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# From Industrial Waste to Art: Innovative applications of jun porcelain waste in sustainable environmental design

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**Abstract**

Amid global emphasis on sustainability, the traditional ceramic industry faces high energy consumption and waste management challenges. This study explores transforming Jun Ware waste into practical and artistic design elements. The research highlights traditional processing issues by analyzing its sources and physicochemical properties and proposes innovative integration into modern design. This approach aims to reduce pollution, conserve resources, and enhance cultural significance. Applications include urban public spaces, landscape design, urban sculptures, murals, and installation art, thereby giving new life and value to Jun Ware waste.

Keywords: Jun Ware; environmental protection; waste utilization; design


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## 1.0 Introduction

Sustainable development is a focus of attention in countries all over the world, affecting not only current economic development but also the living environment of future generations. With rapid industrialization and modernization, the demand for resources has soared, leading to problems such as environmental pollution, ecological damage, and climate change(Tang, E., 2022). The traditional Jun porcelain industry, especially the high-end Jun kiln industry, has long been characterized by high energy consumption and severe pollution. Its production process consumes much energy and produces a lot of waste and air pollution. The main waste products of Jun porcelain include defective porcelain, sludge, and slag. If not properly treated, these wastes can cause large areas of land to become barren and cause severe pollution to the soil, water bodies, and the atmosphere. Jun porcelain waste is a typical type, and its value in environmentally friendly design is gradually being recognized and discovered. This project aims to provide new material resources for the green development of China's Jun porcelain industry through the sustainable use of Jun porcelain waste. The research on the physical and chemical characteristics of Jun porcelain waste and its applicability in design lays the foundation for the application of Jun porcelain waste in environmental protection(Wu, Z., 2023). Design schemes and application cases of Jun porcelain waste are analyzed


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and studied. Based on a complete understanding of the properties of waste Jun porcelain materials, the application possibilities of waste Jun porcelain materials in various environmental protection scenarios are explored using modern design ideas and methods.

## 2.0 Literature Review

In existing research, international scholars have explored the application of waste in new building materials. The emphasis is on minimizing the effect on the environment throughout the entire life cycle, from the selection of raw materials, the production process, and use to final waste disposal. Researchers have recently developed various methods to improve ceramic waste's recovery rate and quality (Chen, L., 2024). For example, it can be converted into reusable particles through pyrolysis or mechanical crushing. Some organizations have organized various activities for participants to experience the creative transformation of ceramic waste first-hand, promoting the inheritance and development of traditional culture. Zhang et al. (2023) discussed the application of ceramic waste in the manufacture of sustainable concrete, emphasizing the pozzolanic activity of ceramic waste and its potential to improve the performance of concrete. Gol et al. (2023) investigated the application of roof tile waste in the formulation of ceramic glazes. They evaluated waste's effect on ceramic glazes' performance through chemical analysis and surface hardness tests. Zaharie et al. (2022) explored the application of ceramic waste in the building materials industry, particularly as an alternative material for new gypsum mortars. The research validated the potential of ceramic waste in reducing the consumption of natural resources and promoting waste recycling through experimental verification. These studies explore the innovative application of industrial waste from different perspectives and demonstrate its great potential in environmental protection and sustainable development. Most of the research has certain limitations, and interdisciplinary cooperation and the application of comprehensive research methods still need to be improved, resulting in a single research perspective and making it difficult to solve the complex problems of transforming and utilizing ceramic waste (Liu, X., 2024). In addition, the connection between policy research and practical technology application needs to be closer, resulting in policy recommendations that lack practical operability.

## 3.0 Methodology

To ensure the depth and breadth of the research, this project will employ a combination of qualitative and quantitative research methods. The qualitative approach will include case analysis and literature review to analyze and summarize Jun porcelain waste's development prospects in art design. We will use quantitative methods to evaluate the waste's physicochemical properties(Wu, Z., 2023). This will include an experimental design to quantify properties such as water absorption, compressive strength, and the chemical composition of the waste. The research will encompass the treatment of waste materials, performance testing, and practical application evaluation. This comprehensive approach will reveal the waste materials' potential utilization value and limitations(Chen, L., 2024). We will systematically study Jun porcelain waste to gain a deeper understanding of its characteristics and utilization prospects. This will provide a theoretical basis for designing Jun porcelain waste, aiming to inform future applications and innovations in the field.

