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Review Paper

Overview of preventive conservation and the museum environment in China

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Based on a nationwide investigation of the current state of preservation of museum objects in China, around 51% of the 35 million museum objects show different degrees of deterioration. Although treatment of objects is necessary, treatment alone is not sufficient. In China's present situation, preventing damage to museum objects is much more cost-effective than allowing damage to happen and then treating it. The number of museums in China is increasing very fast: 23 000 exhibitions are held, 600 million visits are made, and 35 000 archaeological objects are excavated nationwide, each year. At the same time, these museums are widely distributed and have different levels of resources. We need both technical knowledge and preventive conservation to safeguard our precious museum objects. This paper introduces research achievements in preventive conservation, and traces the development of this discipline in China. Starting from the classification of museums in China, legislation is detailed on preventive measures such as selecting appropriate light sources, controlling temperature, relative humidity, light damage, and pollutants. This paper describes achievements in monitoring, analysis, evaluation, and control of museum environments in China. It also proposes future directions for museum environment studies during China's twelfth Five-Year Plan.

Keywords: Preventive conservation, Museum environment, Monitoring, Analysis, Evaluation, Control, Indoor air quality

Introduction

China is a great family of 56 nationalities, all having a very long history. Most of their significant cultural heritage is stored in museums, which are unique and irreplaceable witnesses of our past and are vulnerable to natural disasters and human behaviour. By 2013, the number of museums in China had increased to 3354 from 3055 in 2012, among which the number of private museum is 811. The number of museum visitors annually is 600 million. Based on China's national long-term outline plan for museum development (2011–2020), we expect that by 2020 there will be one museum for every 250 000 people, compared to one per 400 000 in 2014, and that 20% of museums will be privately funded. Owing to the impressive number of museums opened in the twentieth century, a large number of objects has been accumulated and has often been left in unsuitable environments, resulting in irreversible damage. Treatment of individual objects cannot meet the ever-increasing demand. What is more, a survey conducted in 2002–2005 by the State Administration of Cultural Heritage, which targeted the condition of museum objects on a national scale, shocked the whole country. 50.7% of museum objects showed signs of serious degradation, and almost 23 million museum objects had suffered varied degrees of degradation, which amounts to 16.5% of all national museum objects. This increased awareness of the necessity to control environmental conditions (lighting included) was stressed by Thomson who synthesized the importance of microclimate control with the pithy sentence: 'A bad restorer can destroy an item per month. A bad conservator can destroy an entire collection in one year' (Thomson, 1986). The reason for this serious state of degradation is unsuitable museum environments, and although treatment of individual objects is necessary, for the whole collection the first step is improving the environment. Rather than treatment after they show signs of degradation, looking for preventive conservation solutions becomes the most important museum function. Most museums in China are trying to shift their focus from 'salvage conservation' to preventive conservation.

Classification of museums in China

Museums are classified into three grades by the State Administration of Cultural Heritage, and are

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supervised by public organizations and individuals. The classification is evaluated by combining their scores in comprehensive management and infrastructure (200 points), collection management and scientific research (300 points), exhibition and social services (500 points). The combined score of a first-grade museum should be more than 800 points, a second-grade museum should have more than 600 points, and a third- grade museum should have more than 400 points. First-grade museums have the following characteristics: numerous or multi-category collection items, or numerous objects which have very high historical, cultural, scientific, and artistic value. Also, first- grade museums should have a social and educational mission with professional staff and education service areas, and should also have a stable pool of long-term museum volunteers, who should participate in activities more than four times per year. The opening hours of state-owned museums should be more than 300 days per year, or 240 days per year for non-state-owned museums. Basic exhibitions should be open to the public at regular intervals for more than 60 days. The museum system and performance measures should be published on a government-sponsored website for public review. Teenagers should account for a certain proportion among the audience.

Compared to the first- grade museums, provincial museums, small- and medium-sized museums such as those at municipal or county level are housed in historic buildings, not originally designed for exhibition and storage rooms. There are inevitably problems such as unstable temperature (T) and relative humidity (RH), poor insulation, poor heat retention, too much natural light, difficult environmental management, and a shortage of equipment such as central air-conditioning, modern exhibition showcases, dehumidifiers, museum lighting, environment monitoring devices, and insufficient funds for maintenance.

