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Exploring the Application of Green Chemistry in Textile Heritage Conservation and Restoration with the Example of Buzi

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Abstract

Textile conservation and restoration is challenged by environmental damage and the inadequacy of traditional methods, especially for precious textile heritage such as Buzi from the Ming and Qing dynasties. This study aimed to explore the application of green chemistry in textile heritage conservation and restoration by cleaning textiles gently and effectively, and also reinforcing, mending, and dyeing while reducing environmental impacts. It was found that methods such as green cleaning agents were valid in removing stains from Buzi, as well as maintained their texture and color integrity, and were environmentally friendly. Green chemistry methods show great potential to conserve heritage and reduce the environmental burden effectively. Green chemistry has a promising future in textile heritage conservation and restoration, contributing to the sustainable conservation and preservation of textile heritage.

Keywords: *Conservation and Restoration, Textile Heritage, Cultural Heritage, Green Chemistry, Buzi.*

Introduction

Textile protection and restoration are divided into two main categories: preventive protection and restorative protection. The main purpose of preventive conservation is to prevent further damage to textiles, which includes controlling environmental conditions such as humidity, temperature, and light, as well as taking measures to prevent insects and mold. Restorative protection, on the other hand, is aimed at repairing textiles that have already been damaged, including steps such as cleaning, reinforcing, mending, and dyeing, to restore the original appearance of textiles or extend their service life. Specific protection methods include physical cleaning, using dusting tools to remove surface or internal impurities; chemical cleaning, using chemical reagents to remove pollutants, which is divided into wet cleaning and dry-cleaning technology; and biological cleaning, using enzymes and biological metabolism to generate water-soluble substances to achieve the cleaning of this method is safe and environmentally friendly. Reinforcement methods mainly include needle and thread repair methods and silk screen reinforcement technology. Repair technology covers silk thread articulation embroidery repair methods, similar fabric lining repair methods, integration and restoration methods, etc., according to the different conditions of the textiles to choose the appropriate repair method. In addition, other protection methods such as anti-insect and anti-mold treatment and scientific storage are also included to ensure the long-term preservation of textiles. [1]

Among other things, green chemistry shows great potential for application in textile conservation and restoration, with its core concepts running through several key aspects. For example, environmentally friendly and efficient solvents and cleaning agents not only effectively remove stains and pollutants from textiles, but ensure the integrity of their texture and color, achieving the dual goals of cleaning and protection. Using biodegradable materials such as natural fibers and biopolymers as reinforcement and restoration materials significantly reduces the load on the environment during the restoration process. Non-toxic, non-hazardous, and biodegradable dyes maintain the vibrancy and durability of textile colors and further contribute to the environmentally friendly process of textile restoration as well. Nanomaterials and bio-enzymes, etc., are being innovatively applied in the repair of Buzi. Furthermore, surface treatment

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technologies of green chemistry, such as plasma treatment and ultrasonic treatment, significantly enhance the durability and resistance to contamination of textiles by improving their surface properties. These cutting-edge technologies demonstrate the promising future of green chemistry on its part in textile heritage preservation.

Buzi, also known as 'chest and back' or 'official robe', is the Ming and Qing dynasties in the official clothing chest or back of a round or square fabric [2]. Its material composition mainly consists of base material and embroidery thread. The backing is usually made of high-grade silk materials such as a damask to ensure the texture and luster of the Buzi. Embroidery threads, on the other hand, mainly use gold and silver threads as well as colored silks to embroider exquisite patterns [3]. However, with time, Buzi will fade, brittle, torn, and worn due to natural aging, external force, chemical substances, and biological factors, which affect the preservation and display of mending. To protect and pass on the valuable Buzi heritage, the usage of green chemistry in textile heritage preservation and restoration is particularly crucial [4].

By taking Buzi as an example, the question 'How can green chemistry be gently and effectively used to stain removal of textile heritage?' can be explored in depth to investigate relevant methods for the preservation and restoration of textile heritage. The question will be researched to study the involved methods for the cleaning of Buzi, which will contribute to the wisdom and strength of promoting the sustainable development of textile heritage conservation. At the same time, this research will also provide useful reference and inspiration for the conservation and restoration of other textile heritage.

