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AN EXPERIMENTAL STUDY ON THE PRESERVATION OF WOODEN ARTIFACTS DISCOVERED DURING ARCHAEOLOGICAL EXCAVATIONS: A CASE STUDY OF WOOD AND LACQUERWARE FROM THE CITY OF KHAR BALGAS

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ABSTRACT

This Research methodology for the conservation of painted wood products with water content found in archaeological excavations from the Eurasian steppe region has not yet been conducted in Mongolia. Therefore, it aimed to explore and localize restoration methods to preserve and extend the lifespan of wood products with water content found in archeological excavations. Research has shown that it is possible to use sugar solution to strengthen wooden articles found during archeological excavations in the territory of our country, which has an extreme steppe climate, to make for exhibits, and to extend their lifespan based on our laboratory and resources. The wood products found 200 pieces in the Uyghur Kharbalgas Palace, well wooden lighters found in Jujan's tomb were completed between July 23, 2020, and March 2022.

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INTRODUCTION

Annually, domestic and international teams conduct no fewer than one hundred archaeological field research excavations in Mongolia(Oyuntulga M. Museum Studies 2017). As of the previous year, archaeological research and excavations were conducted in 200 soums across all 21 provinces of Mongolia in compliance with relevant regulations. These efforts resulted in the discovery of hundreds of new monuments dating from the Stone Age to the 17th century, along with numerous additional significant findings (Mongolian Archaeology 2023). The artifacts uncovered during these excavations, including pottery, building materials, and bricks, typically do not necessitate specialized preservation methods. In contrast, more delicate materials such as wood, lacquer, and textiles are highly susceptible to degradation and present significant conservation challenges. Despite the annual discovery of fragile artifacts during archaeological excavations, these items' systematic preservation, protection, and integration into research frameworks have yet to be effectively implemented in Mongolia. The primary cause of deterioration for fragile artifacts discovered in tombs and burial sites lies in their initial storage in stable, subterranean environments. Upon excavation, these items are exposed to external environmental factors, which significantly increase their vulnerability to damage and degradation. Drawing upon foundational principles of preservation and protection, the challenge arises in safeguarding these artifacts both during short-term and long-term exposure at excavation sites. This includes conducting material analysis, reinforcing the items using internationally recognized conservation methods, and preparing them for exhibition in stable museum environments. Furthermore, the process entails the development of the artifacts from their initial discovery through to comprehensive research, ultimately facilitating their transformation into viable tourism products. Japan employs various methods for the preservation of wooden artifacts, one of which involves the use of a Trihalos resin solution. Given Japan's rich cultural and historical heritage, coupled with the increasing number of artifacts uncovered through archaeological excavations each year, the challenges of restoring, strengthening, and displaying these objects have become increasingly prominent. In response, new scientific methods for conservation are continually being developed. Among these, the use of a PEJ solution—created by mixing resin with water—has been employed as a method for restoring and repairing wooden artifacts (Oyuntulga, 2020, p. 114). The restoration process utilizes PEJ solutions at concentrations of 20%, 40%, 60%, 80%, and 100%, a method that has been employed in Japan since 1988. Research indicates that it requires approximately 50 years to restore 2,000 artifacts using this approach. However, a significant drawback of this method is the prolonged restoration period, as the PEJ solution gradually permeates the artifacts during the process. Faced with the challenge of restoring thousands of artifacts in a relatively short period, researchers developed and tested a Lacchtol solution, which bears similarities to the PEJ solution. Lacchtol, a sugar-based solution derived through specialized technology for use in food products, has an 80% concentration in its saturated form, compared to the 100% saturation of the PEJ solution. Following a report on the Lacchtol solution, Koji Ito, Director of the Osaka Institute of Cultural Heritage Preservation, adopted this method for restoration. However, the Lacchtol solution exhibited a notable limitation: it penetrated certain areas of the artifact but failed to permeate others. This discrepancy raised concerns regarding its efficacy, prompting the decision to apply and spray the solution on the external surfaces of the artifacts. Daily experimentation was conducted to explore various application methods. In some instances, portions of the artifact adhered to the platform, with the solution settling and adhering to specific areas. Consequently, researchers attempted to apply the solution externally while using a fan to facilitate drying. Both approaches involving the sugar solution were found to have limitations, prompting scientists to initiate further research aimed at refining and improving these methods through continued testing of alternative techniques. Building upon the Lactol solution restoration method, a new restoration approach utilizing a Trehalose solution was introduced in 1996. This method was adopted by research institutions in Japan, Russia, and Hungary throughout the 1990s and up until 2009. Japanese researchers initiated trials of the Trehalose solution in 1990, and by 1996, it had gained widespread application in research settings. After a decade of testing, Trehalose was demonstrated to offer superior results compared to the PEJ and Lactol methods. Additionally, the rising cost of Lactol led to a decline in its usage, resulting in the closure of Lactol production facilities in Ireland and Japan.

