International Journal of Multicultural and Multireligious Understanding

http://ijmmu.com
editor@ijmmu.com
ISSN 2364-5369
Volume 12, Issue 3
March, 2025
Pages: 13-24

Upcycling Ceramic Waste Experiment: Integration of Sustainability and the Value of *Khalifah Fil Ardh*

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http://dx.doi.org/ 10.18415/ijmmu.v12i3.6592

Abstract

Ceramic waste is rarely utilized, despite being non-biodegradable and requiring up to 4,000 years to decompose. This study employs the Practice-Led Research method to explore ceramic waste as an additive to clay. Experiments involved mixing 20% ceramic waste into two types of clay, shaping test pieces, and firing them at temperatures of 900ºC, 1150ºC, and 1210ºC. Results indicate that glazed ceramic waste can be reused to produce ceramics with properties comparable to natural clay, providing a sustainable material solution. This research aligns with the Islamic principle of khalifah fil ardh (stewardship of the Earth), emphasizing human responsibility to maintain environmental balance. By utilizing ceramic waste, this study addresses sustainability challenges while reflecting values of wise resource use. It also opens avenues for further exploration with higher waste percentages and broader applications.

Keywords: *Ceramic Waste; Clay; Upcycling; Sustainability; Experiment; Khalifah Fil Ardh*

Introduction

Ceramics have long been an integral part of human civilization, serving not only as functional objects but also as artistic mediums that reflect local cultures and values. In the context of sustainability, ceramic waste poses a serious issue due to its long decomposition time and significant environmental impact. Sustainable approaches emphasize not only material recycling but also deeper values, such as humanity's responsibility toward Earth. As stewards of the Earth (*khalifah fil ardh*), Islam teaches the importance of maintaining ecosystem balance. This responsibility includes the wise use of resources, minimizing waste, and creating innovative solutions for environmental challenges. Quranic verses such as Surah Al-Baqarah (2:30) highlight humanity's role as caretakers of the Earth, while Surah Al-Anbiya (21:107) reminds us that human existence is meant to bring mercy to all of creation. These principles form the foundation of this research, which aims to utilize ceramic waste to produce new, sustainable materials.

In Indonesia, traditional ceramic production across various regions generates a large amount of waste. According to data from Puslitbang TMB (2005), Indonesia exported 122 million cubic meters of ceramic stones, while approximately 15–30% of local ceramic industry products become waste due to production defects. This data highlights the urgency of finding solutions for managing ceramic waste.

The objectives of this study are as follows:

1. To reduce the environmental impact of ceramic waste by repurposing the material.
2. To integrate the concept of *khalifah fil ardh* into artistic and material design practices.
3. To encourage innovation in sustainable ceramic production through practice-based experimental methods.

Unused ceramic waste typically ends up in landfills or buried in soil, despite its non-biodegradable nature posing an environmental threat. The authors' curiosity about recycling ceramic waste arose from frequent encounters with defective or broken ceramic works, prompting the question of whether such waste could be mixed with clay to produce new ceramics. By adopting the concept of upcycling, this research seeks to minimize the environmental impact of ceramic waste. As a non-biodegradable material, ceramic waste takes up to 4,000 years to decompose (Peter et al., 2019). Globally, the ceramic industry produces approximately 100 million tons of ceramics annually, with 15–30% of it resulting in waste (Awoyera et al., 2021). In Indonesia, ceramic waste is also abundant, yet little research has explored its potential as an additive in new ceramic production.

Existing studies generally focus on the use of ceramic waste for construction materials, such as paving blocks (Irfan & Rholly, 2023) and concrete (Al Bakri et al., 2008). In the arts, Novierti Debby Astuti (2018) utilized Bayat ceramic waste as a craft material. This study seeks to extend such explorations by incorporating glazed ceramic waste into clay for high-temperature ceramics, particularly stoneware and earthenware. The goal is to provide a solution to the global issue of ceramic waste while paving the way for similar research in the future. Notably, research on recycling ceramic waste to produce new ceramics has been conducted in Gifu Prefecture, Japan (Hasegawa, 2012), but such studies have yet to be undertaken in Indonesia. Addressing ceramic waste as a material for new ceramic production is crucial for solving global issues and could serve as a gateway for future research. Furthermore, this study reflects a sense of accountability as an active participant in the ceramic arts field.

