well as any local, national, regional or international law, or treaty relating to wildlife protection or natural history conservation.

2.8 Working Collections

The collections policy may include special considerations for certain types of working collection where the emphasis is on preserving cultural, scientific or technical process rather than the object, or where objects or specimens are assembled for regular handling and teaching purposes (See also 2.1).

2.9 Acquisition Outside Collections Policy
The acquisition of objects or specimens outside the museum's stated policy should only be made in exceptional circumstances. The governing body should consider the professional opinions available to them and the views of all interested parties. Consideration will include the significance of the object or specimen including its context in the cultural or natural heritage and the special interests of other museums collecting such material. However, even in these circumstances, objects without a valid title should not be acquired (See also 3.4).

2.10 Acquisition by Members of the Governing Body and Museum Personnel
Special care is required in considering any item, either for sale, as a donation or as a tax-benefit gift, from members of governing bodies, museum personnel, or the families and close associates of these persons.

2.11 Repositories of Last Resort
Nothing in this Code of Ethics should prevent a museum from acting as an authorized repository for unprovenanced, illicitly collected or recovered specimens and objects from the territory over which it has lawful responsibility.

Removing collections

2.12 Legal or Other Powers of Disposal
Where the museum has legal powers permitting disposals, or has acquired objects subject to conditions of disposal, the legal or other requirements and procedures must be complied with fully. Where the original acquisition was subject to mandatory or other restrictions these conditions must be observed, unless it can be shown clearly that adherence to such restrictions is impossible or substantially detrimental to the institution and, if appropriate, relief may be sought through legal procedures.

2.13 Deaccessioning from Museum Collections
The removal of an object or specimen from a museum collection must only be undertaken with a full understanding of the significance of the item, its character (whether renewable or non-renewable), legal standing and any loss of public trust that might result from such action.

2.14 Responsibility for Deaccessioning
The decision to deaccession should be the responsibility of the governing body acting in conjunction with the director of the museum and the curator of the collection concerned. Special arrangements may apply to working collections (See 2.7; 2.8).

2.15 Disposal of Objects Removed from the Collections
Each museum should have a policy defining authorised methods for permanently removing an object from the collections through donation, transfer, exchange, sale, repatriation, or destruction and that allows the transfer of unrestricted title to the receiving agency. Complete records must be kept of all deaccessioning decisions, the objects involved and the disposition of the object. There will be a strong presumption that a deaccessioned item should first be offered to another museum.

2.16 Income from Disposal of Collections

Museum collections are held in public trust and may not be treated as a realizable asset. Money or compensation received from the deaccessioning and disposal of objects and specimens from a museum collection should be used solely for the benefit of the collection and usually for acquisitions to that same collection. .

2.17 Purchase of Deaccessioned Collections
Museum personnel, the governing body, or their families or close associates, should not be permitted to purchase objects that have been deaccessioned from a collection for which they are responsible.

Care of collection

2.18 Collection Continuity
The museum should establish and apply policies to ensure that its collections (both permanent and temporary) and associated information, properly recorded, are available for current use and will be passed on to future generations in as good and safe a condition as practicable, having regard to current knowledge and resources.

2.19 Delegation of Collection Responsibility
Professional responsibilities involving the care of the collections should be assigned to persons with appropriate knowledge and skill or who are adequately supervised. (See also 8.11).

2.20 Documentation of Collections
Museum collections should be documented according to accepted professional standards. Such documentation should include a full identification and description of each item, its associations, provenance, condition, treatment and present location. Such data should be kept in a secure environment and be supported by retrieval systems providing access to the information by the museum personnel and other legitimate users.

2.21 Protection Against Disasters
Careful attention should be given to the development of policies to protect the collections during armed conflict and other human-made or natural disasters.

2.22 Security of Collection and Associated Data
The museum should exercise control to avoid disclosing sensitive personal or related information and other confidential matters when collection data is made available to the public.

2.23 Preventive Conservation
Preventive conservation is an important element of museum policy and collections care. It is an essential responsibility of members of the museum profession to create and maintain a protective environment for the collections in their care, whether in store, on display, or in transit.

2.24 Collection Conservation and Restoration
The museum should carefully monitor the condition of collections to determine when an object or specimen may require conservation-restoration work and the services of a qualified conservator-restorer. The principal goal should be the stabilization of the

object or specimen. All conservation procedures should be documented and as reversible as possible and all alterations should be clearly distinguishable from the original object or specimen.

2.25 Welfare of Live Animals

A museum that maintains living animals should assume full responsibility for their health and well-being. It should prepare and implement a safety code for the protection of its personnel and visitors, as well as of the animals, that has been approved by an expert in the veterinary field. Genetic modification should be clearly identifiable.

2.26 Personal Use of Museum Collections

Museum personnel, the governing body, their families, close associates, or others should not be permitted to expropriate items from the museum collections, even temporarily, for any personal use.

3. Museums hold primary evidence for establishing and furthering knowledge

Principle: Museums have particular responsibilities to all for the care, accessibility and interpretation of primary evidence collected and held in their collections.

Primary evidence

3.1 Collections as Primary Evidence.

The museum collections policy should indicate clearly the significance of collections as primary evidence. The policy should not be governed only by current intellectual trends or present museum usage.

3.2 Availability of Collections

Museums have a particular responsibility for making collections and all relevant information available as freely as possible, having regard to restraints arising for reasons of confidentiality and security.

Museum collecting and research

3.3 Field Collecting

Museums undertaking field collecting should develop policies consistent with academic standards and applicable national and international laws and treaty obligations. Fieldwork should only be undertaken with respect and consideration for the views of local communities, their environmental resources and cultural practices as well as efforts to enhance the cultural and natural heritage.

3.4 Exceptional Collecting of Primary Evidence

In exceptional cases an item without provenance may have such an inherently outstanding contribution to knowledge that it would be in the public interest to preserve it. The acceptance of such an item into a museum collection should be the subject of a decision by specialists in the discipline concerned and without national or international prejudice (See also 2.11).

3.5 Research

Research by museum personnel should relate to the museum’s mission and objectives and conform to established legal, ethical and academic practices.

3.6 Destructive Analysis
When destructive analytical techniques are undertaken, a complete record of the material analyzed, the outcome of the analysis and the resulting research, including publications, should become a part of the permanent record of the object.

3.7 Human Remains and Material of Sacred Significance
Research on human remains and materials of sacred significance must be accomplished in a manner consistent with professional standards and take into account the interests and beliefs of the community, ethnic or religious groups from whom the objects originated, where these are known (See also 2.5; 4.3).

3.8 Retention of Rights to Research Materials
When museum personnel prepare material for presentation or to document field investigation, there must be clear agreement with the sponsoring museum regarding all rights to such work.

3.9 Shared Expertise
Members of the museum profession have an obligation to share their knowledge and experience with colleagues, scholars and students in relevant fields. They should respect and acknowledge those from whom they have learned and should pass on such advancements in techniques and experience that may be of benefit to others.

3.10 Co-operation Between Museums & Other Institutions
Museum personnel should acknowledge and endorse the need for co-operation and consultation between institutions with similar interests and collecting practices. This is particularly so with institutes of higher education and certain public utilities where research may generate important collections for which there is no long-term security.

4. Museums provide opportunities for the appreciation, understanding and promotion of the natural and cultural heritage

Principle: Museums have an important duty to develop their educational role and attract wider audiences from the community, locality, or group they serve. Interaction with the constituent community and promotion of their heritage is an integral part of the educational role of the museum.

Display and exhibition

4.1 Displays, Exhibitions and Special Activities
Displays and temporary exhibitions, physical or electronic, should be in accordance with the stated mission, policy and purpose of the museum. They should not compromise either the quality or the proper care and conservation of the collections.

