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Original article

Effects of temperature and relative humidity on permanence of Buyid silk

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ABSTRACT

Identifying, assessing, and prioritizing risks of improper temperature (T) and relative humidity (RH) and their degrading effects on objects is a major issue for museum researchers. Methods that quantify deteriorating characteristics of temperature and RH provide useful information and lead to effective preventive solutions. Time-Weighted Preservation Index (TWPI) is a measure that estimates permanence of the organic materials based on a set of T and RH data for a specific period. In this research, we have used TWPI to assess chemical deteriorations of a Buyid silk stored in a museum storage. Furthermore, with the intention to examine effects of parameter fluctuations, a sensitivity analysis is applied to investigate permanence of the object in diverse sets of temperature and RH. Results of this research show that activation energy of the aforementioned Buyid silk is approximately 96.03 kJ/mol and its permanence is converging to a determined amount that can be interpreted as its remainder useful life. Considering the climate of the textile storage, sensitivity analysis shows that lowering the average temperature to the standard range would result in a remarkable increase on the object's permanence.

1. Introduction

Changes in temperature (T) and relative humidity (RH) have direct influence on deterioration of historical objects. A large number of museums still do not use modern HVAC systems; old structure of the buildings and their poor quality of envelope are main reasons that make the environmental conditions uncontrollable in such museums. For these museums, it is hard to follow the strict rules and standards about the proper levels of temperature and relative humidity. Therefore, it is important to create simpler and less expensive methods that might provide a similar acceptable level of conservation for museum collections.

Conservators need a continuous and precise monitoring process to assess constant and gradual risks of temperature and RH imposed on museum objects. The nature of the materials in an object has a great influence on the risk assessment process. Accordingly, there are many qualitative and quantitative methods to outline and quantify risk factors. In qualitative methods, an expert opinion is the most reliable source to express risk consequences, but in quantitative methods, researchers can delineate at least one measurable criterion to evaluate risk level. Temperature and RH are measurable, so it would be possible to develop and use quantitative methods to evaluate their associated risks. Researchers have outlined the impacts of inappropriate levels of T and RH on mechanical, biological, and chemical damages, especially there has been a lot of studies regarding the objects with organic materials, such as papers, textiles, paintings, photographs, and so on. However, the level of these damages vary according to the climate; for low temperature and high relative humidity levels, objects have a high risk of mechanical degradation and low risk of chemical damages. On the contrary, combination of high temperature and low humidity increases risks of chemical damages [1]. Biological damages usually affect objects that are stored in places with more than 65% RH and most germination charts start with the lowest RH level of 70%. Therefore, the most important damage for objects in warm and dry countries is chemical degradation of the objects. Risk management can be applied as an approach that controls, mitigates or eliminates deteriorating agents or their destructive effects in accordance with their importance. Early studies in this area mainly tried to introduce capabilities of quantitative or qualitative methods for managing risks that are related to museum collections. Analytical tools in quantitative methods help researchers identify, prioritize and manage risks regarding to the museum collections. With a preventive conservation strategy to manage museum resources, Waller [2] has identified, categorized and prioritized all risks related to the museum objects. He suggests to apply risk management as a

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decision-making process for preventive conservation of museum collections. Keene [3] also encouraged the use of mathematical modelling, statistical analysis and other quantitative methods by conservators and other museum specialists for scientific museum management.

Studying physical attributes of an object does not provide all necessary information about its vulnerabilities; Environmental and storage conditions are also quite significant in identifying and evaluating its associated risks. Therefore, it is necessary to have a comprehensive attention to environmental data and develop evaluating techniques, which analyze the interactive effects of deteriorating agents, and offer a more accurate estimation of permanence. For example, Feller [4] used photochemical and thermal stability factors to create stability classes for different materials and emphasized on the importance of activation energy of the materials as an attribute of stability in his book. He used light, oxygen, temperature and relative humidity as important deterioration agents and evaluated objects permanence by considering Arrhenius equation and kinetics of materials. Reilly et al. [5] introduced a method that investigates the long-term impacts of storage condition on chemical deterioration of organic materials and evaluates combined effects of temperature and relative humidity on conservational quality of storage in museums. Effects of variations in temperature and relative humidity on storage quality can be measured by Time-Weighted Preservation Index in their proposed method. This index helps researchers compare storage conditions for different museums and determine the most deteriorating conditions for different objects in collections.