The success of this experimental study depends on achieving appropriate material characteristics, as indicated by the plasticity of the clay mixed with ceramic waste, comparable to natural clay for handbuilding techniques. Success is also measured by the clay's ability to withstand high-temperature firing. The study uses 20% ceramic waste in three types of clay from different locations—two earthenware types and one stoneware type—to ensure a focused scope. The 20% ratio aligns with the Japanese *eco-mark* standard of 16% (Kobayashi, 2023). Additionally, the ceramic waste used contains a high silica content (glazed ceramics), which, if added in greater quantities, risks transforming the formula into a glaze material rather than a clay body. The resulting clay from this research aims to add value to ceramic waste (*U-Mics; Upcycling Ceramic Waste*), applied in the creation of functional and test-piece works through handbuilding techniques.

Method

This study documents the experiments conducted by the author, employing the practice-led research method as a comprehensive approach while experimental methods are used to test the characteristics of the samples produced. According to Carole Gray (1996), the principles of practice-led research are as follows:

1. Research is initiated within the practice, where questions, problems, and challenges are identified and shaped based on the needs of the practice and the practitioner.
2. Research strategies are conveyed through practice, employing specific methodologies and methods familiar to practitioners.

Artistic research occurs when artists create art and examine their creative processes, contributing to the accumulation of knowledge through their work and study. Honesty in the practice and processes, including preparing, ideating, implementing, and testing theories through practice, conducting experiments, fieldwork, and documentation, are key aspects of such research (Hedberg and Hannula, 2014). Based on these principles, the research workflow is presented following the practical processes undertaken during the study and creation of works, ensuring integrity throughout. This study adopts an experimental approach to test the properties and characteristics of clay samples, aiming to identify suitable formulations for clay mixed with ceramic waste. The research workflow is illustrated in Figure 1.