## 4.0 Findings

### *4.1 Physical Properties of Jun Porcelain Waste*

#### *4.1.1 Testing Physical Parameters Such as Density, Hardness, and Water Absorption of Jun Porcelain Fragments*

To test their physical properties, the author collected 8 Jun porcelain samples of different colors and glazes from various factories and kilns (Wu, Z., 2023). These tests provided relevant data. The fundamental physical parameters of Jun porcelain fragments include density and hardness (Lu, X., 2021). Density is a core indicator for evaluating the quality of solid waste, while hardness is crucial for assessing the wear resistance of solid waste. Accurate testing can determine its suitability for specific purposes, such as a lightweight filler for low-density waste or durable decorative materials for high-hardness waste (Han, F., 2021). The following are the test results for the physical properties of the Jun Porcelain Fragment Samples.

Table 1: Test Results of Physicochemical Properties of Jun Porcelain Fragment Samples

| Number/test category | Thermal shock resistance | Water absorption | Dissolution of lead and cadmium | | Flexural strength(MPa) | Hardness ($H_v$) | Density(g/cm³) |
|---|---|---|---|---|---|---|---|
| | | | Lead (mg/L) | Cadmium(mg/L) | | | |
| A | crack | 1.0% | 2.0 | 0.3 | 120 | 4 | 2.7 |
| B | NO crack | 2.0% | 1.0 | 0.3 | 100 | 4 | 3.0 |
| C | NO crack | 2.0% | 1.5 | 0.25 | 120 | 5 | 2.9 |
| D | NO crack | 1.0% | 1.5 | 0.3 | 100 | 4 | 2.6 |
| E | NO crack | 1.0% | 2.0 | 0.25 | 150 | 6 | 3.1 |
| F | crack | 1.0% | 1.0 | 0.25 | 110 | 4 | 2.8 |
| G | NO crack | 2.0% | 1.5 | 0.3 | 150 | 5 | 2.9 |
| H | NO crack | 1.0% | 2.0 | 0.3 | 160 | 6 | 3.2 |

*(Source: Author, 2024)*

Testing the physical properties of Jun porcelain fragments revealed excellent flexural strength, thermal shock resistance, and hardness (Zhang, Y., 2023). The fragments' flexural strengths consistently exceeded 100 MPa, indicating reliable performance and durability during daily display and use. The thermal shock resistance of the porcelain fragments was also favorable, with most pieces enduring high-temperature tests and rapid cooling without cracking, making them suitable for extreme weather changes or high-temperature conditions. The fragments had a reasonable water absorption rate, mostly below 2%, and a relatively high density of around 3.0 g/cm³, making them suitable as decorative filler materials. High water absorption rates make these materials ideal for decorative floor tiles, landscape design elements, ceramic grinding tools, and soil conditioners (Wang, L., 2023). Specifically, water treatment materials serve as filtration media in water treatment systems, efficiently eliminating suspended solids and pollutants to enhance water quality (Li, F., 2024). The lead and chromium leaching tests for Jun porcelain fragments were satisfactory, with levels within acceptable limits and meeting environmental standards. Samples A and D are classified as low-density waste and are suitable for use as lightweight fillers. In contrast, samples B, E, and H are classified as high-hardness waste and are suitable for manufacturing durable decorative materials.

*4.1.2 Plasticity and Renewability of Waste Materials*

In recent years, the aesthetic concepts of Jun porcelain have undergone significant changes, expanding from indoor decorative art to outdoor applications (Guo, S., 2018). Currently, the innovative reuse of Jun porcelain waste is a crucial topic. Artists, with their unique artistic vision, seamlessly integrate the texture, color, and other characteristics of Jun porcelain into their works, inspiring public imagination and promoting the sustainable development of modern Jun porcelain art. Artists can more deeply express their inner feelings and appreciate these works from different perspectives with Jun porcelain (Li et al., 2024). Recycling waste is a significant challenge due to its inherent characteristics, which often impose limitations. It cannot follow a fixed model and must adapt flexibly based on the waste's properties. Standard treatment methods include repairing with discarded gold lacquer, drilling and combining, reshaping after breaking, and adding various auxiliary materials to create new forms.