4.2 Interpretation of Exhibits
Museums should ensure that the information they present in displays and exhibitions is well-founded, accurate and gives appropriate consideration to represented groups or beliefs.

4.3 Exhibition of Sensitive Materials
Human remains and materials of sacred significance must be displayed in a manner consistent with professional standards and, where known, taking into account the interests and beliefs of members of the community, ethnic or religious groups from whom the objects originated. They must be presented with great tact and respect for the feelings of human dignity held by all peoples.

4.4 Removal from Public Display
Requests for removal from public display of human remains or material of sacred significance from the originating communities must be addressed expeditiously with respect and sensitivity. Requests for the return of such material should be addressed similarly. Museum policies should clearly define the process for responding to such requests.

4.5 Display of Unprovenanced Material
Museums should avoid displaying or otherwise using material of questionable origin or lacking provenance. They should be aware that such displays or usage can be seen to condone and contribute to the illicit trade in cultural property.

Other resources

4.6 Publication
Information published by museums, by whatever means, should be well-founded, accurate and give responsible consideration to the academic disciplines, societies, or beliefs presented. Museum publications should not compromise the standards of the institution.

4.7 Reproductions
Museums should respect the integrity of the original when replicas, reproductions, or copies of items in the collection are made. All such copies should be permanently marked as facsimiles.

5. Museums hold resources that provide opportunities for other public services and benefits.

Principle: Principle Museums utilize a wide variety of specialisms, skills and physical resources that have a far broader application than in the museum. This may lead to shared resources or the provision of services as an extension of the museum's activities. These should be organized in such a way that they do not compromise the museum's stated mission.

Identification services

5.1 Identification of Illegally or Illicitly Acquired Objects
Where museums provide an identification service, they should not act in any way that could be regarded as benefiting from such activity, directly or indirectly. The identification and authentication of objects that are believed or suspected to have been illegally or illicitly acquired, transferred, imported or exported, should not be made public until the appropriate authorities have been notified. .

5.2 Authentication and Valuation (Appraisal)
Valuations may be made for the purposes of insurance of museum collections. Opinions on the monetary value of other objects should only be given on official request from other museums or competent legal, governmental or other responsible public authorities. However, when the museum itself may be the beneficiary, appraisal of an object or specimen must be undertaken independently.

6. Museums work in close collaboration with the communities from which their collections originate as well as those they serve

Principle: Museum collections reflect the cultural and natural heritage of the communities from which they have been derived. As such they have a character beyond that of ordinary property which may include strong affinities with national, regional, local, ethnic, religious or political identity. It is important therefore that museum policy is responsive to this possibility.

Origin of collections

6.1 Co-operation
Museums should promote the sharing of knowledge, documentation and collections with museums and cultural organisations in the countries and communities of origin. The possibility of developing partnerships with museums in countries or areas that have lost a significant part of their heritage should be explored.

6.2 Return of Cultural Property
Museums should be prepared to initiate dialogues for the return of cultural property to a country or people of origin. This should be undertaken in an impartial manner, based on scientific, professional and humanitarian principles as well as applicable local, national and international legislation, in preference to action at a governmental or political level.

6.3 Restitution of Cultural Property
When a country or people of origin seeks the restitution of an object or specimen that can be demonstrated to have been exported or otherwise transferred in violation of the principles of international and national conventions and shown to be part of that country's or people's cultural or natural heritage, the museum concerned should, if legally free to do so, take prompt and responsible steps to co-operate in its return.

6.4 Cultural Objects From an Occupied Country
Museums should abstain from purchasing or acquiring cultural objects from an occupied territory and respect fully all laws and conventions that regulate the import, export and transfer of cultural or natural materials.

Respect for communities served

6.5 Contemporary Communities
Where museum activities involve a contemporary community or its heritage, acquisitions should only be made based on informed and mutual consent without exploitation of the owner or informants. Respect for the wishes of the community involved should be paramount.

6.6 Funding of Community Facilities
When seeking funds for activities involving contemporary communities, their interests should not be compromised. (See 1.10).

6.7 Use of Collections from Contemporary Communities
Museum usage of collections from contemporary communities requires respect for human dignity and the traditions and cultures that use such material. Such collections should be used to promote human well-being, social development, tolerance and respect by advocating multisocial, multicultural and multilingual expression.
(See 4.3).

6.8 Supporting Organizations in the Community
Museums should create a favorable environment for community support (e.g., Friends of Museums and other supporting organizations), recognize their contribution and promote a harmonious relationship between the community and museum personnel.

7. Museums operate in a legal manner

Principle: Museums must conform fully to international, regional, national, or local legislation and treaty obligations. In addition, the governing body should comply with any legally binding trusts or conditions relating to any aspect of the museum, its collections and operations.

Legal framework

7.1 National and Local Legislation.
Museums should conform to all national and local laws and respect the legislation of other states as they affect their operation.

8. Museums operate in a professional manner

Principle: Members of the museum profession should observe accepted standards and laws and uphold the dignity and honor of their profession. They should safeguard the public against illegal or unethical professional conduct. Every opportunity should be used to inform and educate the public about the aims, purposes and aspirations of the profession to develop a better public understanding of the contributions of museums to society.

Profesional conduct

8.1 Familiarity with Relevant Legislation
Every member of the museum profession should be conversant with relevant international, national and local legislation and the conditions of their employment. They should avoid situations that could be construed as improper conduct.

8.2 Professional Responsibility
Members of the museum profession have an obligation to follow the policies and procedures of their employing institution. However, they may properly object to practices that are perceived to be damaging to a museum or the profession and matters of professional ethics.

8.3 Professional Conduct

Loyalty to colleagues and to the employing museum is an important professional responsibility and must be based on allegiance to fundamental ethical principles applicable to the profession as a whole. They should comply with the terms of the ICOM Code of Ethics and be aware of any other codes or policies relevant to museum work.

8.4 Academic and Scientific Responsibilities

Members of the museum profession should promote the investigation, preservation and use of information inherent in the collections. They should, therefore, refrain from any activity or circumstance that might result in the loss of such academic and scientific data.

8.5 The Illicit Market

Members of the museum profession should not support the illicit traffic or market in natural and cultural property, directly or indirectly.

8.6 Confidentiality

Members of the museum profession must protect confidential information obtained during their work. In addition, information about items brought to the museum for identification is confidential and should not be published or passed to any other institution or person without specific authorization from the owner.

8.7 Museum and Collection Security

Information about the security of the museum or of private collections and locations visited during official duties must be held in strict confidence by museum personnel.

8.8 Exception to the Obligation for Confidentiality

Confidentiality is subject to a legal obligation to assist the police or other proper authorities in investigating possible stolen, illicitly acquired, or illegally transferred property.

8.9 Personal Independence

While members of a profession are entitled to a measure of personal independence, they must realize that no private business or professional interest can be wholly separated from their employing institution.

8.10 Professional Relationships

Members of the museums profession form working relationships with numerous other persons within and outside the museum in which they are employed. They are expected to render their professional services to others efficiently and to a high standard.

8.11 Professional Consultation

It is a professional responsibility to consult other colleagues within or outside the museum when the expertise available is insufficient in the museum to ensure good decision-making.