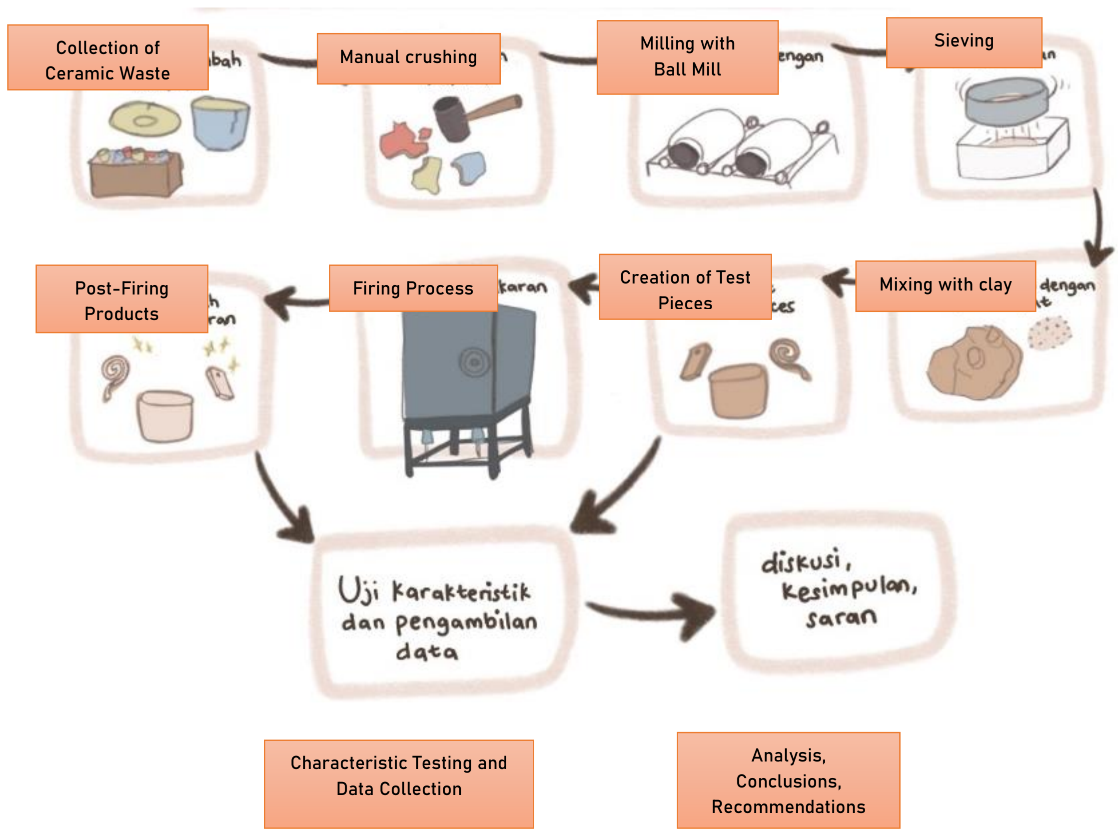


Figure 1. Practice Led Research Flow
(By Nisaul Khaeroty, 2023)

Sample Testing Criteria

The characteristics of the prepared samples were tested based on the following criteria (Levy et al., 2022):

1. Plasticity

Plasticity testing was performed using the coil technique. Clay was shaped into coils and bent to assess flexibility. The fewer cracks or fractures, the higher the clay's plasticity.

2. Dry Shrinkage

Shrinkage was measured using an analog method. The initial length of newly formed clay pieces was measured to calculate the percentage of shrinkage after drying. This was determined by dividing the amount of shrinkage by the original length and multiplying the result by 100.

$$\text{Dry Shrinkage: } \frac{\text{Wet Length} - \text{Dry Length}}{\text{Wet Length}} \times 100\%$$

3. Firing Shrinkage

Firing shrinkage was calculated using the same percentage formula as dry shrinkage, accounting for changes in length after firing.

$$\text{Firing Shrinkage: } \frac{\text{Wet Length} - \text{Fired Length}}{\text{Wet Length}} \times 100\%$$

4. Glaze Testing

A quick method to test thermal expansion compatibility with clay involved applying a known glaze to bisque-fired samples (900ºC). Although greenware samples can be used, bisque-fired samples are safer for this test. The glazed samples were fired at 1150ºC and 1210ºC.

5. Water Absorption (Porosity)

Porosity was determined by measuring water absorption after firing. The weight of fired samples was recorded as the dry weight. Samples were boiled in water for five hours and then submerged for 24 hours. The difference between the dry weight and wet weight represented the amount of absorbed water. This difference was divided by the initial dry weight to obtain the absorption percentage.

$$\text{Water Absorption: } \frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Dry Weight}} \times 100\%$$

Results and Discussion

Sample Preparation

At this stage, the initial process involved selecting clay types and exploring the formulas to be used during the experiments. Considering the clay types widely utilized in Indonesia, particularly in the Yogyakarta region, it was decided to use earthenware and stoneware to determine whether these two types of clay could be mixed with glazed ceramic waste and fired at high temperatures. Bandung clay is a pure clay without any additives, characterized by its creamy-brown color, which led to its classification as earthenware based on its physical traits. Kasongan clay, on the other hand, is a mixture of three types of clay sourced from different locations in Yogyakarta and is also classified as earthenware. Finally, Sukabumi clay is a pure, chunk-formed stoneware clay with no additives. In addition to the two primary materials (ceramic waste and clay), supplementary materials like kaolin and bentonite were prepared to support the experiments.

The ceramic waste used in this study was sourced from Burat Kriasta Studio, which produces glazed ceramic tableware such as cups, plates, bowls, and souvenirs. Burat Kriasta regularly generates defective products that are disposed of in landfills. The studio's ceramics are medium-sized and made using non-toxic, food-grade materials, making it an ideal source of ceramic waste for this research. The ceramic waste was collected periodically, with prior confirmation from Burat Kriasta, and transported to the author's private studio, which was utilized as a simple laboratory for this study.