Fundamental of Green Chemistry

Known as Environment Harmless Chemical or Environmentally Friendly Chemistry, green chemistry aims to meet the needs of the present generation without compromising the ability of future generations to meet their needs sustainably. It emphasizes the minimization or elimination of negative impacts on human health and the environment throughout the life cycle of chemical products, from design and manufacture to application and disposal. [5]

Put green chemistry principles to the conservation and restoration of cultural heritage in textile materials needs to follow the principles of minimizing intervention to maintain the original appearance of the artifacts, adopting reversible conservation materials and restoration techniques for future adjustments, ensuring non-hazardousness to avoid new contamination, prioritizing renewable, biodegradable or recyclable materials and techniques to achieve sustainability, carrying out scientific assessments to determine appropriate options, and conducting continuous monitoring and scientific assessments to determine appropriate programs, and continuous monitoring and documentation throughout the process to ensure the quality and effectiveness of protection and restoration.

Status of Textile Research and Multidisciplinary Integration

Current research on textile heritage covers a wide range of areas including environmental protection, cultural heritage conservation and restoration, materials science, art and culture, artificial intelligence applications, and heritage management.

Previous studies have focused on the field of environmental protection, especially on dye contamination. Sharma and others have demonstrated the effectiveness of biodegradation by Pseudomonas fluorescens and Bacillus subtilis for decolorization of Acid Blue 9 (AB9) using biodegradation method [6]. The use of nanoparticle catalytic oxidation in the treatment of textile wastewater has also been explored to reduce environmental pollution and improve water utilization [7]. These studies aim to promote the application of sustainable development and green technologies and to provide new ideas and methods for solving environmental pollution problems.

The cultural heritage conservation has also received attention, with Amin and Rashed using a variety of techniques for textile restoration and conservation, such as scanning electron microscopy (SEM) and ultraviolet (UV) spectrometry, to identify and analyze fibers, and to determine the types of dyes and binders

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[8]. Gao, Xu, He, and Tian also explored the use of digital media technologies in the inheritance of cultural heritage, such as virtual restoration and display techniques [9], and the creation and promotion of digital archives [10]. These studies aim to extend the lifespan of cultural relics, to pass on and promote outstanding traditional Chinese culture, and to promote the application of digital humanities technologies in cultural heritage preservation. Previous research has also introduced other cultural heritage conservation techniques, such as the behavior of laser cleaning technology in the protection of textile artifacts [11, 12] and the effectiveness of hydraulic suction in cleaning historical tapestries [13-15]. These studies aim to enhance the standard of heritage conservation and promote the development and application of related technologies.

Materials science aspects, such as, Nwuzor and others developed dye extraction techniques and optimized the extraction process using response surface methodology such as the use of central composite design (CCD) and locally manufactured combined dye extractor and dryer which successfully extracted dyes in a shorter period and at higher temperatures at a higher extraction rate [16]. These studies aim to promote the application of sustainable natural dye extraction techniques and novel materials with the use of advanced analytical techniques for artifact studies. Abdel-Kareem and Sulochani also focused on the development and application of novel materials such as composites made from discarded textiles and packaging materials from the textile industry and assessed the feasibility of their application in the construction sector [17, 18]. These studies aim to promote the circular economy model and sustainable development, as well as to provide new ideas and methods for solving environmental pollution problems.

The art and culture have received equal attention. Studies have inherited and promoted the excellent traditional Chinese culture through the restoration and conservation of textile relics. For example, Amin and Ahmed restored and conserved Abbasid-era textiles from the Egyptian Textile Museum and demonstrated the effectiveness of needle and thread support techniques in reinforcing fragile textiles [8,19]. Gao and someone also utilized digital media technologies, such as VR and AR, to enhance public participation and cultural experience, and to promote the transmission and development of cultural heritage. For example, they constructed a 4-layer architecture prototype system for knowledge organization of farming image resources and analyzed its application value to promote the development of farming culture research [9]. These studies aim to preserve historical and cultural information, promote cultural heritage and development, and facilitate cultural exchange. Researchers have also focused on the digital preservation and knowledge organization of farming images and explored their application values, such as spatiotemporal dimension analysis, production technology analysis, content composition analysis, and social communication research.

The application of artificial intelligence technology in cultural relics conservation has also received attention. Researchers have used AI technology for intelligent management of cultural heritage data, such as clustering, analysis, and retrieval of cultural relics, to promote preventive conservation [11]. AI technology is also used for virtual restoration and display of cultural relics to expand the way of displaying cultural relics and break the space-time limitations. For example, TOF-SIMS coupling technology has achieved in situ, non-destructive, micro-area analysis of wool fabric dyes from the Han Dynasty in Xinjiang, successfully identifying the blue dye as indigo and the red dye as vermilion [15]. These studies aim to enhance the efficiency and precision of heritage conservation, promote preventive conservation, and expand the ways of displaying cultural relics.