The subject of our current research is the site of the ruins of Khar Balgas of the Uyghur capital, located in the Khotont soum of Arkhangai province. The site features a fortress-like structure known as the Ordon City or Citadel, which constituted the central part of a vast urban area spanning 35 square kilometers. This city was established by the second khan of the Uyghur Empire in the mid-8th century. Approximately a century later, the city was attacked and destroyed by the Kyrgyz, longstanding adversaries of the Uyghurs. The remnants of the Citadel, or Ordon City, remain visible from a distance in the heart of the steppe. In 2018, a joint Mongolian-German research team conducted archaeological excavations at this site, uncovering a 12-meter-deep well. The well-contained water and its wooden structure were remarkably well preserved. Numerous well-preserved artifacts were retrieved from the bottom of the well, including several wooden objects that have since been restored. In the future, we plan to develop and undertake experimental research focused on strengthening painted wooden artifacts discovered during archaeological excavations in Mongolia. This research will explore the use of solution-based methods to preserve the original form, structure, and coloration of these objects. This article aims to present the results of our experimental research on wood and lacquerware that were reinforced using the solution-based strengthening method for restoring wood with high water content. This method, developed by Japanese researchers Tetsuo Imazu and Koji Ito, has been employed internationally since 1990. Specifically, in 2018, a collaborative Mongolian-German research team undertook the strengthening and restoration of over 200 artifacts, including wood and lacquerware recovered from the 12-meter-deep Ordon Well in Khotont Soum, Arkhangai aimag—located in the former capital of the Uyghur Empire—as well as a wooden lighter from the Jujan tomb. These restoration efforts were carried out using methodologies tailored to the unique characteristics of the artifacts.

METHODOLOGY

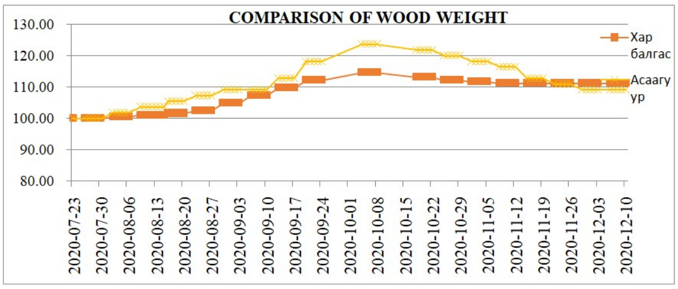
This study was conducted in the laboratory of the Kharkhorum Museum from 2019 to 2022. The necessary equipment for the research was provided by the Ministry of Environment, and Tourism, as well as the Ministry of Culture, through the project of the Fund for promoting Culture and Art. The laboratory was outfitted with various instruments, including a drying oven, drying tank, sugar solution measurement device, crystal cleaning apparatus, Trehalose sugar, and other restoration-related equipment. To identify tree species, a method involving expert sample preparation was employed. Three cuts were made with a thin knife for each sample: a cross-sectional cut of the tree ring, a vertical section, and a tangential section. The samples were then placed on 0.03 mm thick glass slides, with a cover glass applied and adhered using Mount-Quick “Aqueous” water-drying glue, followed by a 24-hour drying period. The prepared specimens were magnified using a cell microscope, with magnification ranging from 40 to 1000 times, allowing for comparison of the wood’s structural characteristics with the actual specimen to determine the species. In selecting the solution method, the Trehalose solution was chosen after laboratory tests compared the crystallization rates of Trehalose, Lactitol, and two other compounds.