The subsequent researchers have used diverse methods to assess vulnerability of objects in museum exhibitions or storages. A majority of these studies have considered the role of exhibit or storage conditions in creation of damages. Temperature, relative humidity, and pollution have been the main environmental deteriorating agents in many of these studies. For example, Waller [6] described risks of improper levels of temperature and relative humidity as constant and gradual risks for museum objects or collections in storage. Martens et al. [7] studied the role of conservation and preventive conservation on climates in museums and historical buildings. This study mainly focused on decreasing variations in temperature and relative humidity regarding to different standards of exhibit and storage spaces for museum objects and staffs. Schieweck et al. [8,9], Reilly et al. [10] and Steeman et al. [11] have developed evaluating techniques for the assessment of air quality, the behavior of temperature and relative humidity, and their detrimental effects on the objects in historic buildings, museums and storages. Krüger and Diniz [12] monitored temperature and relative humidity data inside and outside of several museums in Brazil and compared their storage conditions and the deterioration process in papers according to preventive conservation standards and TWPI (Time-Weighted Preservation Index) method. Martens [13] mentioned climate risk assessment with especial emphasis on temperature and relative humidity. In his research, in addition to assessing the effects of climate on objects according to the standards, he used simulated data and evaluated the effects of temperature and relative humidity in a determined interval of time on deterioration of museum objects. Huijbregts et al. [14] applied a damage function to estimate damages for the objects that are exposed to varying climates. Their method used lifetime multiplier for chemical degradations, germination curves for biological damages, and stress-strain as the main factor for mechanical damages. Their lifetime multiplier was calculated for a constant level of T and RH. Other recent topics about the effects of environment on museum objects can be found in the studies of Karaca [15], Huijbregts et al. [16] and Balocco et al. [17] that have used scientific/quantitative methods to evaluate risks on the historic objects.

A significant portion of the studies in the field of conservation belongs to the analysis of environmental agents and their deteriorating effects on vulnerability of museum objects and artefacts. The long-term effect of the storage condition changes the physical and chemical properties of objects. Hence, a group of researchers in the field of preventive conservation have tried to evaluate or estimate the effects of temperature, relative humidity, light, etc. on objects permanence and create experimental methods or logical relations in order to create a mechanism for predicting the future conditions of museum objects and collections.

Preservation Index (PI) makes it possible to assess the effects of storage condition on organic materials in the museum collections. The main assumption in using PI and TWPI is that temperature and relative humidity interactions accelerate or decelerate chemical deterioration of organic materials. Therefore, we can use them for different sets of temperature and RH in a determined period to estimate permanence of objects and evaluate the efficiency and effectiveness of storage condition. Of course, it would be necessary to incorporate experimental methods with these indexes in order to include essential characteristics of the objects like activation energy in assessment of permanence.

2. Research aim

The ability to quantify the effects of environmental conditions on objects permanence is a prerequisite for physical modifications in the storages and employing (or improving) HVAC systems. According to Reilly et al. [5], PI and TWPI evaluate simultaneous effects of temperature and relative humidity on chemical deterioration of organic-based objects. In addition to these external factors, activation energy of the object, which is related to its chemical characteristics and structure, is the main internal factor that has an influence on the deterioration rate of different objects.

In our proposed method, we have estimated the permanence of objects in museum collections for a single or a set of temperature and RH data in a specific period. This measure can guide scholars and museum managers analyze current storage quality for different collections (mostly textiles, papers, paintings and images) and decide about the investment priorities that are necessary to improve environmental conditions by changing temperature and RH levels.

Different objects – although categorized in the same collection – might differ in structure and characteristics and display diverse vulnerability against environmental conditions. Therefore, it is key part of the study to employ practical methods to identify their structure and features.

3. Methodology

Quantitative risk assessment calls for a measurable index in order to analyze the effects of storage condition on museum objects. There are different aspects about the deteriorating agents of museum objects that might be more or less effective in diverse conditions. In this research, we have focused on the organic-based objects and considered TWPI as our risk assessment index that is directly related to the chemical deterioration of objects.

Water plays an important role in most chemical reactions, whether as catalyzer or a reactant. Moisture level is one of the factors that affect the deterioration of organic-based objects in hydrolysis reaction, which is directly linked to the relative humidity of the climate or microclimate of the object. As for the second factor, each reaction has quantified sensitivity to the temperature (T) and it usually progresses faster with the increase of T. As mentioned by Sebera [18], when T and RH change simultaneously from its primary condition (T_1, RH_1) to a different level (T_2, RH_2) in the storage