ANALYSIS OF THE SUSTAINABLE DEVELOPMENT OF QINZHOU NIXING POTTERY WASTE CLAY UNDER CIRCULAR ECONOMY "3R" PRINCIPLE*

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Received 21 May 2026; Revised 15 June 2026; Accepted 17 June 2026

Abstract

This article analyzes the current situation of waste clay management in the Qinzhou Nixing Pottery industry and proposes a sustainable development framework grounded in Circular Economy principles. As a representative of traditional Chinese pottery, Qinzhou Nixing Pottery faces increasing environmental pressure due to inefficient material use during production. Field investigations indicate that approximately 40% of clay is discarded during the shaping process, resulting in significant resource waste and potential environmental risks.Drawing on the "3R" (Reduce, Reuse, Recycle) strategy, this study examines technical pathways for regenerating unfired waste clay and explores policy-driven mechanisms to support a resource closed-loop system. The research is based on field surveys, case studies, literature analysis, and expert interviews conducted between 2017 and the present. By integrating national and local policy frameworks related to low-carbon development and China's "Double Carbon" targets of carbon peaking and carbon neutrality, the study

Citation:

* XIE XIE and Arnuphap Chantharamporn. (2026). Analysis Of The Sustainable Development Of Qinzhou Nixing Pottery Waste Clay Under Circular Economy "3r" Principle. Journal of Interdisciplinary Social Development, 4(4), 1623-1634.;

DOI: https://doi.org/10.

Website: https://so12.tci-thaijo.org/index.php/JISDIADP/

proposes a closed-loop production model that enables waste clay to be reprocessed into usable raw materials.The analysis demonstrates that, through appropriate technical interventions, unfired waste clay can be efficiently reintegrated into the production cycle, significantly reducing dependence on primary clay resources. Under theoretical conditions, this closed-loop model could substantially extend resource availability while lowering material loss and carbon emissions. In addition, policy incentives and regulatory guidance are shown to play a critical role in encouraging enterprises to adopt recycling technologies and improve waste management practices.The study concludes that the sustainable transformation of the Qinzhou Nixing Pottery industry requires coordinated efforts between enterprise-level technological innovation and government policy support. Such synergy is essential for establishing a competitive, green-certified manufacturing value chain and promoting the long-term sustainability of traditional pottery industries within a circular economy framework.

Keywords: Qinzhou Nixing Pottery, Circular Economy, Sustainable Development, Resource Reutilization

Introduction

Nixing clay, as its core material, directly determines the craftsmanship and artistic value of a piece. Sourced from the unique clay of the Qinjiang River basin, it undergoes screening and washing to achieve an extremely fine texture, providing an excellent foundation for shaping, carving, and decoration. Its high plasticity allows it to adapt to various complex shapes, fully showcasing the creator's artistic conception, while its excellent high-temperature resistance ensures that the pottery is not prone to cracking or deformation during firing, giving it greater durability. This natural clay not only supports the exquisite expression of handcraftsmanship but also promotes the unique development of

Qinzhou Nixing pottery in the ceramics world, giving it both traditional aesthetic appeal and modern practical functionality.

Furthermore, the unique kiln-transformation effect of Nixing clay during firing is a significant aspect of its artistic value. This kiln transformation makes each piece unique, showcasing naturally flowing colors and textures, endowing Nixing pottery with an irreplaceable aesthetic characteristic. Compared to other ceramic arts such as Yixing purple clay and Jianshui pottery, Nixing pottery's uniqueness lies not only in the fineness and plasticity of its clay but also in its distinctive kiln-transformation effect, setting it apart from other traditional ceramic art forms. Therefore, protecting and rationally utilizing this precious resource not only contributes to the sustainable development of the Nixing pottery industry but also plays a positive role in the diversity and innovation of Chinese ceramic culture.