In Wang Ximeng's "A Thousand Miles of Rivers and Mountains," a lovely landscape painting, the artist sourced Jun porcelain waste materials from regions such as Yuzhou in Henan. He selected porcelain pieces of various colors and labeled them accordingly. Using unique restoration and gold-building techniques, he organically integrated these pieces. The final creation presents the distinctive scenery of "A Thousand Miles of Rivers and Mountains," depicting continuous mountain ranges, vast rivers, and tranquil villages. The painting is dense with boat shadows, vibrant colors, distinct mountain shapes, and rich, varied lines. The structure is clear, and the rhythm is dynamic and measured. These small, carefully pieced-together fragments form a unique sense of rhythm, with each turn encapsulating the flow of mountains and rivers (Chen, L., 2024). Using green and earthy yellow fragments, chosen for their resemblance to natural landscapes, Wang aimed to create a gradient of green tones. Despite the subtle differences between individual parts, they collectively produce a sense of visual depth and rhythm, with alternating distances and varying heights. "Heavy Mountains" creatively uses Jun porcelain waste and incorporates Dongyang wood carving, a constituent of Jiangnan culture, into its creation process.

Fig 1: Jun Porcelain Waste Artwork "Heavy Mountains"
*(Source: Photograph from various artist's studios, 2024)*

*4.2 Chemical Properties of Jun Porcelain Fragments*

*4.2.1 Composition Analysis of Waste Porcelain Fragments*

Chemical composition tests were conducted on the Jun porcelain fragment samples to assess their chemical stability, safety, environmental compatibility, weather resistance, and slip resistance(Hao et al., 2023). The chemical stability of these fragments is primarily attributed to the silicates and oxides that constitute these inorganic non-metallic compounds, which maintain their stability in high-temperature environments. Safety is ensured by the absence of heavy metals or other potentially toxic elements within safe standards(Peng et al., 2022). This is particularly important for materials used in public urban spaces, where Jun porcelain fragments, such as walkway bricks and landscape walls, frequently come into contact with people. Studying the chemical composition of Jun porcelain waste is crucial for understanding its chemical properties. Analyzing the waste's main components, like silicon, aluminum, and iron, evaluates its chemical stability and potential reactivity. These data are critical for determining the suitability of the waste in various applications. The following table presents the chemical composition test results of eight Jun porcelain fragment samples.

Table 2.Chemical Composition Test Results of Jun Porcelain Fragment Samples

| Number/ composition | SiO2 | Al2O3 | CaO | MgO | K2O | Na2O | Fe2O3 | TiO2 | CuO | ZnO | SnO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 66.16 | 18.62 | 0.65 | 1.26 | 1.87 | 1.98 | 0.18 | 0 .00 | 2.34 | 0 .00 | 5.18 |
| B | 71.26 | 17.72 | 1.31 | 1.56 | 0.78 | 1.40 | 0.38 | 0.00 | 0.69 | 0 .00 | 4.30 |
| C | 61.01 | 16.23 | 3.18 | 1.06 | 3.23 | 3.75 | 0.38 | 0.00 | 3.85 | 0 .00 | 6.26 |
| D | 70.14 | 16.19 | 1.02 | 1.53 | 0.85 | 2.04 | 0.35 | 0.00 | 0.67 | 0 .00 | 5.69 |
| E | 68.26 | 19.10 | 1.54 | 1.70 | 0.62 | 0.60 | 0.62 | 0.02 | 0.52 | 0 .00 | 6.80 |
| F | 68.10 | 18.60 | 0.35 | 1.36 | 0.34 | 2.50 | 1.76 | 0.01 | 0.05 | 0 .00 | 5.90 |
| G | 62.28 | 16.81 | 3.54 | 0.85 | 2.46 | 3.21 | 0.63 | 0.00 | 3.52 | 0 .00 | 4.41 |
| H | 64.31 | 18.80 | 3.31 | 1.06 | 1.02 | 2.36 | 0.26 | 0.01 | 1.53 | 0 .00 | 4.82 |