THE RESULTS

As a result of this research, over 200 artifacts, including wood and lacquerware retrieved from the 12-meter-deep Ordon Well in the city of Kharbalgas, the capital of the Uyghur Empire, as well as wooden lighters found in the Jujan tomb, were reinforced using a Trehalose sugar solution. The solution was prepared in a tank, and the wooden objects were impregnated with the solution at concentrations ranging from 20% to 70%. The Trehalose sugar solution was observed to form two types of crystals: Crystals and Amarpass. Trehalose is a natural, non-toxic compound that, due to its fine texture, penetrates deeply into the wood without promoting the growth of mold or mildew, even after prolonged use. The treated wooden objects were then hardened in a saturated solution and allowed to crystallize at room temperature. Subsequently, the crystals were carefully cleaned, and the shape of the wooden objects remained preserved throughout the process. As the concentration of the solution was increased, its viscosity also rose. The process of solution absorption into the wood was monitored daily using a weighing scale. Based on these measurements, a graph was constructed to track the progress of absorption. Once the weight of the wood stabilized, the concentration of the solution was subsequently increased. Through the application of expert techniques and tools to measure solution concentrations and analyze wood species, it was determined that deciduous and coniferous trees comprise the majority of the wood samples. Storing the restored and reinforced wooden objects in a controlled environment will enable the preservation of these artifacts in their original form for centuries to come. The optimal conditions for the long-term storage of wooden artifacts are a temperature range of 15-20°C and a relative humidity of 50-60%. Given the presence of various detrimental factors, such as fungi, insects, bacteria, organic acids, and volatile compounds like formaldehyde and ammonia, which are commonly associated with hot and humid environments, it is essential to conduct comprehensive studies on environmental pollution and other related factors that may affect the preservation of these materials.

Figure 1. Illustrates the setup of the drying oven and tank, which will serve as the foundation for the subsequent reinforcement process

Both Trehalose and Lactitol solutions consist of fine particles, which facilitate the rapid penetration of the sugar into the wood. This is due to two primary factors: first, the solutions are fine-grained, with 10% of the solution consisting of water and the remaining portion being sugar; and second, the sugar dissolves quickly in water. Once the solution penetrates the wood, the water evaporates rapidly, leading to the formation of sugar crystals. The efficient crystallization process prevents decomposition, thereby preserving the shape and color of the artifact. When the practice of reinforcing wooden objects with sugar solutions was introduced in our country, we conducted experiments with lactate and Trehalose to determine which formed finer crystals. Consequently, restoration work was carried out for five years.



Диаграмм 1. Модон эдлэлийн хадгалалт хамгаалалтын өнөөгийн байдал

Figure 2. Demonstrates the sealing of wood products using the RP (Reinforcement Process) method