However, with the rapid development of the Nixing pottery industry, the problem of waste clay generated during production has become increasingly prominent, posing a key challenge to the industry's sustainable development. Statistics show that approximately 40% of the clay used in the shaping process is converted into waste clay due to operational losses(Table 1). This waste clay is mostly disposed of through landfill or dumping, not only wasting resources but also potentially causing environmental problems such as land pollution. The circular economy theory provides a feasible solution to this problem, with its "closed-loop system," "resource recycling," and the "3R principle" (reduction, reuse, and recycling) providing theoretical support for the efficient utilization of waste clay. However, currently, Nixing pottery enterprises, especially small and medium-sized enterprises, generally lack a complete waste clay recycling system and treatment technology. Coupled with insufficient policy support and weak consumer awareness of environmental protection, the process of waste clay recycling is lagging behind.

This study aims to explore the integration of circular economy theory with the practice of Nixing pottery waste mud treatment, construct a sustainable model for the green development of Qinzhou Nixing pottery, provide a reference path for resource utilization and environmental protection in the traditional handicraft industry, and help the Nixing pottery industry achieve ecological transformation in the new era.

Body of Knowledge

Overview of Nixing Pottery

Nixing pottery production area is located in Qinzhou City, Guangxi Zhuang Autonomous Region, China. Nixing pottery clay is produced on both the east and west banks of the Qinjiang River. The area on the east bank of the Qinjiang River is mostly alluvial plains in low-lying basins, with soft texture, hence the name "Eastern Clay" and is white. The area on the west bank of the Qinjiang River is mostly hilly terrain, with hard texture, hence the name "Western Clay" and is red.

Nixing pottery is one of the four famous potteries in China (Ma, 2014), renowned for its unique kiln-transformation effects achieved through the use of its distinctive clay, showcasing a unique artistic charm. Nixing pottery clay is made from a mixture of purplish-red and white clay unique to Qinzhou. This iron-rich clay not only gives the pottery a warm purplish-red hue but also possesses excellent breathability and heat retention, making it particularly suitable for teaware. During the high-temperature firing process, Nixing pottery achieves the effect of "one color going into the kiln, myriad colors coming out," through kiln-transformation techniques, giving each piece unique glaze variations and artistic value, making it an indispensable and important representative of Chinese ceramic culture.

Analysis of waste mud problems

The pottery production process generates a large amount of waste clay, with the most significant waste occurring during the finishing stage. Since finishing mainly involves processes such as cutting, scraping, and grinding, the surface layer of the clay is removed, and these scraps usually contain moisture and impurities. If not recycled, this waste clay is often discarded directly, resulting in resource waste. Furthermore, long-term accumulation of waste clay can affect the working environment and even pollute soil and water sources during landfill disposal. Therefore, how to efficiently recycle and reuse this waste clay under a circular economy model has become a crucial issue that needs to be addressed for the sustainable development of the ceramics industry.

Sample number	Before embryo trimming (g)	After embryo trimming (g)	Loss (g)	Loss percentage (%)
A	133.2g	84.3g	48.9g	36.71%
B	120g	111.2g	8.8g	7.33%
C	259.7g	111.6g	148.1g	57.01%
D	254.7g	96.9g	157.8g	62.0%
E	176.8g	90.7g	86.1g	48.68%
Average	-	-	-	47.47%

Table 1 Statistics of Embryo Repair Losses

Project	Numerical values
Total amount of clay	1,712,000 Tons
Annual consumption	2,000 Tons
Annual waste (30%)	949.4 Tons
Total waste	812,686.4 Tons
Depletion time without recycling	856 Year
Depletion time under recycling conditions	≈1629.5 Year
Recycling can delay depletion time	≈773.5 Year