The collected ceramic waste was first manually crushed with a hammer, then further refined using a ball mill for 8–10 hours in a wet grinding process. The resulting material was sieved through a standard mesh to obtain fine ceramic powder. This powder was subsequently added to the clay samples for further testing.

Figure 2. Ceramic Waste from Burat Kriasta
(By Nisaul Khaeroty, 2023)

Code	Formula (1kg)
U-Mics #01	20% Ceramic waste 80% Bandung clay
U-Mics #02	20% Ceramic waste 70% Bandung clay 10% Kaolin
U-Mics #03	20% Ceramic waste 60% Kasongan Clay 10% Kaolin 10% Bentonite
U-Mics #04	20% Ceramic waste 80% Sukabumi Clay

Table 1. Sample Code U-Mics
(By Nisaul Khaeroty, 2023)

Sample Formulation

At this stage, formulations were developed to mix ceramic waste into clay, allowing for the testing of their characteristics. Four clay samples with a 20% ceramic waste content were created for this study. The formulas for these samples are outlined in Table 1:

The sample codes were assigned to facilitate the direct testing process for each clay type. Before mixing, preliminary tests were conducted to assess the plasticity of each clay sample. Bandung clay, being the most plastic, was used in the first formulation (U-Mics #01) with ceramic waste. After forming test pieces, significant shrinkage was observed after drying. Considering that dry shrinkage is generally proportional to a clay's performance during firing, kaolin was added to create U-Mics #02, with the aim of improving its durability at high firing temperatures. Kasongan clay exhibited the lowest plasticity among the three types, leading to the addition of bentonite in U-Mics #03 to enhance its plasticity. Since

Kasongan clay is earthenware, 10% kaolin was also added to ensure the sample could endure high firing temperatures. Finally, Sukabumi clay, which demonstrated moderate plasticity, was used in the fourth formulation (U-Mics #04) with ceramic waste added directly.

Bandung clay is the most plastic, which is why the first formula created used only Bandung clay mixed with ceramic waste. In the production process, the U-Mics #01 sample was made first. After attempting to form test pieces, significant shrinkage was observed in the sample after drying. Considering that drying shrinkage is generally proportional to the clay's ability to withstand firing, U-Mics #02 was made by adding 10% kaolin to ensure it could endure high-temperature firing. Kasongan clay has much lower plasticity compared to the other two clays, so the formula was modified by adding bentonite to enhance its plasticity. Since Kasongan clay is an earthenware clay, U-Mics #03 also included 10% kaolin to allow the sample to withstand high-temperature firing.

The final formula designed used Sukabumi clay, which has medium plasticity but is not as plastic as Bandung clay. Therefore, this clay was also mixed with ceramic waste in the U-Mics #04 sample. Each sample was also formed into a cup using combined handbuilding techniques. Data collection was carried out periodically in line with the sample production process, from shaping, drying, bisque firing at 900ºC, glaze firing at 1150ºC, and glaze firing at 1210ºC. During the shaping stage, plasticity and drying shrinkage were tested. After complete drying, a 900ºC bisque firing was carried out, followed by tests for shrinkage and porosity. The same process was applied for the 1150ºC and 1210ºC firings.

Each sample was formed into cup shapes using a combination of handbuilding techniques. Data collection was conducted periodically throughout the production process, from forming, drying, bisque firing at 900ºC, glaze firing at 1150ºC, and glaze firing at 1210ºC. At the forming stage, plasticity and dry shrinkage tests were performed. After drying, samples were bisque-fired at 900ºC, followed by tests for firing shrinkage and porosity. These tests were repeated for the samples fired at 1150ºC and 1210ºC.