Legislation
In 1982, legal protection of cultural heritage in the People's Republic of China was adopted, and conservation procedures were established and subsequently amended several times in 1991, 2002, 2007, 2013, and 2015. Implementation plans listed museum objects as a separate category in May 2003, which set up the principle of the conservation of the original form of museum objects, an innovative policy which translates as 'protection is lord, rescue the first, valid protection, reasonable exploitation, strengthen the management'. This policy attaches importance to the leading role of conservation and also to the museum environment.

At present China has 83 accredited museum design units, 92 accredited museum conservation units, and 81 first- grade museums. Since 2002, the State

Administration of Cultural Heritage has been preparing standards for the museum environment and in 2007 they trialled the museum environmental specifications, including suitable T and RH ranges for different materials. For metals like iron, the RH should be below 40%, and for all materials, the RH should never exceed 60%. In 2009, the State Administration of Cultural Heritage issued a national museum development plan, which defines conservation as the control of the environment to minimize the decay of artefacts and materials. 'Technical specifications for monitoring of museum environment quality' were announced (WW/T0016-2008), which introduced standard methods of monitoring museum environments, including the equipment, materials, and solutions. From 2006 to 2010, China invested ¥600 million (around $100 million) for the conservation of museum objects, and conducted more than 500 conservation projects for 2000 damaged objects, which suppressed the trend in deterioration. However, in view of the enormous amount of objects, we still have a lot to do. Based on China's twelfth Five-Year Plan for the museum industry (2011–2015) and national conservation science and technology development (2011–2015), China has established micro-environmental monitoring system for museums and macro-environment monitoring for historic heritage sites, and is trying initially to build the framework for a risk management system for museum objects and historic heritage sites in order to improve the performance of conservation management significantly. This also indicates that, over the next few decades, preventive conservation will still be our country's main task.

Museum lighting: the current situation
In 2009, China issued a National Standard for the Design of Museum Lighting (GB/T 23863-2009), which was formulated using the National Standard for the Design of Museums, the National Code for Lighting in Civil Buildings, and the National Standard for Lighting Design in Industrial Premises for reference. This code articulates the different deterioration phenomena caused by light and establishes the highest levels of illumination to limit damage. China has divided museum objects into three categories, low, medium and high sensitivity. For high sensitivity objects, the total amount of illumination should be less than 50 000 lux-hours per year, which limits the number of display days to less than 125 per year when the illuminance is 50 lux for eight hours. For medium sensitivity objects, it should be less than 360 000 lux-hours per year. The National Standard for the Design of Museum Lighting (GB/T 23863-2009) also specifies that museums should limit ultraviolet (UV) radiation of natural light and artificial light to less than 75 µW/lm.

For these categories (high, medium, and low), China refers to international guidelines for museum lighting, defined using the industrial lightfastness standards known as the ISO Blue Wool Standards (BWs). These are a set of textiles, originally numbered one to eight, each about two to three times as sensitive as the next. High sensitivity was defined as materials rated as BW1–3; medium as BW4–6; and low as BW7–8 or better (CIE 2004).

Based on a survey of the current situation of museum lighting inside Chinese museums and galleries, there are three categories of museum buildings: (1) specially designed, (2) transformed from general galleries, and (3) transformed from historic buildings. There are three methods of illumination: natural lighting supplemented by artificial lighting; a combination of natural lighting and artificial lighting; and artificial lighting, which accounts for a lower percentage in China and has a comparatively short history of about 20 years.

Until now there have been six types of light sources suitable for general lighting in China: tungsten filament lamps, tungsten–halogen lamps, fluorescent lamps, metal halide lamps, LEDs, and fibre-optic lighting. Starting from 2011, China began to eliminate tungsten filament lamps for museum lighting due to their low energy efficiency. The use of tungsten–halogen lamps for museum lighting mostly focuses on exhibition areas, the colour rendering index must be close to 100 and quartz lamps must have ultraviolet filters. Fluorescent lamps account for a very large proportion of museum lighting; they have a considerable UV output and also need to be filtered. The percentage of metal halide lamps is less than 2% in China, and the number is even less when it comes to museum lighting, although the Central Lobby of the National Museum of China uses metal halide lamps. LEDs are used for non-exhibition areas of the National Museum of China such as the entrance hall and aisle; in recent years LEDs with high color rendering index (>95) have been gradually replacing tungsten–-halogen lamps for museum exhibition areas. With their extremely low heat and UV output, fibre-optics will not damage delicate items on display, making this technology ideal for lighting rare books and manuscripts, paintings, textiles and any other item prone to degradation by light. The National Museum of China uses fibre-optic lighting for exhibiting museum objects.