Table A4.1 Glossary (http://icom.museum/code2006_eng.pdf)

Appraisal	The authentication and valuation of an object or specimen. In certain countries the term is used for an independent assessment of a proposed gift for tax benefit purposes.
Conflict of interest	The existence of a personal or private interest that gives rise to a clash of principle in a work situation, thus restricting, or having the appearance of restricting, the objectivity of decision making.
Conservator-Restorer	Museum or independent personnel competent to undertake the technical examination, preservation, conservation and restoration of cultural property. (For further information, see ICOM News, vol. 39, n°1 (1986), pp. 5 6.)
Cultural Heritage	Any thing or concept considered of aesthetic, historical, scientific or spiritual significance.
Dealing	Buying and selling items for personal or institutional gain.
Due diligence	The requirement that every endeavor is made to establish the facts of a case before deciding a course of action, particularly in identifying the source and history of an item offered for acquisition or use before acquiring it.
Governing Body	The persons or organizations defined in the enabling legislation of the museum as responsible for its continuance, strategic development and funding.
Income-generating activities	Activities intended to bring financial gain or profit for the benefit of the institution.
Legal title	Legal right to ownership of property in the country concerned. In certain countries this may be a conferred right and insufficient to meet the requirements of a due diligence search.
Minimum Standard	A standard to which it is reasonable to expect all museums and museum personnel to aspire. Certain countries have their own statements of minimum standards.
Museum [1]	A museum is a non-profit making permanent institution in the service of society and of its development, open to the public, which acquires, conserves, researches, communicates and exhibits, for purposes of study, education and enjoyment, the tangible and intangible evidence of people and their environment.
Museum professional	Museum professionals consist of the personnel (whether paid or unpaid) of museums or institutions as defined in Article 2, paras. 1 and 2, of the Statutes, who have received specialized training, or possess an equivalent practical experience in any field relevant to the management and operations of a museum and independent persons respecting the ICOM Code of Ethics for Museums and working for museums or

	institutions as defined in the Statute quoted above, but not persons promoting or dealing with commercial products and equipment required for museums and museum services.
Natural Heritage	Any natural thing, phenomenon or concept, considered to be of scientific significance or to be a spiritual manifestation.
Non-profit organization	A legally established body- corporate or unincorporated- whose income (including any surplus or profit) is used solely for the benefit of that body and its operation. The term "not-for-profit" has the same meaning.
Provenance	The full history and ownership of an item from the time of its discovery or creation to the present day, from which authenticity and ownership is determined.
Valid title	Indisputable right to ownership of property, supported by full provenance of the item from discovery or production.

Ethics of Acquisition

ICOM has always given a special attention to the ethical dimension of the museum profession.

The ethical aspect was at first primarily linked to the museum acquisitions and international circulation of cultural property.

This "Ethics of Acquisitions" Statement (1970) was one of the first ICOM documents drawn to prepare a comprehensive “Code of professional Ethics”. The Code was adopted by the 1986 General Assembly in Buenos Aires (Argentina) and revised in 2001 and in 2004 by the General Assemblies in Barcelona (Spain) and in Seoul (Rep. of Korea).

Ethics of Acquisition (1970)

- The first agreement form
- ICOM recommendations
- Some museum policy example
- National policy example
- List of experts participants

In April 1970 a group of ICOM experts met in Paris to study the problem of ethical rules governing museum acquisitions. The result of this meeting was the adoption by ICOM of the resolutions which are reprinted below, based on the following fundamental principles:

"Whatever the subject matter or discipline of the museum and wherever it may be situated in the world, certain principles of ethics and professional integrity in relation to acquisition can be presumed to be applicable. Briefly, this means there must be a full, clear and satisfactory documentation in relation to the origin of any object to be acquired. This is quite as important for an object generally classified in the category of art as for an object of archaeology, of ethnology, or of national and natural history."

Since that time the ICOM Secretariat has been at work implementing the recommendations made to ICOM by the committee. This document precedes and announces the publication later this year of a summary of the laws of each country governing field research and exportation of cultural property. The publication will follow the format of the example of Afghanistan found below.

It is now time to invite the museum profession at large to examine the recommendations of ICOM, in view of adopting them as a framework for their own statutes governing acquisitions. The adoption of these resolutions by a museum will become effective upon the return of the attached form to the ICOM Secretariat. Since the resolutions of ICOM cannot be taken as a final code, applicable to all museums, we are also publishing here the summarized policies of museums which have recently taken an initiative in establishing individual ethical policies. These examples are given to provide guidelines for the museums pledging adherence to the ICOM resolutions in working out their own policies.

A first list of all museums which have agreed to follow these ethical rules will be published with the publication of the laws governing antiquities. It is hoped that the greatest possible number of museums will join the ten original experts of the 1970 meeting in adhering to the policies set down here, thus providing a basis for professional cooperation in this important matter.

As a first step in establishing a professional ethical code regarding acquisition, the staff of the .... museum accepts the ICOM recommendations as a minimum standard for the collection of objects, thereby agreeing to assist other countries in safeguarding and enriching their cultural heritage and to give preferential treatment in all professional activities to other museums adhering to the code.

Date: Signature of responsible officer:

Signing of the agreement is valid upon receipt of this form along with a description of the museum's programme and acquisition policy and a description of acquisitions and services requested by the museum to ICOM Secretariat, Unesco House, 1 rue Miollis, Paris 15e.

ICOM recommendations (Ethics of Acquisitions, 1970)

1. The museum of today is not a mere repository of objects: it is concerned with the acquisition of the objects as an integral part of a specific programme of:
    a. scientific research,
    b. education,
    c. conservation,
    d. the demonstration of National and International, Natural and Cultural Heritage.
2. Some museums may encompass all aspects of this far-reaching programme, whilst others may specialize in certain parts of it. Consequently no object should be acquired which has no part to play in the aims of the museum as demonstrated by its programme.
3. The object being considered for acquisition may come from anywhere within a wide spectrum of definitions, the two extremes of which may be briefly summarized as being:
    a. objects recognised by scholarship and/or the community where they have their full cultural significance as having a unique quality and are therefore beyond value;
    b. objects which, though not necessarily rare in themselves, nevertheless have a value which derives from their cultural and natural environment.
4. The significance of the object (cultural and scientific) will depend upon its being fully documented. As a matter of principle no acquisition should be made without this full documentation, with the possible exception of certain objects which come near to that end of the spectrum characterized by definition (a), paragraph 3, when the essential documentation relative to the latter may be obtained by systematic research after acquisition.
5. In most fields, direct acquisitions are best obtained by scientifically conducted research missions. They may occur in the mission' s own country or abroad. In the latter case they must be conducted with the agreement or the cooperation and according to the laws of the host country.
6. Direct acquisitions can also be made through cooperation with a museum or with an institution responsible for the safeguard of the national cultural heritage, in the country possessing the required object. These same principles may also be profitably applied "mutatis mutandis" to objects, which come near to that end of the spectrum characterized by definition (a), paragraph 3.

7. The object acquired by direct means is as well documented as possible; this is not always the case with indirect acquisitions. Whereas direct acquisitions conducted as described in paragraphs 5 and 6, will always conform to ethical standards, this may not always be the case with the indirect system.
8. The indirect acquisition, which includes the gift and bequest, is that which has been acquired through one, or more intermediaries. When a museum feels obliged to acquire an object indirectly, this should always be done in observance of the laws and interests of the country from which it is obtained, or the country of origin when the country from which it is obtained is only a place of commercial transit.
9. The responsibility of the museum professional in those museums which have as their primary function the preservation of the national heritage is threefold:
    a. to acquire and preserve for the country concerned a comprehensive collection illustrating all aspects of the nation's cultural and natural heritage;
    b. to control the international movement of objects belonging to this heritage;
    c. to cooperate with foreign museums and other scientific institutions to ensure adequate representation of that culture on an international scale.
10. It is imperative that if the museum is to fulfil completely its roles in education and intemational understanding, its professional staff must observe the highest ethical standards not only in the very important process of acquisition but also in the other fields of their professional activity.