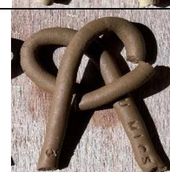
Figure 3. Samples after applyed glaze
(Oleh Nisaul Khaeroty, 2023)

Testing of U-Mics Test Pieces

Plasticity Test Results

Plasticity testing determines how well the clay retains its shape when manipulated. The test was performed using the coil method, where clay was rolled into coils and bent to observe for cracks or breaks. The results are as follows:

Table 2. Plasticity test result

Sample Code	Image	Plasticity
U-Mics #01		Plastic
U-Mics #02		Plastic
U-Mics #03		Low plasticity
U-Mics #04		Plastic Enough

(By Nisaul Khaeroty, 2023)

Dry Shrinkage Results

Dry shrinkage was measured by comparing the length of clay samples in their wet state to their length after drying. Each sample initially measured 50 mm in length.

Table 3. Dry Shrinkage test result

Sample Code	Wet Length (mm)	Dry Lenght (mm)	Dry Shrinkage(%)
U-Mics #01	50	47	6%
U-Mics #02	50	47	6%
U-Mics #03	50	48	4%
U-Mics #04	50	48	4%

(By Nisaul Khaeroty, 2023)

Firing Shrinkage Results

The firing shrinkage of the clay samples was measured after firing at 900ºC, 1150ºC, and 1210ºC. Shrinkage percentages were calculated based on the reduction in length after firing.

Firing Shrinkage at 900ºC

Table 4. Firing Shrinkage at 900ºC test result

Sample Code	Wet Length (mm)	Fired Lenght (mm)	Firing Shrinkage(%)
U-Mics #01	50	44	12%
U-Mics #02	50	44	12%
U-Mics #03	50	47	6%
U-Mics #04	50	47	6%

(By Nisaul Khaeroty, 2023)

Firing Shrinkage at 1150ºC

Table 5. Firing Shrinkage at 1150ºC test result

Sample Code	Wet Length (mm)	Fired Lenght (mm)	Firing Shrinkage(%)
U-Mics #01	50	40	20%
U-Mics #02	50	40	20%
U-Mics #03	50	43	14%
U-Mics #04	50	43	14%

(By Nisaul Khaeroty, 2023)

Firing Shrinkage at 1210ºC

Table 6. Firing Shrinkage at 1210ºC test result

Sample Code	Wet Length (mm)	Fired Lenght (mm)	Firing Shrinkage(%)
U-Mics #01	50	40	20%
U-Mics #02	50	40	20%
U-Mics #03	50	43	14%
U-Mics #04	50	43	14%

(By Nisaul Khaeroty, 2023)

Water Absorption (Porosity) Results

Porosity was assessed by measuring the percentage of water absorption after firing. Lower porosity indicates denser clay bodies.

Porosity at 900ºC

Table 7. Porosity at 900ºC test result

Sample Code	Dry Weight (g)	Wet Weight (g)	Porosity (%)
U-Mics #01	9.1	10	9.8%
U-Mics #02	10.1	11.8	16.8%
U-Mics #03	13.6	15.8	16.1%
U-Mics #04	13.2	15.3	10%

(By Nisaul Khaeroty, 2023)

Porosity at 1150ºC

Table 8. Porosity at 1150ºC test result

Sample Code	Dry Weight (g)	Wet Weight (g)	Porosity (%)
U-Mics #01	9.8	10	2.0%
U-Mics #02	11.4	11.6	1.7%
U-Mics #03	13.0	13.9	6.9%
U-Mics #04	14.1	14.6	3.5%

(By Nisaul Khaeroty, 2023)

Porosity at 1210ºC

Table 9. Porosity at 900ºC test result

Sample Code	Dry Weight (g)	Wet Weight (g)	Porosity (%)
U-Mics #01	9.8	10	2.0%
U-Mics #02	10.2	10.4	1.9%
U-Mics #03	12.7	12.8	0.7%
U-Mics #04	14.0	14.1	0.7%

(By Nisaul Khaeroty, 2023)

Functional and Panel Samples from U-Mics

Functional test pieces were shaped into cups using handbuilding techniques. The results for each sample are as follows:

Table 10. Functional smple test result

Sample Code	Image	Description
U-Mics #01		The sample cracked in multiple areas after bisque firing (900ºC), so the testing process was discontinued.
U-Mics #02		The sample successfully withstood firing at 1210ºC despite significant shrinkage.
U-Mics #03		The sample successfully withstood firing at 1210ºC.
U-Mics #04		The sample successfully withstood firing at 1210ºC.