Air quality guidelines

In China there are no specific air quality guidelines for the museum environment, but when it comes to air quality in museums, the National Standard for Indoor Air Quality (GB/T 18883-2002, see Table 1), established by the Chinese government in 2002, can be considered as a reference.

As China has industrialized, various forms of pollution have increased, such as acid rain, which first emerged as an important environmental problem in China in the late 1970s. As a result of significant SO_2 emissions, widespread acid rain is observed in southern and southwestern China. The concentrations in some places are higher today than that reported from the 'black triangle' in central Europe in the early 1980s (Environmental Yearbook, 2003). Between 1993 and 2005 the acid-rain-polluted area has extended greatly to about 1.5 million km^2. Until now the acid-rain zone has accounted for 30 –40% of national territory, which makes China the most polluted nation in the world (Zhang, 2010). This fact puts Chinese cultural heritage and collections at high risk.

Acid deposition from SO_2 and NO_x emitted to the atmosphere in Beijing city has caused serious deterioration of stone building materials and also stone objects, for example in the Palace Museum, although outdoor marble and limestone have long been preferred materials for constructing durable buildings, monuments, and sculpture. Marble and limestone both consist of calcium carbonate ($CaCO_3$), and although these are recognized as highly durable materials, they are now being gradually eroded away by acid rain, which can easily destroy details and relief work. In the last twenty years the deterioration rate has been speeding up, which damages life-like stone sculpture beyond recognition.

Most major museums in China such as the mausoleum of the first Qin emperor, Zhejiang Provincial Museum, the Capital Museum, and the Palace Museum, have successively installed instruments to detect levels of SO_2, NO_x, NO_2, O_3, and $PM_{2.5}$. The results from the 24-hour monitoring system show that the environmental indices of the National

Table 1 Indoor air quality standard (GB/T 18883-2002)

Parameter	National standard limit	Remarks
Temperature/°C	22~28	Summer air-conditioning
	16~24	Heating in winter
Relative humidity/%	40~80	Summer air-conditioning
	30~60	Heating in winter
SO_2 (mg/m^3)	0.50	1 hour average
NO_2 (mg/m^3)	0.24	1 hour average
TVOC (total volatile organic compounds) (mg/m^3)	0.60	8 hour average
O_3 (mg/m^3)	0.16	1 hour average
HCHO/(mg/m^3)	0.10	1 hour average
PM_{10} (mg/m^3)	0.15	Daily average

Table 2   Air quality of the National Museum of China and relevant national standards

Name	Air quality of the national museum of china	National standards
SO_2	2.369 ppb = 6.77 µg/m^3 On-line monitoring equipment: sulfides analyser EC 9852	First- level standard (annual mean) 20 µg/m^3 Second- level standard (annual mean) 60 µg/m^3
O_3	2.372 ppb = 5.08 µg/m^3 On-line monitoring equipment: ozone analyser EC 9810	First- level standard (8 h average) 100 µg/m^3 Second- level standard (8 h average) 160 µg/m^3
NO_2	8.027 ppb = 16.45 µg/m^3 On-line monitoring equipment: oxides of nitrogen analyser EC 9841	First- level standard (annual mean) 40 µg/m^3 Second- level standard (annual mean) 40 µg/m^3
NO_x	17.01 ppb On-line monitoring equipment: oxides of nitrogen analyser EC 9841	None
PM_{10}	28.84 µg/m^3 On-line monitoring equipment: Grimm Aerosol Technik Model 180	First- level standard (annual mean) 40 µg/m^3 Mean concentration for 24 h is 50 µg/m^3 Second- level standard (annual mean) 40 µg/m^3 Mean concentration for 24 h is 150 µg/m^3
$PM_{2.5}$	22.64 µg/m^3 On-line monitoring equipment: Grimm Aerosol Technik Model 180	First- level standard (annual mean) 15 µg/m^3 Mean concentration for 24 h is 35 µg/m^3 Second- level standard (annual mean) 35 µg/m^3 Mean concentration for 24 h is 75 µg/m^3
$PM_{1.0}$	21.53 µg/m^3 On-line monitoring equipment: Grimm Aerosol Technik Model 180	None

Museum of China had reached the national primary standard, see Table 2.