Suggestions for the Implementation of the Recommendations

11. Museum programmes should be published. This will encourage exchange and outside help.
12. The acquisition of objects by any museum should not be limited to what is necessary for the exhibition halls, but sufficient objects should be collected for study and conservation purposes, for exchange with and for supply to local museums and for international exchange. However, objects should never be accumulated solely for their commercial value.
13. Material for exchange should encompass objects of sufficiently high standard to attract objects of similar standard from other museums. Exchange should mean not merely object against object but also object against services and equipment.
14. Documentation acquired by a scientific expedition should be made available to the country in which the expedition was carried out, after a certain agreed period of time, during which the scientific rights are reserved to the discoverer. The same documentation should be made available under the same conditions to the museum in the country, which organised the expedition.
15. With due regard to legal requirements and UNESCO recommendations and conventions relative to sharing the products of field research, every endeavour should be made to respect the ecological association of a group of objects. Certain objects and collections are sometimes lent to a foreign museum or scientific institution for study purposes. On such occasion they should be returned to the institution to which they belong in the shortest time possible.
16. With due regard to legal requirements and UNESCO recommendations and conventions, the museum which has reason to doubt the licit quality of a previously acquired object should contact the museum or other professional

organisation in the country of origin with a view to examining, in each particular case, the steps which should be taken to best preserve the interests of both parties.

17. If a museum is offered objects, the licit quality of which it has reason to doubt, it will contact the competent authorities of the country of origin in an effort to help this country safeguard its national heritage.
18. Gifts and bequests should only be accepted with a proviso that in the event of any object proving to have been illicitly exported from another country the authorities of the museum should be empowered to take action as above.
19. Museums of those countries, which, by virtue of political or economic circumstances hold an important part of the cultural property of countries, which were not in a position to safeguard their cultural heritage adequately, should remind their authorities and collectors that they have a moral duty to assist in the future development of museums in these countries.
20. The museums of any country, which bind themselves to follow the ethical rules and the practical proposals formulated in Paragraphs 1 to 19 of this document, will agree to offer each other preferential treatment in all professional activities, compatible with the existing laws.

SUMMARY

By the turn of century, increasing interest in archaeology in Jordan had resulted in more excavations and explorations of archaeological sites, and an increase in the number of monuments and antiquities being revealed. In response, it was necessary and urgent to establish museums in which to display such remains, aesthetically and historically and to ensure their protection. This was achieved over a fairly short period of time, and museums have the role of displaying and safeguarding the collection in its custody. However, a preliminary check gave the impression that most museums in Jordan do not have the necessary human and material resources to perform this function satisfactorily.
In recent years, museum science experienced a strong advancement, in particular when dealing with issues of indoor environment, and models of requirements have been designed. This thesis aims to describe, analyse and discuss the current situation of a number of selected museums in Jordan, with a focus on aspects of indoor environment. It intends to be an inclusive study that would provide recommendations and suggestions, hopefully enabling official senior level museum staff to address these needs, and work to improve them in order to portray a good image of Jordan and its historical legacy.
It has been noticed that, at present, some artefacts are suffering deterioration and damage due to uncontrolled environmental conditions and mishandling by untrained staff; if this situation is not addressed promptly it may well lead to the destruction of these valuable and vulnerable objects. For this reason, a study of the processes of deterioration is required, prior to any recommendations concerning conservation treatments. In fact, excavated archaeological objects can be conserved and stabilized by a combination of instruments, whether these objects are on display or kept in storage. Therefore the indoor museum environment should be controlled and the staff properly trained to deal with objects adequately. These are basic necessities to ensure that museums and staff are able to fulfil the role of a modern museum, i.e. to be a sustainable social and educational resource.

Chapter 1 is a general introduction for the whole thesis. It introduces the concept of museum, its history and current use, as well as the types of museums. In the second part the chapter turns to Jordan, where the strong climatic variation throughout the country provides a complex outdoor environment for the museums. Furthermore, a concise overview is given concerning the regulations for the discovery and loan of museum objects in Jordan.
Chapter 2 presents a theoretical introduction to the indoor environment in museums in general. Also it gives a background and offers a review of most of the recently published articles. This literature review chapter maps out the different approaches to understanding how museum environments as a discipline have been studied. The literature discussed is also reviewed in order to examine the types of subjects in the field of museum environment that specialists have researched, and which areas have been rather neglected.
In addition, the close relation of museums to the context of museum environment, and the many situations that show the necessity of an adequate museum environment are widely discussed in this chapter.
Chapter 3 intends to evaluate “visually and theoretically” the current situation at Jordanian museums from different aspects. Ten museums namely: Aqaba Archaeology Museum; Irbid Archaeology Museum; Jarash Archaeology Museum; Jordan Archaeology Museum; Karak Archaeology Museum; Madaba Archaeology Museum;

Petra Archaeology Museum; Salt Archaeology Museum; Museum of Archaeology / Jordan University; Museum of Jordanian Heritage / Yarmouk University were visited and visually evaluated. Therefore, a description of these museums is illustrated in this chapter. Each museum was visited several times, and interviews were made with the staff and the museum curator/ director. The visits of these museums took place in the period of 2007-2009. This chapter deals with the description of the selected museums in a semi-detailed manner. As limited written data was available on their history the researcher to depended mainly on visual examinations, and on interviews with administrative staff of the museums. This chapter forms the base of any related study to these museums. The museum buildings are scattered all over Jordan and described internally and externally including the management team and hierarchy of the employees. This chapter finally discusses the way the collection is exhibited, interpreted and documented, including a quality assessment of each of the selected museums in relation to ICOM standards.
The illumination system at the featured Jordanian museums was investigated using the ELSEC 764 environmental monitor, which was borrowed from the Cultural Heritage Inspectorate in the Netherlands and this is described in **chapter 4**. The light sources at the investigated museums differ from one museum to another. Several museums were selected in this study; they vary, based upon the collection they exhibit and their location. The investigated museums are: The Ajloun museum; The Archaeology museum/ Jordan University; The Aqaba museum; The Dar Alsaraya Museum; The Folklore museum; The Jarash museum; The Jordan Museum of Popular Traditions; The Jordan National Gallery of Fine Arts; The Museum of Jordanian Heritage / Yarmouk University; The National Heritage Museum / University of Jordan; The Natural History Museum / Yarmouk University; The Petra Museum; The Salt Museum and The Umm Qeis Museum. The ELSEC 764 provides reading and examination of light intensity for both visible and ultra violet light; also temperature and relative humidity were measured with the same device. The data from the ELSEC 764 was compared with the current recommended international guidelines for museum lighting. Furthermore, another comparison was made between the different monitored museums, depending on the susceptibility of their collections to exposure to unsuitable illumination. Finally, the available light sources in each museum were investigated, in order to determine the best lighting possibility, depending on the availability of the light types in the Jordanian local market and the museum’s budget. The results of the study demonstrated that all museums in Jordan depend on both natural and artificial light, but in different ratios. The artificial light lamps used in illuminating the museums in general are not UV filtered lamps; they are either fluorescent or incandescent tungsten lamps with different intensities. The investigation also found that the glass of the windows of museums are non-filtered glass, and without any curtains in most cases.

In preservation environments, there are a number of environmental factors, which can cause the degradation of materials and artefacts. Among these are temperature, humidity, particulates, and gaseous pollutants. Of these, the gaseous pollutants are the most destructive. Gaseous pollution today is caused primarily by the burning of fuels in power plants, factories, commercial and domestic buildings, and automobiles.
Yet today, the three main pollutant gases found throughout the industrialized world are sulphur dioxide (SO_2), ozone (O_3), and nitrogen dioxide (NO_2). While automotive and industrial emissions are considered as being the largest contributors of SO_2, O_3, NO_2, and chlorides, there are also many significant sources of internally - generated pollutants. Example of these materials and activities are associated with restoration and

conservation laboratories; but also many artefacts and archival materials, and employees and patrons themselves can contribute to the overall pollutant level in preservation environments as described in **chapter 5**.