(By Nisaul Khaeroty, 2023)

Panel Displayed from U-Mics Test Piece Samples

Panel compositions of the test pieces were also created, showcasing various stages of the ceramic samples (greenware, bisque-fired, glazed-fired at 1150ºC, and glazed-fired at 1210ºC), alongside their test results.

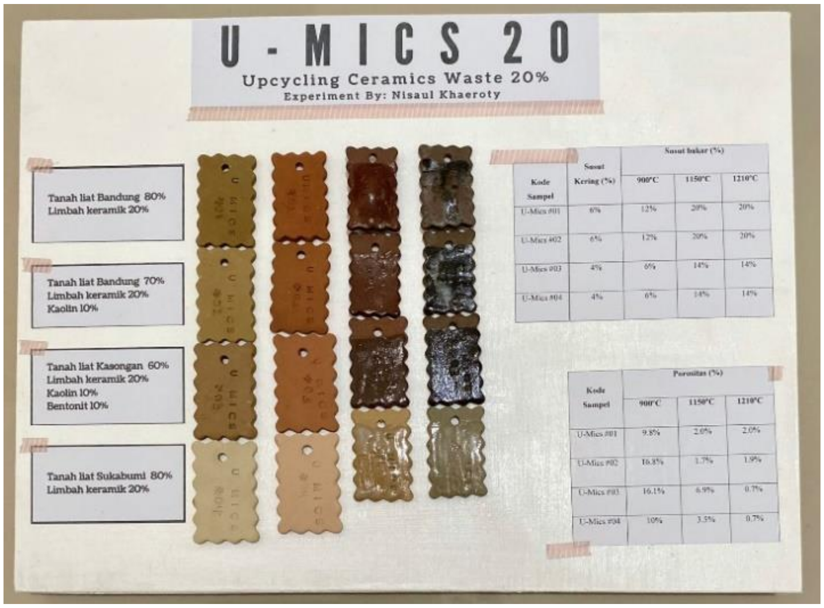


Figure 4. Panel Displayed of U-Mics 20 Test Pieces Samples
(By Nisaul Khaeroty, 2023)

The next panel work presents a collection of coil samples from the test pieces that have been shaped and arranged according to the composition of frame size, color, and the number of samples that were previously formed. At the bottom, the results include samples that were less plastic as well as those that broke during transportation to the firing site. The samples that naturally broke were due to insufficient plasticity, namely all the samples made with the U-Mics #03 code, as well as some samples from U-Mics #02, though most of the latter survived in their initial shape. Additionally, some broke during transportation to the firing location.

Figure 5. Panel Displayed of U-Mics 20 *Plasticity Samples*
(By Nisaul Khaeroty, 2023)

Conclusion

This study demonstrates that glazed ceramic waste can be utilized as an additive to clay for producing new ceramics. Among the four tested formulations, U-Mics #04 showed the best performance during high-temperature firing, maintaining its form without significant distortion. This research opens opportunities to optimize formulations further by introducing additional supporting materials and increasing the proportion of ceramic waste.

In the context of *khalifah fil ardh*, this study represents humanity's responsibility to protect the environment through upcycling. Reducing ceramic waste and repurposing it into new products is a tangible step toward sustainability, as emphasized in Islamic teachings. By integrating these principles, the study provides a concrete contribution to addressing ceramic waste issues at both local and global levels.

This research also highlights the importance of collaboration between art, technology, and spiritual values to create sustainable solutions. Recommendations for future studies include:

1. Using a larger sample size for more accurate data.
2. Limiting bentonite content to a maximum of 5% to maintain clay stability.
3. Increasing the percentage of ceramic waste for further experiments.
4. Exploring applications of upcycled ceramics for installation art or functional products.

By leveraging ceramic waste, this research underscores a significant step toward sustainable practices in ceramic production, aligning environmental goals with Islamic principles of stewardship.

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