Figure 3. Trehalose

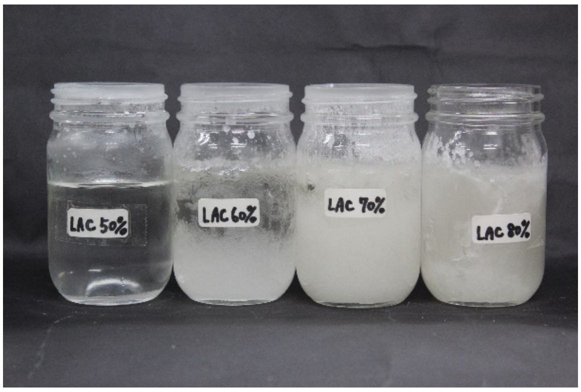


Figure 4. Lactitol

As a result of the research, approximately 200 complete and fragmented wooden pieces were reinforced using a Trehalose resin solution. Wood artifacts retrieved from the ruins of the Ordon Well in the KharBalgas of the Uyghur capital were analyzed to determine the tree species. The primary cellular component of the wood artifacts was identified through the genetic structure of cellulose. Unlike pollen grains and fossils, wood is less mobile, making it a valuable indicator for determining the local vegetation and identifying tree species. A total of over 30 tree samples were collected and studied. The majority of the wood artifacts were found to be larch. Larch wood is characterized by its straight grain, durability, and hardness, making it the hardest among coniferous species. While the wood's surface is rough, its grain is visible. If the central part of the wood is not adequately removed or dried during processing, there is a heightened risk of cracks and fissures developing in the trunk, as well as wood distortion, shrinkage, and the appearance of black spots on the surface. Larch is primarily used in construction, shipbuilding, and the manufacturing of various tools and equipment. In Japan, distinct species of larch are found, whereas Siberian larch predominates in Mongolia.

Figure 5. depicts Ruins of KharBalgas of the Uyghur, as documented by the Mongolian-German Expedition in 2019. The image specifically highlights the 12-meter-deep well discovered during the excavation

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Table 1. Presents a list of tree taxonomy, as classified by Kaneahrara Yumiko

No	Result （tree taxonomy）		Explain
024	*Larix*	Larch	
029	*Abies*	Jodoo	Long, large piece of wood without cross-section
030 1	*Larix*	Larch	
030 2	*Larix*	Larch	
030 3	*Larix*	Larch	
032	*Larix*	Larch	
033	charcoal fraguments	Carbonated	
034	*Larix*	Larch	
038	Bambusoideae	Bamboo	Cross section
039	*Abies*	Jodoo	
040	*Betula*	Birch	
043	*Betula*	Birch	black lacquerware
047	*Lagenaria siceraria* Standl.	Rice	Broken fragment
052	*Abies*	Jodoo	piece of black lacquer shell
097	*Betula*	Birch	ball
103 1	*Larix*	Larch	
103 2	*Betula*	Birch	
106	*Larix*	larch	
107	charcoal fraguments	Carbonated	
108	*Larix*	Larch	
109	*Larix*	Larch	
109	*Larix*	Larch	
113 1	*Larix*	Larch	
113 2	*Larix*	Larch	
115	*Larix*	Larch	
116	*Larix*	Larch	
118	*Larix*	Larch	
119	*Larix*	Larch	
120	*Larix*	Larch	
126	*Betula*	Larch	
127	*Larix*	Larch	
128	*Larix*	Larch	
129	*Larix*	Larch	
131 1	*Larix*	Larch	
131 2	*Larix*	Larch	
133	*Larix*	Larch	

CONCLUSION

This article presents the findings of a study focused on the strengthening and restoration of over 200 artifacts, including wood and lacquerware, recovered from the 12-meter-deep Ordon Well in KharBalgas of the Uyghur capital, located in KhotontSoum, ArkhangaiAimag, as well as a wooden lighter discovered in the Jujan tomb. The research demonstrated that wooden artifacts uncovered in the archaeological excavations of the steppe region, characterized by its harsh climate, can be effectively reinforced using a sugar solution. These artifacts can subsequently be displayed as exhibits and preserved. Wooden and metal artifacts are not only distinctive examples of nomadic art but also significant representations of craftsmanship and foreign relations. The wooden artifacts uncovered at the monument are being reinforced using Japanese methodologies and stored in a controlled environment for preservation. Throughout this research, a novel technique for strengthening wood and lacquerware with Trehalose syrup was developed and successfully implemented in Mongolia. A key outcome of the study is that certain artifacts treated with this method can now be exhibited at both domestic and international exhibitions, further showcasing the potential for their long-term preservation and cultural significance. This research is significant for enhancing the expertise of professional restorers, archaeologists, and students, as well as for improving the restoration and preservation practices of wooden artifacts. Additionally, it contributes to the development of an independent methodology that aligns with the core principles of conservation science. Moving forward, plans are in place to conduct further experiments and research on strengthening painted wooden artifacts uncovered during archaeological excavations in Mongolia. These studies will focus on the application of solution-based methods to preserve the original form and coloration of the objects, ensuring their long-term conservation.

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