Therefore, the Environmental Reactivity Coupons (ERCs) monitors are typically exposed to the environment for a period of 30-90 days and are then analyzed to measure the amount and type of corrosion that has formed. This technique can provide cumulative reactivity rates; an assessment of average environmental conditions over time; and can give an indication of the types and relative levels of corrosive gaseous pollutants. ERCs may be used to indicate the presence of SO_2, O_3, NO_2, Cl_2, and many other corrosive materials which can cause the deterioration of metals, cellulose, and organic materials. The installation of these coupons took place from the period of August 2008 until February 2009. In this study, nine museums were selected and also the main repository and archive of the Department of Antiquities (DoA) in Jordan. The study found that the indoor air is in direct contact with the outdoor air in most of the buildings concerned. Therefore, in cases where there are non-sealed windows or open showcases and open doors, it can be concluded that there is a serious contribution of the outdoor air to the indoor environment. Subsequently, based on several locations there might be even a serious influence explained by the geographical location of the museum.

The OnGuard^{TM} 3000 Atmospheric Corrosion Monitor (ACM) was used to determine the corrosion levels, and to monitor temperature and relative humidity as it was described in **chapter 6**. Later the data from the ACM was transferred to a computer to be analyzed. The device was installed in the Museum of Jordanian Heritage (MJH) and the Department of Antiquities main storage (DoAS). In order to make a comprehensive study the decision was made to monitor the indoor climate of the two cultural heritage institutions in two periods; one month in winter and another month in the summer during 2009. The monitoring periods were divided into two stages of approximately one month per stage. The study found that a correlation existed between the indoor atmosphere and outdoor atmosphere at the DoAS; this was reflected by temperature and relative humidity rates, which reflected negatively at the corrosion level. As a contrast the case at the MJH was much better; it appears that the museum has a closed indoor environment, which is less affected by the outdoor atmosphere.

This present research aims to illustrate the current situation of Jordanian museums. This study seeks to reduce as far as possible the damage caused by inappropriate environmental aspects in Jordanian museums, within the available capabilities of the selected museums. In order to do this, it is important to reduce the damage to objects caused by unsuitable environment to a minimum. This kind of study and research is applicable not only to museum buildings, but could also be applied to other institutions with collections, such as libraries, archives, churches, and historical buildings.

The number of museums in Jordan is increasing. They are fast becoming one of the main tourist destinations for the local and global community. Despite this, an evaluation of the current status of Jordanian museums remains far from the specialized researcher's interests, both locally and at an international level. Noteworthy, most of the museums in Jordan are archaeological museums.

In general, museums are advised to display objects, which are not in excess of 10% of their assets. However, in the Jordanian situation, the selected museums seem to display most of their possessions in permanent exhibitions. The displayed collections at the Jordanian museums, which are deteriorating continuously, are not undergoing any conservation treatments or assessment procedures. Furthermore, as far as the researcher is aware, the study of repositories has been almost neglected and researchers have paid hardly any attention to this issue in spite of the importance of museum repositories because they usually host the same type of collections as their museums do.

In conclusion, this investigation into and monitoring of the indoor environment of Jordanian museums has made it possible to determine the current situation of Jordanian museums generally. Museum buildings in Jordan are usually constructed from concrete bricks, and the exterior façade from stone bricks. This kind of building in general does not provide an adequate insulation environment for objects being kept or displayed in these buildings.

Most of the museum indoor environments in Jordan correlate with the outside environment. Influences from the outdoor environment pass through side openings, which are usually opened upon the staff demand on the basis of weather conditions. This is always reflected on the museum indoor environment, and consequently upon the exhibited objects.

Various environmental factors can cause the deterioration and destruction of cultural materials. If they are not checked and dealt with the effects on the objects may make the conservation treatment of objects difficult or even impossible. Therefore, this study has noted the deterioration and damage that the collections on display in the Jordanian museums suffer from on a daily basis. In particular objects that are vulnerable to RH and temperature fluctuation appear to be at risk of damage. This damage would ruin the chances of any later intervention conservation. Consequently - and to conclude with suggestions for how to enhance the selected museums' functions - the current priority should be to address the stabilization of the museums' environmental conditions thereby preventing further deterioration.

SAMENVATTING

De laatste decennia heeft de groeiende interesse in de archeologie van Jordanië geleid tot meer opgravingen en onderzoek van archeologische vindplaatsen. Dit leidde tot een significante toename van het aantal ontsloten monumenten en oudheidkundige voorwerpen. Als reactie op deze toename, werden met spoed locaties ingericht als musea zodat de gevonden artefacten ten toon gesteld konden worden en hun bescherming gegarandeerd zou zijn. Een vooronderzoek naar de wijze van tentoonstellen en beschermen van een aantal museumcollecties wekte echter sterk de indruk dat de meeste musea in Jordanië hun taken niet adequaat kunnen uitvoeren. Zij leken niet te beschikken over voldoende mankracht en kennis en ook niet over voldoende apparatuur en middelen om te voldoen aan de museale taken van catalogiseren, goed en veilig opslaan en op de juiste manier tentoonstellen van hun collecties.

De afgelopen jaren heeft binnen de museale wetenschappen een sterke toename van kennis plaatsgevonden, in het bijzonder op het gebied van het veilig en duurzaam opslaan van museale artefacten, waarbij negatieve interacties tussen de objecten en het binnenmilieu worden geminimaliseerd. Ook zijn voor musea diverse modellen van eisen opgesteld. Deze kennis en eisen kunnen goed worden toegepast op de Jordaanse museale situatie.

Dit proefschrift heeft dan ook als doel om de museale situatie van een aantal geselecteerde musea in Jordanië op wetenschappelijke wijze te beschrijven, te analyseren en te bespreken. Hierbij zal het accent liggen op het binnenmilieu van de musea. Het proefschrift wil een omvattende studie zijn, waarin ook aanbevelingen en suggesties zijn opgenomen, die hopelijk zullen leiden tot het verbeteren van de situatie in Jordaanse musea en van de kennis en vaardigheden van het museumpersoneel, zodat het Jordaanse cultureel erfgoed wordt veiliggesteld en een goed beeld van het land wordt gegeven.

Het moet vooraf worden opgemerkt, dat momenteel al vele artefacten vergaan door degradatie als gevolg van slechte milieuomstandigheden of door foute behandeling van ongetraind personeel. Als in deze situatie niet snel een ommekeer komt, is de kans groot dat veel waardevol historisch materiaal verloren gaat. Daarom is het van belang dat het onderzoek zich ook richt op de degradatieprocessen van opgegraven archeologische artefacten voordat enige conservering ervan in zicht komt, zodat zij stabiel worden opgeslagen dan wel worden tentoongesteld. Stabiele opslag hangt samen met een stabiele conditie van de binnenlucht in die opslagruimtes en met goed opgeleide medewerkers, die op de juiste wijze voor de voorwerpen zorg dragen. Dit zijn de basale vereisten om een museum en zijn staf in staat te stellen de functie van een modern museum uit te voeren, namelijk om een duurzame sociale en educatieve rol te vervullen.

Dit proefschrift is opgebouwd uit zes hoofdstukken.

Hoofdstuk 1 is een algemene inleiding. Het introduceert het historische en huidige gebruik van het begrip museum, alsook de diverse typen van musea. Vervolgens wordt de aandacht gericht op Jordanië, dat verspreid over het kleine land een bijzonder grote variatie in klimaat heeft en daarmee een complex buitenmilieu voor de musea. Vervolgens wordt een beknopt overzicht gegeven van de regelgeving voor het ontdekken en het uitlenen van museale objecten in Jordanië.