*(Source: Author, 2024)*

The test results analysis shows that samples A-H of the porcelain fragments have the highest content of $SiO_2$ and $Al_2O_3$, with $SiO_2$ exceeding 60% and $Al_2O_3$ exceeding 16%. The chemical composition of the glaze and porcelain body determines the chemical stability of the Jun porcelain fragments. The primary components, $SiO_2$ and $Al_2O_3$, ensure the excellent chemical stability of Jun porcelain. $SiO_2$ forms a stable glass structure, reducing the probability of chemical reactions in the material. The presence of $Na_2O$ and $K_2O$ in the Jun porcelain fragments lowers the melting point of the glaze, making the material more compact and further enhancing its chemical stability(Li et al., 2024). The fragments also contain $Fe_2O_3$ and CuO, which act as colorants and react with other chemical components to form a stable glaze color, indirectly enhancing the chemical stability of Jun porcelain. The high content of SiO2 and Al2O3 in the fragments endows them with excellent weather resistance, allowing them to withstand temperature changes, humidity, and ultraviolet rays. CaO and MgO in the fragments contribute to weather resistance by forming stable crystalline phases with silica, enhancing the glaze's resistance to weathering. Jun porcelain fragments' smooth and dense glaze surface prevents moisture and pollutants from penetrating, maintaining their appearance and performance in long-term outdoor use, which is especially important for applications in public urban spaces. The chemical composition analysis indicates that Jun porcelain fragments possess excellent wear resistance, determined by the body composition and sintering degree(Zhang, Y., 2023). The transformation of $Al_2Si_2O_5(OH)_4$ in the ceramic body into mullite ($Al_2Si_2O_7$) at high temperatures imparts high hardness and wear resistance. The $SiO_2$ component in the fragments also enhances wear resistance, preventing the material from breaking easily under external forces. The chemical composition of Jun porcelain fragments determines their chemical stability, weather resistance, and wear resistance, ensuring their long-term application and preservation in public spaces.

*4.2.2 Role of Chemical Properties in Design*

The chemical properties of Jun porcelain fragments directly affect their reutilization. The kiln transformation of Jun porcelain during firing causes various chemical reactions, enriching the glaze color and enhancing the feasibility of redesigning waste fragments(Liu, X., 2024). Different glaze compositions can produce various glaze structures, allowing designers to create diverse artworks based on the effects of different glazes. The chemical properties of Jun porcelain also influence the environmental adaptability of artistic works, such as the durability and corrosion resistance of the fragments. Excellent corrosion resistance allows waste materials to serve as acid and alkali-resistant decorative materials, while certain properties may limit their use in specific environments. Understanding these characteristics helps designers correctly select waste materials and predict their applications.

*4.3 Application of Waste Jun Porcelain Fragments in Design*

*4.3.1 Application in Urban Public Spaces*

Research and exploration of the repeated reutilization of waste porcelain fragments have shown that these fragments can be transformed into artistic pavement materials and decorative elements(Cai, C., 2020). These materials are aesthetically pleasing and durable, adding cultural richness to urban environments and conveying the ideas of environmental protection and sustainable design. When utilizing waste porcelain fragments, their environmental performance must be considered, ensuring they do not contain heavy metals and possess good wear resistance, flexural strength, and hardness.

*4.3.2 Application in Landscape and Garden Decoration*

Utilizing the natural colors and textures of Jun porcelain waste, it can be incorporated into landscape design to create unique rockeries, water features, and other elements(Ren, X., 2023). Reusing waste materials enhances the natural beauty of gardens, conserves resources, and shows respect for the environment.

*4.3.3 Application in Urban Sculptures, Murals, and Art Installations*

Recycling Jun porcelain waste is an innovative material choice and a form of environmental protection in urban sculptures, murals, and art installations. By utilizing the waste materials' unique texture and color, these artworks can embody rich cultural heritage and contemporary aesthetics, transforming waste into culturally significant and modern artistic creations(Cheng, Z., 2021).

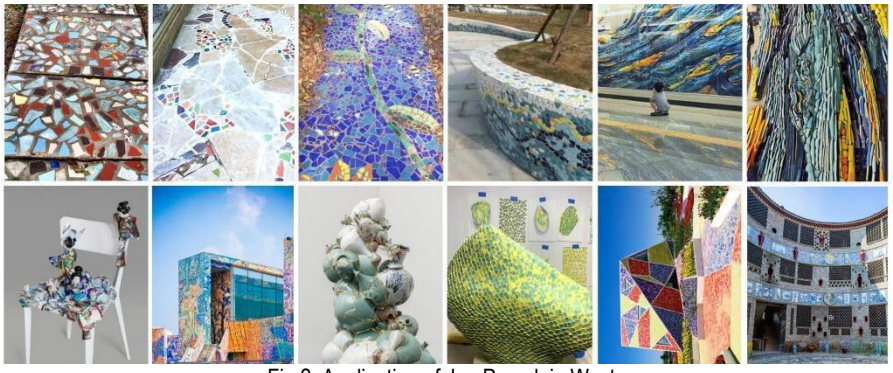

Fig 2: Application of Jun Porcelain Waste
*(Source: Photograph from various artist's studios, 2024)*