Conservation research into practice

In recent decades, Chinese conservation scientists have also made numerous advances in scientific research. For example, Panlu from the National Museum of China conducted a large number of simulation experiments on the effect of environmental pollution on bronzes. These showed that when the environmental RH is under 35%, it is safe for storage and exhibition (Panlu, 2005). So for all bronzes in the National Museum of China, 35% RH has become a mandate for the museum environment.

History and development of preventive conservation in China

Preventive conservation is almost a traditional concept in the world of museums, but it is only within the last 30 years that it has started to become more organized. China started late in the application of preventive conservation and has no related systematic theory. The early history is characterized by the progressive integration of science into the museum world and the strengthening of collaborations between curators, conservators, and conservation scientists. In recent years, awareness of preventive conservation has been raised, with preventive conservation strategies first focusing on thefts, fires, vandalism, and earthquakes, then developing to avoid or reduce the degradation of artworks though monitoring and controlling of environmental conditions within exhibition areas and conservation laboratories. Preventive conservation for museum objects will become the main task of the conservation industry in China. Starting from 2001, the museum department of the State Administration of Cultural Heritage started to make specifications for the museum environment, and also translated two books to serve as routine manuals for staff working in the museum. In 2005 the State Administration of Cultural Heritage set up a research laboratory in Shanghai Museum, which initiated a new era for a clean and stable microenvironment (Wu et al., 2008). From the beginning of March 2005, a joint research project between China, America, and Hong Kong has been conducting air pollution monitoring of the Qin terracotta warriors and horses, and has established a database for future environmental management. At the end of 2010, the International Academic Conference on Museum Environments was held by the research laboratories in Shanghai. Meanwhile, the twelfth Five-Year Plan (2011–15) for museum development and conservation science development stipulates a development index such as more than 100 monitoring centres and networks for museum environment, and also insists on policy and valid protection, reasonable access, and strengthening of museum management. On 21 December 2015, the State Administration of Cultural Heritage held a training course on professional standards of preventive conservation for nationwide museum staff, which focused on how to start a preventive conservation project, and on the principal technical methods for monitoring the museum environment. It introduced active and passive microclimate control methods.

By 2013 there were more than 4000 museums across China, ten times more than that in 1978. These museums house over 19 million collection items, all of which make us have to wrestle with big challenges for conservation and preservation of cultural heritage.

These museums are all over the country, and climatic conditions in China vary greatly: the south is humid, but the north is very dry, and the RH there is always 20–30%. If museum objects have already adapted to this RH, if we followed the uniform standard, which is almost 50%, it would cause more damage. We would also need more facilities and funds, which is also unnecessary. Each museum in China should align with local climatic conditions: then the control of microclimates for sensitive objects will be much more practicable.

Tourism and conservation

Normally in China, the government is in charge of cultural heritage protection and tourism sites. Under the People's Republic of China's newly amended law on protection of cultural relics in 2005, tourism development should not be promoted at the cost of loss or deterioration of historical and cultural assets. There is no doubt that government and legal interventions can be important for heritage protection at heritage sites. China currently ranks second in the world when it comes to cultural heritage sites, behind Italy, with 45 world heritage sites on the UNESCO list. There are 981 world cultural heritage sites around the world. China is also the world's most popular destination for tourists. Domestic tourist sites saw a total of 3.3 billion visitors last year, and travellers' enthusiasm has caused great pressure on our standards and safety measures. In order to stimulate the national economy, a so-called gold week comprising May Day and National Day has been put in force by the government, and the first gold week holiday began on 1 October 1999. Statistical data show that about 15 000 visitors were received each day by Emperor Qin's Terracotta Museum during such a gold week. To evaluate the effects of tourism on indoor air, airborne samples were collected by the sedimentation plate method for five minutes during the October gold week period of 2006, and both composition and changes of airborne bacteria and fungi in indoor/outdoor air in the museums were investigated. The results show that museum air was affected by human activity; therefore, it is imperative that the number of visitors be strictly limited. The Palace Museum in Beijing is a renowned world cultural heritage site with a history extending 600 years, which has received more than 10 million visitors annually in recent years. During the last three years, the museum's annual average visitor numbers have exceeded 15 million, far more than its counterparts such as the Louvre in Paris, France, and the British Museum in London, UK. According to the museum's announcement the Palace Museum will launch a pilot scheme to limit the daily visitor numbers to 80 000 in order to control museum air quality and reduce vandalism.

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