Hoofdstuk 2 beschrijft de theorieën van een goed binnenklimaat in musea. Dit hoofdstuk is tot stand gekomen op basis van een literatuurstudie en op basis van discussies met deskundigen op dit gebied. Hierdoor is tevens een overzicht gevormd

van de recente ontwikkelingen en visies op het terrein van museaal binnenklimaat. Vanuit dit overzicht wordt ook aandacht geschonken aan gaten in kennis en onderzoek. Verder wordt uitgebreid ingegaan op de nauwe relatie tussen musea en hun milieucontext alsook op de vele situaties waarvoor een afgestemd museummilieu noodzakelijk is.
Hoofdstuk 3 bespreekt diverse aspecten van de huidige situatie van de volgende tien Jordaanse musea: De archeologische musea van Aqaba, Irbid, Jarash, Amman Citadel, Karak, Madaba, Petra en Salt, alsmede de archeologische universiteitsmusea van Amman en Irbid (Jordaans Erfgoedmuseum). Al deze musea zijn visueel geëvalueerd op grond van meerdere bezoeken in de periode van 2007 tot 2009. Ook werden museumpersoneel en directeuren geïnterviewd met als doel kennis te vergaren over deze musea en over hoe men omgaat met de aanwezige collectie. Daar er weinig geschreven materiaal beschikbaar was over de geschiedenis van de musea is voornamelijk uitgegaan van de gevoerde gesprekken en visuele inspecties om een beeld te krijgen van het functioneren van deze musea. De geselecteerde musea staan verspreid over Jordanië en zijn intern en extern beschreven, inclusief de hiërarchie van het personeel. Tenslotte behandelt het hoofdstuk ook de manier waarop de museumcollecties worden tentoongesteld, geïnterpreteerd en gedocumenteerd, onder toevoeging van een kwaliteitsbeoordeling op basis van ICOM standaarden (ICOM = International Council of Museums). Dit hoofdstuk vormt de basis voor verder gerelateerd onderzoek van deze musea.

De kwaliteit van de verlichting werd in veertien musea onderzocht met een ELSEC 764 ‘Environmental Monitor’, welke geleend was van de Nederlandse Erfgoedinspectie. Dit onderzoek en de bijbehorende resultaten zijn weergegeven in **Hoofdstuk 4.** De veertien musea zijn: het Ajloun Museum, het Archeologisch Museum van de Universiteit van Jordanië in Amman, het Aqaba Museum, het Dar Alsaraya Museum, het Folklore Museum, het Museum van Jarash, het Jordaanse Museum van Volkstradities, de Jordaanse National Gallery of Fine Arts, het Jordaans Erfgoedmuseum van de Yarmouk Universiteit in Irbid, het Nationaal Erfgoedmuseum van de Universiteit van Jordanië te Amman, het Petra Museum, het Archeologisch Museum van Salt en het Museum van Umm Qeis. Met de ELSEC 764 werden metingen verricht naar de mate van de lichtintensiteit voor het zichtbare en het ultra violette (UV) gedeelte in het lichtspectrum. Tegelijkertijd werden ook de heersende temperatuur en relatieve vochtigheid met dit apparaat geregistreerd. De verkregen resultaten zijn vergeleken met internationale richtlijnen. Tevens werd onderzocht of de aanwezige collecties mogelijk nadelige effecten konden ondervinden door de aanwezige lichtbronnen. Vervolgens zijn voor elk van de musea aanbevelingen gedaan op basis van de bestaande lichtbronnen en van de mogelijkheden die de lokale Jordaanse markt en het museumbudget bieden voor verbetering ervan. Uit dit onderzoek is gebleken dat alle musea zowel natuurlijk als kunstlicht toepassen, maar in sterk verschillende verhoudingen. Bovendien werd duidelijk dat in de meeste musea kunstlicht zonder UV filter wordt toegepast. Ook natuurlijk licht wordt ongefilterd, en meestal zonder gordijnen in de ruimten toegelaten.

Naast licht, zijn er diverse andere factoren in het binnenmilieu die artefacten kunnen aantasten. Dit zijn temperatuur, relatieve vochtigheid, (stof)deeltjes en luchtverontreinigingen. De gasvormige luchtverontreinigingen worden primair veroorzaakt door verbranding van brandstoffen (verkeer, industrie, gebouwen) en vormen een grote bedreiging voor het erfgoed. Drie belangrijke gasvormige stoffen zijn zwavel dioxide (SO_2), stikstof dioxide (NO_2), ozon (O_3) en chlorides. Verkeer en industrie worden gezien als grootste leveranciers van deze verontreinigingen, maar de binnenlucht kan ook door diverse andere bronnen verontreinigd worden. Dit zijn bijvoorbeeld de objecten zelf, de gebruikte bouwmaterialen en de mens. In **Hoofdstuk 5** wordt nader ingegaan op de aanwezigheid van deze verontreinigingen. Hiertoe zijn in negen musea zogenaamde 'Environmental Reactivity Coupons' (ERC) toegepast. Naast de negen geselecteerde musea zijn ook de opslag en de archiefruimte van het Departement van Oudheden (DoA) in Amman onderzocht. Gedurende een periode van 30-90 dagen werden deze ERCs in ruimten geplaatst waarna de mate en het type van corrosie werd geanalyseerd. Met deze techniek kan een cumulatieve waarde worden verkregen over de mate van luchtcorrosie. Zo kan vast worden vastgesteld of de stoffen SO_2, NO_2, O_3 en chloor (CL_2) aanwezig waren. De metingen vonden plaats in de periode van augustus 2008 tot en met februari 2009. Uit dit onderzoek is gebleken dat de genoemde verontreinigingen in de binnenlucht van de ruimten van de onderzochte musea en het DoA aanwezig zijn. Er is dus een directe uitwisseling van de (verontreinigde) buitenlucht met de binnenlucht. Dit effect is groter naarmate er meer niet-gesloten ramen, open deuren en open vitrines aanwezig zijn. Ook de geografische locatie van het museum blijkt van invloed te zijn op de aanwezigheid van verontreinigingen in de gebouwen.

Om gedurende een bepaalde tijd de mate en reactiviteit van verontreinigingen vast te kunnen stellen in een ruimte is gebruik gemaakt van een OnGuard™ 3000 Atmospheric Corrosion Monitor (ACM). Deze registreert continu de mate van luchtcorrosie, temperatuur en relatieve vochtigheid. Dit onderzoek is weergegeven in **Hoofdstuk 6**. De verkregen data van de metingen met de ACM zijn afkomstig van het Museum van Jordaans Erfgoed (MJH) van de Yarmouk Universiteit te Irbid en van het hoofddepot (Store) van het Departement van Oudheden (DoAS) in Amman. Gedurende een zomermaand en een wintermaand in 2009 is de binnenluchtkwaliteit met de ACM in de genoemde locaties onderzocht. Op basis van dit onderzoek bleek dat er een correlatie aanwezig was tussen de buiten- en de binnenluchtkwaliteit bij de DoAS. Er was daar tevens een grote overeenkomst van temperatuur en vochtigheid tussen de buiten en binnenlucht, waarbij deze een effect hadden op de mate van luchtcorrosie. Daarentegen bleek de situatie in het MJM veel gunstiger te zijn. Hier werd de binnenluchtkwaliteit vrijwel niet door de buitenlucht beïnvloed.

De resultaten van het totale onderzoek illustreren duidelijk de huidige situatie van de Jordaanse musea. Tijdens deze studie werd onder andere gezocht naar mogelijkheden om schade aan artefacten door een slecht binnenklimaat te minimaliseren, waarbij rekening werd gehouden met de mogelijkheden binnen deze musea. Naast de betrokken musea kunnen de bevindingen en de mogelijkheden voor het verbeteren van de huidige situatie ook worden toegepast op instituten als bibliotheken, archieven en historische gebouwen.

Het aantal musea in Jordanië neemt nog steeds toe. Zij vormen snel een van de belangrijkste toeristische attracties voor zowel lokale als buitenlandse bezoekers. De meeste musea in Jordanië zijn archeologische musea, maar de daarmee verbonden lokale en internationale gespecialiseerde onderzoekers lijken weinig interesse te tonen in de groeiende betekenis van deze musea.

