



## Silica Purification using Acid Method from Various Types of Ash: A Comprehensive Characterization Study

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**ABSTRACT:** Industrial development in Indonesia correlates with increasing energy demand, leading to the widespread use of biomass combustion. This process generates scouring ash as a significant byproduct, which poses environmental challenges if not managed. This study focuses on the extraction and purification of silica ( $\text{SiO}_2$ ) from two types of scouring ash—wood burning ash and satay charcoal ash—using the acid leaching method with 4 jM HCl. The results demonstrated that silica extracted from wood burning ash achieved a significantly higher yield of 67.8% with a water absorption capacity of 70%, compared to satay charcoal ash which yielded 26.6% with an absorption capacity of 52%. Morphological analysis via digital microscopy revealed that the purified silica from wood burning ash appeared as a gray powder (diameter 0.01–0.02 mm), while satay charcoal ash produced white silica (diameter 0.02–0.09 mm). These findings suggest that scouring ash, particularly from wood combustion, is a viable and low-cost source for high-value eco-material production.

**Keywords:** Scouring ash, silica extraction, acid leaching, waste valorization, eco-materials.

### 1. INTRODUCTION

Industrial development in Indonesia is rapidly expanding, directly correlating with an increased demand for sustainable energy sources [1]. To address this demand, many industries have transitioned to biomass combustion as a cost-effective and renewable energy alternative. However, this industrial shift produces significant amounts of solid waste, particularly scouring ash [2]. Scouring ash is a general term for the fine powder byproduct generated from

various wood-based combustion processes, such as brick manufacturing or traditional cooking using hardwood [3]. Historically, this ash was used for simple domestic purposes like cleaning, but its potential as a source of high-value materials remains largely underutilized [4].

One of the most valuable components present in biomass ash is silica (silicon dioxide,  $\text{SiO}_2$ ). Silica is a versatile chemical compound widely used in the production

of ceramics, cement, tire reinforcements, adsorbents, and catalyst supports [5], [6]. While silica is traditionally obtained from mineral mining, biomass ash offers a more sustainable and abundant alternative [7]. Compared to other agricultural wastes like rice husk ash which may require high-energy thermal treatment, scouring ash provides a cheaper and readily available source for silica extraction [8].

Recent studies have shown that the purity and morphological characteristics of the extracted silica are heavily influenced by the raw material source and the leaching parameters [9]. The acid leaching method, typically utilizing hydrochloric acid (HCl), is effective for removing metallic impurities and increasing the SiO<sub>2</sub> content [10]. This process focuses on the purification of the silica network rather than a complex chemical synthesis [11]. Despite its potential, comparative studies on silica yield from different types of scouring ash, such as wood burning ash versus satay charcoal ash, are still limited.

## 2. MATERIALS AND METHODS

### 2.1 Materials

The primary raw materials used in this study were two types of scouring ash: wood burning ash (obtained from local brick production) and satay charcoal ash (sourced from traditional food vendors). The chemical reagents included hydrochloric acid (HCl, 4 M) as the leaching agent and distilled water (H<sub>2</sub>O) for the washing and purification process.

The laboratory equipment utilized for the extraction process consisted of a hot plate stirrer with a digital temperature controller, analytical balance, reflux apparatus, and vacuum filtration system using Whatman filter paper. Characterization was performed using a digital microscope for morphological

analysis and physical testing for water absorption capacity.

### 2.2 Methodology

The extraction of silica was conducted through an acid leaching process. Initially, each type of ash was cleaned of macroscopic impurities and dried. A specific amount of ash was then reacted with 4 M HCl solution. The mixture was heated on a hot plate at a constant temperature of 90°C for 60 minutes while being stirred to ensure an optimal leaching rate. This temperature was selected to ensure the effective dissolution of metallic impurities and the stabilization of the silica network.

After the leaching process, the solution was cooled and filtered to separate the silica-rich residue from the filtrate. The obtained residue was washed repeatedly with distilled water until a neutral pH was achieved to ensure the removal of residual acid. The purified silica was then dried in an oven at 105 °C for 24 hours to remove moisture, followed by grinding to produce a fine powder for further characterization.