Heritage management researchers have elaborated on the principles of preventive conservation, minimal intervention, and reversibility, and introduced specific measures for heritage management in museums, such as systems, environments, technologies, archives, and staff training. They emphasized the importance of advanced heritage conservation technologies, such as non-destructive testing, digital technology, and virtual reality, which have injected new dynamics into heritage conservation [20]. In addition, much attention has been paid to the challenges of heritage management, such as environmental factors, human factors, technological limitations, and financial investment [12]. These studies aim to ensure the safety of cultural heritage, prolong the life span of heritage, and promote cultural exchange.

In conclusion, research in textiles has made remarkable progress but still faces many challenges. Especially in the field of conservation and restoration of cultural heritage [21]. These include the complexity and

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uncontrollability of microbial communities, the relatively high cost and low efficiency of green methods, negative public perceptions of microorganisms, damages caused by environmental factors, threats from pests and microorganisms, challenges of complex restoration techniques, aging problems of materials, and insufficient stability of nanoparticle catalysts. Therefore, gentle and effective removal of textile heritage stains using green chemistry is a matter of importance in this study.

Green Reagents in Textile Heritage Conservation and Restoration

Buzi heritage may be subjected to a variety of conditions under the influence of environmental factors such as temperature, time, light, and moisture [22,23]. For example, high temperatures lead to brittleness and color fading of the Buzi fibers. Low temperatures lead to hardening and physical damage such as cracks and fractures. Frequent temperature fluctuations accelerate aging. The strength of the Buzi fibers decreases with time. Strong ultraviolet radiation causes discoloration of the Buzi. High humidity causes the Buzi to absorb water and expand, increasing the risk of deformation and tearing. Low-humidity environments cause the Buzi to dehydrate, making it fragile. Moisture penetration into the interior of the Buzi can lead to problems such as mold growth and corrosion, which can damage the structure and integrity of the Buzi. Therefore, special care should be taken to control these environmental factors when preserving and displaying the Buzi to ensure their long-term preservation and display [19]. Of course, this condition is controllable but unavoidable.

However, the greasy, pigmented, and protein stains carried by the Buzi can be cleaned and restored by chemical, biological, and physical methods [24]. Researchers need to choose appropriate cleaning methods and cleaning reagents according to the specific situation. Table 1 demonstrates the conventional cleaning reagents and their functions and also shows that there is room for improvement in the reagents. There is a need to discover innovative green reagents for environmentally friendly and effective restoration.

Table 1. Uses and Shortcomings of Traditional Cleaning Agents

Conventional Cleaning Agents	**Usage**	**Disadvantages**
Physical cleaning with a soft brush	Dust and impurities on the surface	Not effective in removing deep or stubborn stains.
		For textile artefacts that are fragile or delicate in texture, the use of physical cleaning agents may cause damage.
Aromatic hydrocarbons	Unsaturated oil stains	Higher toxicity, especially benzene, must be used with safety precautions to prevent poisoning.
		It evaporates slowly and may cause some damage to textile artefacts, such as fading colors or brittle texture.
Alcohol compounds	Insect glue, resin, varnish, paint stains	Improper use may cause damage to textile artefacts, such as breaking fibers or fading colors.
		Alcohol cleaners are flammable and need to be used safely.
Acetone, ethyl acetate and other solvents	Nitrocellulose adhesive, acetate-based adhesive stains	Careful handling is required to avoid scratching textile artefacts.
		Solvents evaporate quickly and may cause some damage to textile artefacts.

It was found that the following two types of cleaning agents can make up for the shortcomings of traditional cleaning agents, as shown in Table 2, which can be selected based on natural ingredients, such as plant extracts or biological enzyme agents, avoiding the use of harmful chemicals [25]. During the cleaning process, care should be taken to control the water temperature and cleaning time to avoid damage to the Buzi. The Buzi can be soaked in a diluted green cleaning agent and gently scrubbed or gently brushed with a soft brush to remove stains and impurities. After rinsing with clean water, dry the patch naturally or

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use a low-temperature dryer to avoid damage to the Buzi caused by high temperature.