In het algemeen kan gesteld worden dat circa 10% van een museale collectie wordt tentoongesteld voor het publiek. De situatie in Jordanië is echter anders, want de betrokken musea lijken het merendeel van hun totale collectie in een permanente tentoonstelling te hebben. De tentoongestelde collecties in Jordanië zijn echter continu aan degradatie onderhevig. Ook bestaan er geen specifieke beoordelingsprocedures en conserveringsbehandelingen om de objecten in een goede staat te houden. Aandacht voor de kwaliteit van opslagruimtes is vaak ver te zoeken, ondanks dat deze uitermate belangrijk zijn voor het behoud van het opgeslagen erfgoed.

Concluderend kan gezegd worden, dat door dit onderzoek, mede op basis van metingen aan het binnenklimaat van geselecteerde musea in Jordanië, de huidige Jordaanse museale situatie in kaart kon worden gebracht. Vele museumgebouwen zijn van beton met een buitenzijde van natuursteen. In het algemeen geven de zo geconstrueerde gebouwen geen goed geïsoleerd binnenklimaat, waardoor de opgeslagen en tentoongestelde objecten aan slechte bewaaromstandigheden worden blootgesteld. In vele musea volgt het binnenmilieu het buitenmilieu, waardoor onder andere verontreinigingen van buiten vrijelijk naar binnen kunnen komen. Komt daar nog bij, dat het personeel weerafhankelijk regelmatig ramen en deuren openzet.

Allerlei milieufactoren dragen bij tot de degradatie van historische objecten. Als deze factoren niet worden waargenomen zullen, mede door gebrek aan beschikbaarheid van de juiste conserveringstechnieken, objecten voorgoed verloren gaan. Tijdens dit onderzoek werd dan ook veelvuldig toenemende schade aan objecten in de musea waargenomen. Schade veroorzaakt door sterk fluctuerende relatieve vochtigheid, temperatuur en luchtverontreinigingen, welke bovendien de kansen op een latere conserverende maatregel te niet doet. Het is dan ook van groot belang, mede op basis van de resultaten uit dit onderzoek, dat musea in Jordanië prioriteit geven aan het stabiliseren van hun binnenklimaat om zo het aanwezige erfgoed te behoeden tegen verder verval.

ملخص

منذ مطلع القرن العشرين، بات الاهتمام في علم الآثار يشكل هاجساً لدى مؤسسات الدولة والأفراد في الأردن. تمخض عن هذا الاهتمام زيادة في عدد الحفريات الأثرية؛ مما أدّى إلى زيادة أيضاً في عدد القطع الأثرية المكتشفة. واستجابة لذلك كان من الضروري إنشاء متاحف قادرة على حفظ هذه المكتشفات وعرضها بصورة آمنة وجميلة، وهذا ما حصل خلال فترةٍ وجيزة من الزمن، إلا أن هذه المتاحف تفتقر إلى القدرة المادية و البشرية لإنجاز أهدافها على أكمل وجه.

وعلى الرغم من التقدم الحاصل في علم المتاحف، لا تزال المتاحف الأردنية تعاني من عدم توفر البنية التحتية لها مع افتقارها إلى معظم أساسيات إنشاء المتاحف وضروراتها. من أجل هذا كله، أقيمت هذه الدراسة لتقييم هذه المعطيات وتحليلها وتقديم بعض الحلول والمقترحات التي من الممكن أن تؤدي إلى تحسين واقع المتاحف في الأردن وتمكن أصحاب القرار من الاستفادة منها في تحسين إدارتها لرسم صورة أجمل عن الأردن في عيون زائريه.

وتعاني المتاحف الأردنية في الوقت الراهن من التلف التدريجي للقطع المعروضة نتيجة البيئة الداخلية للمتحف غير المحكمة ومن إساءة التصرف غير المقصود من الموظفين غير المؤهلين. هذا وإن لم يكن هنالك حد للوضع الحالي بالسرعة الممكنة فإن القطع المعروضة سوف تكون عرضة لدمار نهائي غير قابل للترميم. ولهذا كان من المهم أن تكون هناك دراسة لتقييم هذا التلف الناتج، قبل تقديم أي مقترحات بخصوص الصيانة والترميم للقطاع التالفة.

ويمكن حفظ القطع الأثرية المكتشفة من خلال طرق عدة سواء أكانت هذه القطع في صالة العرض أم محفوظة في المخزن. ولهذا فإنه لا بد من السيطرة على البيئة الداخلية لهذه المتاحف وتدريب الموظفين العاملين فيها وتأهيلهم، إذا ما أريد أن تكون المتاحف الأردنية في حالةٍ أفضل

.وقسّمت دراستي إلى خمسة فصول:

الفصل الأول منها عرضت فيه مقدمة نظرية ناقشت فيها واقع البيئة المتحفية بشكل عام. ويقدم أيضاً مراجعة وخلفية لمعظم الدراسات المتخصصة في هذا المجال

والمنشورة مؤخراً. وفي هذا الفصل أيضاً تم مناقشة العلاقة ما بين المتاحف من منظور البيئة المتحفية وبين الجوانب التي بحاجة إلى دراسة والتي تفتقر الساحة العالمية لها. تعريف وأنواع المتاحف تم التطرق لها أيضاً في هذا الفصل.

وفي **الفصل الثاني** بيّنت نتائج زياراتي لعشرة متاحف أردنية ووصفها وتقييمها وهي:

متحف الآثار في الجامعة الأردنية، متحف إربد الأثري، متحف البتراء الأثري، متحف التراث الأردني في جامعة اليرموك، متحف جرش الأثري، متحف السلط الأثري، متحف الكرك الأثري، متحف العقبة الأثري، وأخيراً متحف مأدبا الأثري.وتم زيارة كل متحف من هذه المتاحف عدة مرات في الفترة الواقعة ما بين عام 2007 حتى عام ٢٠٠٩، تم من خلال هذه الزيارات الاطلاع على واقع هذه المتاحف وإجراء

مقابلات مع الموظفين ووصف هذه المتاحف وصفاً دقيقاً. إن محدودية المعلومات الـ مكتوبة أو الموثقة عن هذه المتاحف حالت إلى اتخاذ الباحث منحى وصفي تقييمي للمباني والقطع المعروضة وطريقه العرض والبيئة الداخلية، ولاعتماد بدرجة أقل على المقابلات مع الموظفين، لكي يشكل هذا الفصل بالنهاية أساس لأي دراسة مستقبليه لهذه المتاحف. زيادة على ذلك فقد تم وصف مباني المتاحف الأردنية والمنتشرة في جميع أنحاء الأردن وصفاً داخلياً وخارجياً بما في ذلك الهيكل التنظيمي لموظفي هذه المتاحف.

أما في **الفصل الثالث** من هذه الدراسة فقد ناقشت موضوع الإضاءة وكفاءتها و ملاءمتها للمتحف من خلال فحص الإضاءة وتقييمها باستخدام جهاز ELSEC 764 (المرقاب البيئي)، وجدت أن مصادر الإضاءة في المتاحف الأردنية تختلف من متحف لآخر، حيث إن بعض المتاحف الأردنية تعتمد على الإضاءة الطبيعية بنسبة أكبر من الإضاءة الصناعية، بينما متاحف أخرى تعتمد أكثر على الإضاءة الصناعية. في حين أردنية تم اختيار عدة متاحف من أجل هذه الدراسة وهي تختلف عن بعضها من خلال معروضاتها وموقعها الجغرافي وهي: متحف الأردن للتراث الشعبي، متحف الآثار / الجامعة الأردنية، متحف أم قيس، متحف البتراء الأثري،

متحف التاريخ الطبيعي / جامعة اليرموك، متحف التراث الأردني / جامعة اليرموك، متحف التراث الشعبي / الجامعة الأردنية، متحف دار السرايا، متحف جرش الأثري،متحف الحياة الشعبية، متحف السلط الأثري، متحف عجلون الأثري، متحف العقبة الأثري، المتحف الوطني الأردني للفنون الجميلة .