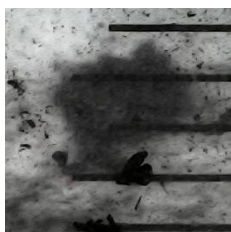
The yield of the extracted silica was calculated based on the mass ratio of the final product to the initial ash. The morphology and particle size were observed using a digital microscope. Additionally, the water absorption capacity was measured to evaluate the porosity and surface properties of the resulting eco-material.

## 3. RESULTS AND DISCUSSION

The extraction process using the acid leaching method at 90°C demonstrated varying efficiency depending on the raw material source. The silica yield obtained from wood burning ash was significantly higher at 67.8%, whereas satay charcoal ash only produced a yield of 26.6%. This disparity suggests that the silica content in wood burning ash is more accessible or

more abundant compared to charcoal-based ash [3]. The use of 4 M HCl at an elevated temperature proved effective in dissolving metallic impurities, thereby concentrating the silica in the final residue [10]. Such high yield results from wood ash are consistent with studies indicating that biomass-derived ash is a potent source for high-purity silica extraction when treated with mineral acids [8].

Morphological observation through digital microscopy revealed distinct physical differences between the two products. Silica extracted from wood burning ash appeared as a gray powder with a particle diameter ranging from 0.01 mm to 0.02 mm. In contrast, satay charcoal ash yielded a white silica powder with a larger diameter of 0.02 mm to 0.09 mm.



**Figure 1.** Research Result

These variations in color and size are likely attributed to the differing carbon content and the thermal history of the raw materials [9]. The smaller particle size observed in wood ash-derived silica indicates a higher surface-to-volume ratio, which is generally desirable for adsorbent or catalyst applications [7]. The white color of the charcoal-derived silica suggests a more thorough removal of organic matter during the leaching process, although at the cost of a lower overall yield [11].

The effectiveness of the extracted silica as an eco-material was further evaluated through its water absorption capacity. Wood burning ash silica exhibited a superior absorption capacity of 70%, while satay charcoal ash silica showed a capacity of 52%. This higher absorption rate in wood-derived silica correlates with its

smaller particle size and potentially higher porosity [5].

**Table 1.** Result Data Test

No.	Types of Waste (Ash)	Yield (%)	Capacity Absorption (%)
1	Wood burning	67.8	70
2	Satay charcoal	26.6	52

Previous research has shown that the surface properties of silica extracted from biomass are highly dependent on the leaching conditions and the nature of the precursor [6]. In this study, the high absorption capacity suggests that the silica produced from wood burning ash has significant potential to be utilized as a functional material in environmental applications, such as moisture control or as a carrier for agricultural nutrients [4].

#### 4. CONCLUSION

This study concludes that high-value silica can be successfully extracted from scouring ash waste using the acid leaching method with 4 M HCl at an optimized temperature of 90°C. The experimental results indicate that the raw material source significantly influences the final silica properties. Wood burning ash proved to be a superior precursor, achieving a significantly higher silica yield of 67.8% and a water absorption capacity of 70%, compared to satay charcoal ash which yielded only 26.6% with 52% absorption capacity. Morphological analysis further confirmed that wood-derived silica has a finer particle size (0.01–0.02 mm), which contributes to its enhanced physical properties. These findings highlight the potential of utilizing scouring ash, particularly from wood combustion, as a sustainable and low-cost source for the production of functional eco-materials.

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## AUTHOR CONTRIBUTION

Conceptualization, B.A. and D.; methodology, K.M.A.A.; software, K.M.A.A. and D.; validation, BA. and K.M.A.A.; formal analysis, D.; investigation, D.; resources, B.A.; data curation, D. and K.M.A.A.; writing—original draft preparation, D.; writing—review and editing, B.A. and K.M.A.A.; visualization, D.; supervision, C.S. All authors have read and agreed to the published version of the manuscript.