Table 2. Green Reagents and Their Benefits and Contributions

Green Cleaning Agent	Advantages	Bridging the Gap Between Traditional Methods
Bio-enzymes, bio-surfactants, bio-flocculants	Suitable for a wide range of safe and environmentally friendly applications.	For toxic reagents that cause negative changes in textiles, e.g. aromatic compounds, alcohols.
	Non-toxic, harmless, easy to degrade, in line with environmental requirements.	
	Safe, scientific and effective prolongation of the life of cultural objects.	
Very fine bran mixed with detergent solution (surfactant) or organic solvent with a little vinegar	It can be used on delicate textiles that cannot be washed wet or dry.	For reagents that do not work on fine textiles and are more damaging to artefacts, e.g. physical cleaning of soft brushes, aromatic hydrocarbons, solvents such as acetone and ethyl acetate.
	By covering textile stains, the stains are dissolved or dispersed and then removed cleanly with less damage to textile artefacts.	

When cleaning textile heritage, green chemistry can be used to ensure that its integrity continues; similarly, green conservation concepts can be put into practice during subsequent reinforcement, mending, and dyeing processes. For reinforcement, polymeric reinforcements such as natural resins or plant fibers are applied to the fragile parts of the Buzi in an appropriate and even manner, to enhance its structural stability and to avoid overloading and hardening. For mending, cotton or silk threads similar to the material and color of the Buzi material are used, and the mending material is firmly bonded to the damaged area through concealed mending methods such as flat stitching or backstitching. As for dyeing, environmentally friendly vegetable or mineral dyes are used, and the dyeing conditions are finely adjusted according to the characteristics of the dyes and the materials of the Buzi, including immersion time, temperature, concentration of the dye solution and pH value, to achieve even dyeing results. After dyeing, appropriate color-fixing treatments, be they thermal or chemical, are carried out to enhance the firmness of the dyeing and safeguard the intactness and beauty of the textile heritage in all aspects.

During the conservation and restoration process, it is important to keep the working environment clean and strictly control the parameters, such as temperature, time, and consistency, to ensure effectiveness. At the same time, regular maintenance of the equipment is carried out, starting with a small test of the cleaning agent in a hidden place, cleaning with a mild detergent and a soft bristle brush, avoiding scratches, and drying quickly after cleaning. For stubborn or special stains, consider seeking professional help or using special methods [26].

Result and Discussion

This study focuses on the use of green chemistry techniques in the field of textile heritage conservation and restoration, particularly for the conservation and restoration of rare textile materials such as the Ming and Qing period Buzi. The research results reveal that traditional cleaning means, such as physical cleaning using soft brushes and reliance on solvents such as aromatic hydrocarbons, alcohol compounds, acetone, ethyl acetate, etc., have significant drawbacks, including incomplete cleaning effect, high toxicity, easy volatilization, and the possibility of irreversible damages to textile artifacts. In contrast, green cleaning media, such as bio-enzymes, plant extracts, etc., show great potential, they are not only safe and environmentally friendly, but non-toxic and easily biodegradable, to meet the needs of environmental protection. In practice, these green cleaning agents can efficiently remove stains from the surface of patches

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while maintaining their original texture and color. In addition, the study points out that the use of polymers such as natural resins or plant fibers as reinforcement, as well as the use of hidden stitching techniques and environmentally friendly dyes for coloring, can all be used to implement the principle of green conservation while preserving the textile heritage. Precise control of parameters such as temperature, duration, consistency, etc., as well as regular maintenance of the equipment during the conservation and restoration process, are essential to ensure the effectiveness of conservation and restoration.

Conclusion and Outlook

The conclusions of this study show that green chemistry has demonstrated significant advantages in textile heritage conservation and restoration, especially when dealing with precious textiles such as Ming and Qing period Buzi, where its gentle yet effective cleaning not only effectively removes stains, but also maintains the texture and color integrity of textiles, while greatly reducing the negative impact on the environment. Through the use of green cleaning agents such as bio-enzymes and plant extracts, as well as natural resins or plant fiber reinforcements and environmentally friendly dyes, this study has successfully explored the concept of green conservation and provided strong support for the sustainable conservation and inheritance of textile heritage. In the future, with the continuous development and innovation of green chemistry technology, the prospect of its application in the field of textile heritage conservation and restoration will be even broader. Researchers need to continue to explore more efficient and environmentally friendly cleaning agents and restoration materials, and at the same time strengthen interdisciplinary cooperation, integrating knowledge from multiple fields, such as humanities, environmental sciences, artificial intelligence, etc., to enhance the technical level and effectiveness of conservation and restoration. In addition, strengthening public education and publicity to raise the awareness and attention of the whole society to textile heritage conservation is also an important direction for future work.

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