ولدى الجهاز المستخدم قدرة على تزويد المستخدم بنتائج فحص شدة الإضاءة للأشعة المرئية والأشعة فوق البنفسجية، ويتمكن الجهاز أيضاً من فحص حرارة الجو ونسبة الرطوبة في الجو إذا ما أريد ذلك. بعد ذلك تم مقارنة النتائج الخارجة من الدراسة مع المعايير الدولية لشدة الإضاءة المسموحة في المتاحف. ثم عقدت مقارنة أخرى بين المتاحف نفسها طبقاً لمعروضاتها ونسبة تأثرها بالضوء غير المناسب. في حين تم فحص مصادر الضوء في كل متحف بصورة مستقلة لكي يتم تحديد أفضل إضاءة ممكنة، بالاعتماد على إمكانية كل متحف.

و أوضحت النتائج بأن جميع المتاحف الأردنية تعتمد في إضاءتها على الإضاءة الطبيعية والصناعية معاً، ولكن بنسب متفاوتة. وتبين أنّ الإضاءة الصناعية المستخدمة هي إضاءة غير مفلترة من الأشعة فوق البنفسجية وهي إما أن تكون مصباح نيون أو مصباح التنجستن الكهربائي، وقد تفاوتت المصابيح في إضاءتها حسب قدرة كل منها. كما أثبتت الدراسة بأن زجاج النوافذ غير عازل للأشعة فوق البنفسجية ناهيك عن عدم استخدام الستائر.

في البيئة المحافظة هنالك عدد من العوامل المؤثرة في تردي وضع القطع المعروضة، هذه العوامل هي: الحرارة، الرطوبة، الغبار، والتلوث البيئي. من هذه العوامل تعد الملوثات الغازية الناتجة عن التلوث البيئي العمل أكثر تأثيراً على القطع المتحفية. في الوقت الحالي ينتج التلوث البيئي بشكل أساسي من خلال مخلفات الوقود المحروق. الغازات الثلاث الناتجة عن هذا الحرق هي ثاني أكسيد الكبريت، ثاني أكسيد النتروجين، والأوزون،بالإضافة إلى غاز الكلورايد. حيث إن وسائل النقل هي أكبر المنتجين لهذه الغازات في الجو . هذه العوامل وتأثيرها على القطاع المتحفية تمت مناقشتها في هذه الدراسة من خلال **الفصل الرابع**.

وعليه فقد تم استخدام شرائح رصد التفاعل البيئيّ للكشف عن التلوث الموجود داخل المتاحف المختارة لهذه الدراسة. وتم عرض هذه الشرائح للجو المتحفي لفترة تتراوح ما بين ٣٠ إلى ٩٠ يوم. وبعدها تم تحليل هذه الشرائح للكشف عن نوع التلوث وكميته التي تعرضت له. ويمكن أن تكشف هذه الشرائح وجود الغازات السالفة الذكر بكل سهولة وأيضاً عن غازات أخرى ممكن أن تكون سبباً في تدهور حالة القطع المتحفية.

و في هذه الدراسة تم اختيار ثمانية متاحف أردنية بالإضافة للمخزن والأرشيف التابعين لدائرة الآثار العامة. فأثبتت أن هنالك تداخلاً ما بين البيئة الداخلية للأماكن المختبرة والبيئة الخارجية في معظم الحالات. ولهذا يمكن الإجمال أن يكون التأثير متوافقاً من الموقع الجغرافي لكل متحف.

وقد استخدمت الدراسة في **فصلها الخامس** جهاز OnGuard™ 3000 (مرقاب التلوث الجوي) لرصد مستويات التآكل ومراقبة درجات الحرارة ونسبة الرطوبة في الجو، والذي يعمل على تحديد المعلومات المطلوبة وتخزينها ومن ثم يمكن إرسالها إلى جهاز حاسوب لتحليلها ضمن برنامج خاص. وتم تثبيت هذا الجهاز في متحف التراث الأردني وفي مخزن دائرة الآثار العامة لكي يرصد الوضع الداخلي مرةً في العام "مرة في الشتاء وأخرى في الصيف" لتكون فترة الرصد في كل مرة شهر واحد من عام ٢٠٠٩. كشفت نتائج هذا الفحص عن وجود تداخل بيئي بين الوضع الداخلي والخارجي لمخزن دائرة الآثار العامة. أما بالنسبة لمتحف التراث الأردني فقد كان الوضع أفضل بكثير حيث إن الجو الداخلي للمتحف ليس متداخلاً مع الجو الخارجي .

والمتابع للمتاحف الأردنية يجدها في ازدياد مستمر، حيث إنها الوجهة الأولى للسياح و للأردنيين على حد سواء. على الرغم من هذا فإن تقييم هذه المتاحف كان بعيداً عن اهتمام الباحثين، مع الإشارة إلى أن معظم المتاحف في الأردن هي متاحف أثرية. وفي المجمل فإن المتاحف عادةً ما تعرض ما يقارب ١٠ ٪ من موجوداتها، ولكن الوضع في المتاحف الأردنية غير ذلك، حيث إن المتاحف في الأردن عادةً ما

تعرض معظم موجوداتها. وهذه القطع المعروضة والمعرضة للتلف لا تندرج تحت أعمال الصيانة والترميم .

وبشكل عام فإن هذه الدراسة هدفت إلى إبراز الوضع الحالي للمتاحف الأردنية و إلى الحد من تدهور وضع القطع المتحفية قدر الإمكان والناتج عن عرضها في بيئة غير ملائمة. هذا النوع من الدراسة لا يطبق على المتاحف فقط بل يمكن تطبيقه أيضاً على الأرشيف أو المكتبات أو الأماكن التاريخية. ومن الجدير بالذكر أن مباني المتاحف في الأردن عادة ما تبنى من الأسمنت المسلح وتلبس من الخارج بالحجر الجيري. وهذا النوع من المباني لا يوفر بيئة متحفية ملائمة للقطع.

إذا بقيت معظم العوامل المؤثرة في الجو الداخلي المتحفي على حالها فإنها سوف تعرض القطع المتحفية إلى تلف مستمر. وعليه فإن إمكانية ترميم هذه القطع تكون أصعب أو حتى مستحيلة. ولهذا فإن هذه الدراسة ركزت على التحقق من الأسباب المؤدية إلى هذا التلف. وبناء على ذلك كان لابد من إبداء مقترحات وتوصيات تؤدي إلى تحسين الوضع الحالي للمتاحف الأردنية لتكون قادرة على عرض وحفظ مقتنياتها دون الخوف عليها من التلف في المستقبل.

CURRICULUM VITAE

Raed Yousef Sayied Alghazawi was born on June 12^{th}, 1972 in Irbid, Jordan. He lived in Irbid until 1990, where he finished his high school. He received his B.Sc. in Political science and diplomatic studies from the Applied Science University in Amman, Jordan. In 2000, he enrolled in the MA program in Archaeology, at the Yarmouk University in Irbid, Jordan. The focus of the MA program was on museology and he graduated in 2003. After the completion of his MA, he stated working at the Hashemite University, Queen Rania's Institute of Tourism and Heritage as a lecturer, with a primary task of teaching museum studies courses. In December 2006, he was awarded a grant by the Netherlands organization for international cooperation in higher education (NUFFIC) and he became a PhD candidate under supervision of Prof. Dr. Willem J.H. Willems, Dr. John B.G.A Havermans and Dr. Gerrit van der Kooij, in the Faculty of Archaeology at Leiden University. He intends to pursue a career in academia.

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