Table 2 Statistics on Mud Consumption

Analysis of Circular Economy Theory

The circular economy is a collection of ideas arising from the convergence and integration of multiple disciplines. Currently, there is no unified definition of the circular economy, and experts and scholars both domestically and internationally hold different views on it. The circular economy originated from Boulding's spaceship theory [Boulding, K.E. Earth as a Space Ship; Washington State University: Pullman, WA, USA, 1965.], who proposed that humanity should not treat its environment as a dumping ground for waste, but rather that humans are an integral part of the overall ecological environment. British environmental scholars Pearce et al. (Pearce & Turner, 1990) first proposed the term "circular economy." At the end of the 20th century, the concept of the circular economy was systematically introduced into the domestic academic community, and relevant scholars defined it. Professor Chu Dajian (Zhu, 1998) combined the basic

ideas of the circular economy with the current stage of domestic development, arguing that the main theoretical basis for developing a circular economy is the ecological economics theory, which emphasizes sustainability, rather than the neoclassical economics with weak sustainability. With in-depth research, traditional circular economy theory has been further expanded to include three types of circular economies with sustainable development significance: waste recycling, product recycling, and service recycling.

Current research suggests that the circular economy originated from Balding's spaceship theory. However, as early as 1894, Marx (Marx, 2004) mentioned the concept of waste recycling in *Capital*, arguing that almost all consumer goods could be introduced into the production process as waste. Although Marx did not use the term "circular economy," he fully explored how human production and life should be characterized by resource conservation and waste recycling, which essentially aligns with the principles of the circular economy: "reduction, reuse, and recycling."

Demonstrate that discarded ceramics can be recycled into aggregates, functional fillers, and decorative materials after classification and processing, partially replacing primary raw materials such as clay and quartz. Their findings show that recycled ceramic materials exhibit stable mechanical and chemical properties and contribute to reduced resource consumption and carbon emissions within a circular economy framework (Pan & Tan, 2025).

China has been introducing the circular economy for over two decades. In July 2021, with the approval of the State Council, the National Development and Reform Commission (NDRC) issued the "14th Five-Year Plan for Circular Economy Development." In 2024, discussions included considerations of a sustainable blue economy (Dong, 2024). In December 2025, seven departments, including the NDRC, issued the "Action Plan for the Application and Promotion of Recycled Materials," aiming to strengthen the application and promotion of

recycled materials and improve the waste recycling system (National Development and Reform Commission [NDRC] et al., 2025). A KPMG report projects that during the 15th Five-Year Plan period, the dual-driven effect of policy and market will become increasingly significant, and the circular economy industry will experience a wave of accelerated development, with the scale of China's resource recycling industry expected to approach 10 trillion yuan by 2030 (Tian, 2025).

Definition and characteristics of circular economy

Achieving a balance between environmental protection, economic growth, and social development through the efficient utilization and recycling of resources. Key characteristics: 1) Closed-loop system: Achieving a closed-loop cycle of production and consumption by reducing raw material consumption, waste emissions, and pollution. 2) Resource recycling: Focusing on the reuse and value maximization of resources throughout their entire life cycle. 3) Systemic: Encompassing optimization of the entire chain of production, consumption, recycling, and regeneration. The 3R principle: Reduce: Reducing resource use and waste. Reuse: Extending the lifespan of products and materials. Recycle: Transforming waste into usable resources.

Analysis of the Current Situation of Qinzhou Nixing Pottery Industry

On March 29, 2017, the 28th meeting of the Standing Committee of the 12th People's Congress of Guangxi Zhuang Autonomous Region approved the "Regulations on the Protection of Nixing Clay Resources in Qinzhou City," which came into effect on October 1, 2017.This provided a "protective umbrella" for Nixing clay. Subsequently, the "Special Plan for the Protection of Nixing Clay Resources in Qinzhou City" was formulated and implemented. According to the delineation principles, the planning area was divided into 3 protected areas (A) for near-term development and utilization, 4 protected areas (B) for medium- and long-term reserve resources, and 6 urban planning overlay areas (C), with a total area of 718.1705 square kilometers.