## 5.0 Discussion

Jun porcelain shards have been tested for their physical and chemical performance and have been found to have reliable performance, durability, and environmental friendliness. Their good thermal shock resistance means that most shards will not crack after being tested at high temperatures and then rapidly cooled, making them suitable for use in extreme weather or high-temperature conditions—tests for the dissolution of lead and cadmium show that Jun porcelain shards have an acceptable environmental performance. Chemical composition tests have shown that the main chemical components of Jun porcelain shards are $SiO_2$, $Al_2O_3$, $Al_2Si_2O_7$, $Fe_2O_3$, and CuO, which give them high hardness and wear resistance. The chemical composition of Jun porcelain shards determines their chemical stability, weather resistance, wear resistance, environmental compatibility, and non-slip properties, ensuring their long-term use and preservation in public spaces. Recycling Jun porcelain waste has significant advantages, reducing environmental pollution and conserving resources. Transforming waste into new materials for contemporary art and design can effectively reduce dependence on raw materials, reduce energy consumption, and reduce carbon dioxide emissions. These dual benefits align with sustainable development principles and provide new approaches to environmental protection and resource management. Recycling Jun porcelain waste also faces some challenges. The process involves complex social and ecological issues, and the main difficulties center on the technical aspects of recycling. The unique material and firing process of Jun porcelain makes traditional recycling methods ineffective. The small size of the fragments makes collection more difficult and increases the cost of sorting. In order to solve these problems, it is necessary to conduct research on the recycling and utilization of Jun porcelain waste and improve related technologies. In future research on Jun porcelain waste, research can be carried out in the following directions: material recovery and remanufacturing, the preparation of new materials with unique properties in combination with other industrial by-products, and the construction of a closed-loop supply chain system for the Jun porcelain industry. This research provides new material resources for the green development of China's Jun porcelain industry and lays the foundation for applying Jun porcelain waste in environmental protection.

## 6.0 Conclusions and Recommendations

### *6.1 Main Research Conclusions*

After conducting physical and chemical performance and chemical composition tests on Jun porcelain fragments, it was found that they have reliable performance, durability and environmental friendliness, chemical stability, weather resistance, and wear resistance, and can be used in public places for a long time. The creative use of Jun porcelain waste provides a sustainable way to balance economic benefits and environmental protection. This research provides a theoretical basis for the sustainable use of Jun porcelain waste, proving that waste can be transformed into beautiful and practical materials, reducing environmental pollution and waste of resources. The innovative methods of this research have great potential for promoting the sustainable use of traditional materials. Experimental and case studies have shown great potential for developing and utilizing Jun porcelain waste based on its physicochemical characteristics. Waste can be transformed into high-quality building and decorative materials with appropriate processing and design. In addition, case studies have shown that waste reuse can enhance design's cultural content and improve product market competitiveness.

### *6.2 Practical Recommendations*

To maximize the use of Jun porcelain waste, designers should develop design solutions based on the physical and chemical characteristics of the waste. For example, designers can use the unique colors and textures of the waste to create unique decorative and building materials. Exploring the combination of waste with other materials can further expand its scope of application. Government support in the form of tax, financial, and marketing incentives is crucial to promote the recycling of Jun porcelain. The government should develop a comprehensive set of recycling guidelines and strengthen public education to raise awareness and participation in recycling activities. How to efficiently recycle and dispose of Jun porcelain waste remains a technical challenge, and designers need help finding a balance between practicality and functionality. In future research, cross-disciplinary collaboration models should be strengthened,

such as integrating the construction industry, fashion industry, and scientific research institutions to explore the realization of environmentally sustainable development of the industry.

## Paper Contribution to Related Field of Study

The paper contributes by presenting innovative methods to repurpose Jun Ware waste into sustainable design elements, addressing energy and waste challenges while promoting environmental sustainability, resource conservation, and cultural enhancement in ceramics and modern design.

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