However, Nixing clay is a non-renewable resource; every bit used is precious! Although Qinzhou City has taken active protection measures, the current situation regarding the protection and development of clay resources remains far from optimistic. First, the mining and utilization of Nixing clay resources is disorderly, with rampant illegal mining and excavation. Second, Nixing clay resources are being extensively damaged and wasted. Large quantities of high-quality Nixing clay are being used to produce low-value-added bricks, tiles, and other ordinary building materials. Furthermore, during urban development and construction, a large amount of Nixing clay is being buried, with much of the high-quality clay being used for site leveling and roadbed filling in engineering projects. Third, the problem of mineral overburden is prominent. Some infrastructure projects, industrial projects, urban construction projects, and rural residential construction have buried large amounts of valuable Nixing clay resources. Fourth, enterprises lack a strong awareness of legally developing and utilizing these resources.(Qinzhou Municipal Bureau of Culture, Radio, Television, Sports and Tourism, 2019).

According to the 2012 "Preliminary and General Survey Geological Report on Nixing Pottery Clay Mines in Qinzhou City, Guangxi", the red pottery clay deposits total 1.48 billion tons (559 km²), and the white pottery clay deposits total approximately 240 million tons (92 km²), with a total mineral resource reserve of about 1.7 billion tons. Although Nixing pottery clay resources are abundant and readily available, their wide and scattered distribution, easy open-pit mining, and extremely difficult supervision make protection work very challenging. The actual usable amount is only 1.712 million tons (Pan, 2023, p. 109).

Waste clay treatment methods

First, landfill is one of the most traditional and direct waste disposal methods. Its advantages lie in its simplicity and suitability for large-scale

processing of ceramic waste, especially that which is difficult to decompose or reuse. However, landfilling has significant drawbacks. Due to the high density of clay and the presence of other additives, it hardly decomposes in soil. Places where Nixing clay is landfilled are difficult to cultivate, consuming vast amounts of land resources and potentially causing long-term pollution and damage to the environment. Furthermore, improper management during landfilling can lead to groundwater pollution and other environmental problems. Therefore, while landfilling offers the advantage of quickly resolving waste accumulation in the short term, its long-term environmental cost is high and detrimental to sustainable development.

Secondly, a few clay refining plants possess automated equipment with more environmentally friendly and faster processing methods. Through processes such as ball mill crushing, filter press dewatering, and vacuum refining, waste clay can be converted into new clay. This method not only reduces waste generation but also effectively conserves raw material resources and lowers production costs. However, recycling also faces certain challenges, mainly due to the complexity of the recycling process, the high energy consumption and cost of recycling equipment, and the mismatch between input and output for small and medium-sized enterprises, leading them to prefer disposal over recycling. Furthermore, the small, scattered, and disorganized layout of Nixing pottery enterprises makes large clay refining plants unwilling to provide on-site collection services. Therefore, to improve the efficiency and economics of recycling, it is necessary to increase the government's attention, improve the recycling mechanism through policy, increase policy support and incentives, and enhance the economic motivation of enterprises.

The disposal method for waste clay should be selected based on the enterprise's scale, resource conditions, and environmental requirements. Under the concept of a circular economy, the government can increase preferential policies and cooperate with enterprises. Small businesses can purchase new clay

while clay processing plants recycle waste clay, achieving optimal treatment and maximum utilization of resources for waste clay. This not only reduces production costs but also effectively reduces environmental pollution, thereby promoting the sustainable development of the Nixing pottery industry.

Conclusions

The study demonstrates that the Qinzhou Nixing pottery industry faces a critical sustainability challenge characterized by an annual waste rate of 30%, which equates to approximately 949.4 tons during the production process. Based on the analysis of clay consumption, it is concluded that while the unique clay resources are estimated to be depleted within 856 years under current practices, the implementation of a recycling system could extend this timeline to approximately 1,629.5 years and effectively delay resource depletion by 773.5 years. Furthermore, transitioning to a circular 'closed-loop' model significantly reduces the soil and groundwater pollution caused by waste mud while simultaneously lowering long-term raw material costs for artisans. Technical analysis further confirms that waste clay can be successfully reintegrated into the production line as a high-value raw material, suitable for both traditional pottery and the development of eco-friendly building materials.

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